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Mapping and Assessment of Ecosystems and their Services

Potential of ecosystem services for the areas identified in the LIFE-BioScape project

BioScape

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Potential of ecosystem services for the areas identified in the LIFE-BioScape project

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1. Summary

The report presents an assessment of the potential for ecosystem services related to nutrient regulation, climate change mitigation, and biodiversity in case study areas that are part of the LIFE BioScape project.

The three areas selected for the BioScape project represent important ecosystem services, that are currently deteriorating. In addition to nature restoration, key factors and focus of BioScape is to develop new collaboration methods, demonstrate tools for multifunctional land consolidation as well as education of farming students.

The aim of these MAES (Mapping and Assessment of Ecosystem Services) analysis is to help making decision and provide information for the implementation of the agro-environmental measures and restoration activities planned at the three project areas. The analyses evaluate the potential for restoring and maintaining ecosystem services in the selected areas and assessing the cost-effectiveness of proposed measures,

The assessment is based on TargetEconBES, a modelling framework developed through the MAES-DK project, which was conducted in a collaboration between Aarhus University (AU) and The University of Copenhagen (UCPH).

The MAES-DK project focused on the development of a national-scale mapping and assessment of ecosystem services, using a combination of spatial data and expert knowledge to identify the key ecosystem services provided by different land use types. Unfortunately, not all ESS can be analysed, as there is no background modelling for hydro morphological alteration of streams causing e.g. hazardous flooding of populated areas and soil processes.

2. Introduction

This report presents an assessment of the potential for ecosystem services related to nutrient regulation, climate change mitigation, and biodiversity in case study areas that are part of the LIFE BioScape project. The LIFE BioScape project is a European Union-funded initiative focused on restoring key ecosystem services in Denmark, and the main purpose of this research project is to provide support for the LIFE BioScape project in achieving its objectives.

By evaluating the potential for restoring and maintaining ecosystem services in the selected areas and assessing the cost-effectiveness of proposed measures, this analysis will aid decision-making and provide information for the implementation of the agro-environmental measures and restoration activities planned by the LIFE BioScape project. The project plans to implement these measures in three areas: Lake Byn, island of Endelave, and Aastrup Fen.

Lake Byn is a lobelia lake, a nutrient-poor freshwater lake, and is part of Natura 2000 area no. 65. The lake is home to 26 threatened species, including the Water Awlwort, which only lives in this lake, and seven EU-protected species, such as the Eurasian Otter. However, the lake is at risk of pollution due to discharge from surrounding agriculture, especially phosphorus and sediments, which have deteriorated the lake's condition. The project aims to restore the ecosystem in Lake Byn through multifunctional land consolidation and stakeholder involvement. The project will also work to protect the lake's unique and threatened species and improve the water quality.

Endelave is part of Natura 2000 area no. 56. The island is characterized by its exceptionally valuable nature and breeding ground for 76 protected species. Endelave has a population of 150 inhabitants and attracts 15,000 tourists every year. However, the island's groundwater resource is limited and threatened by contamination from surrounding cultivated areas, which cover 60% of the island's landscape. The project aims to restore ecosystem services in Endelave through multifunctional land consolidation and stakeholder involvement. The project will also work to restore and protect the island's valuable nature and improve the living conditions for its protected species.

The stream Rårup Å runs through **Aastrup Fen** before continuing into Skjold Å, which leads to flooding of nearby buildings and infrastructure resulting in significant damages. The area is characterized by protected habitat types, with approximately 23 protected species, including the Northern Lapwing and Annex IV species like the Eurasian Otter. However, the nature in the area is highly fragmented, which makes the living conditions for these species difficult. The BioScape project aims to restore the ecosystem in Aastrup Fen through multifunctional land consolidation and stakeholder involvement.

The three project areas selected for the project represent important ecosystem services that are currently deteriorating. The project activities will intersect across these three areas, allowing the municipalities to share experiences and help each other with the concrete activities. In addition to nature restoration, a key focus of the BioScape project is to demonstrate tools and develop new collaboration methods that can be implemented both nationally and internationally.

Information about the project and its three focus areas was retrieved from project materials found on its webpage https://www.life-bioscape.eu/.

We base our assessment on TargetEconBES, a modelling framework developed through the MAES-DK (Mapping and Assessment of Ecosystem Services) project, which was conducted in a collaboration between Aarhus University (AU) and The University of Copenhagen (UCPH). The past and current statuses of this work are described in Termansen et al. (2017, 2018, 2023). The model development is also built on the TargetEconN model development, described in Hasler et al (2022). The TargetEconBES model is a framework for mapping and valuing ecosystem services with the existing databases in Denmark.

The MAES-DK project focused on the development of a national-scale mapping and assessment of ecosystem services, using a combination of spatial data and expert knowledge to identify the key ecosystem services provided by different land use types.

The work relied on EU research funding, particularly from the Openness project (https://oppla.eu/groups/openness/openness-project), as well as on commissioned work made for the Ministry of Environment and Ministry of Food, Fisheries and Agriculture, as part of the contract on public advise related to Resource and socioeconomics between the Institute for Resource and Food Economics (UCPH) and the Ministries.

The present project aims to evaluate the potential for restoring and maintaining ecosystem services in the selected areas, drawing on prior research conducted at the Department of Food and Resource Economics. The resulting report will analyze the ecosystem services potential of these areas and focus on assessing the cost-effectiveness of proposed measures to improve water quality, enhance biodiversity, and decrease CO2 emissions.

3. Ecosystem services

The concept of ecosystem services emerged in the late 90’s, as a result of concern about the nature degradation seen in the world. Ecosystem services are defined as the goods and services that humans enjoy from nature's ecosystems, i.e. natural processes that have value for humans.

These include food production, erosion protection, clean drinking water, climate adaptation and recreation. In this way, ecosystem services also form the basis for human living conditions, economy, and well-being. The concept of ecosystem services can thus help us demonstrate the critical importance of nature for our society and economy.

EU launched in 2010 the Mapping and Assessment of Ecosystems and their Services (MAES) initiative, which was based on the EU Biodiversity Strategy. The starting point for the EU's work on ecosystem services was thus the loss of biodiversity. The biodiversity strategy included the objective of mapping and assessing the ecosystems of EU countries, their state and their derived services.

One of the overall objectives of the MAES initiative is to develop common guidelines for this mapping and assessment of ecosystem services for all EU countries. The purpose of introducing ecosystem services in MAES was thus to halt the decline in biodiversity and degradation of ecosystems by highlighting the interdependence between ecosystems and society.

The first Danish MAES report (Status of mapping of ecosystems, ecosystem services and their values in Denmark; 2015) provides a status of mapping of ecosystems, ecosystem services and biodiversity in Denmark. In addition, a description of relevant knowledge and data for mapping the economic value in relation to ecosystem services and biodiversity was provided. In addition, an assessment was made of the most important challenges and potentials for conducting a holistic mapping of ecosystem services and biodiversity in Denmark.

Later in 2017, a new analysis presented tools and data, that could potentially illustrate the interaction between changes in a number of ecosystem services, when agricultural or forest areas were taken out of use. If it were possible to identify areas where set-aside could have a major effect across important ecosystem services, it would be possible to develop a tool to support multi-faceted land-use planning. The report has used the areas around the catchment areas of the Limfjord as a background to the study. It is data from this that is the basis of the Danish model, and which is used here in the analyses.

Due to a lack of suitable data, it is not possible to carry out calculations for all selected ecosystem services. Therefore, it has not been possible to investigate all ecosystem services for the BioScape project. It has been necessary to omit analyses of this as there is no background modelling for hydromorphological changes in watercourses that cause, for example, flooding of populated areas or modelling for soil processes.

4. Methodology and Data

The modeling approach used in this analysis is built on Termansen et al., 2023 and Hasler et al., 2022. It integrates economic, hydrological, and agronomic data in an optimization framework. The approach is compartmental, with independent models exchanging input and output data, allowing for effective processing and integration of relevant information.

At the core of this approach is the TargetEconBES model, which operates at the field parcel level and covers all of Denmark. External models, land-use register data, and selected publications provide inputs for TargetEconBES, as shown in Figure 1. Table 1 provides information on the agro-environmental measures considered in the model, including their costs, effects, and potential areas for implementation, while the data layers and their sources are listed in Table 2.

The model considers the feasibility, effectiveness, and cost-efficiency of these measures with the aim of help decisionmakers make informed choices about which measures to implement, considering the available options and desired outcomes.

The analysis will consider the following measures (Table 1): land retirement, afforestation, restoration of wetlands, the establishment of buffer zones, and the permanent removal of forested areas from timber production.

Land retirement involves removing land from agricultural production and can be used to restore ecosystems, protect natural resources, or achieve other environmental goals. Afforestation entails planting trees in areas that previously had no forest cover and can be done for a variety of purposes, such as carbon sequestration and wildlife habitat creation. Wetland restoration includes a range of activities aimed at improving the health of wetland ecosystems, including reducing or eliminating threats such as pollution or development, and implementing measures to restore the natural hydrology and vegetation of the wetland. Buffer zones are implemented in areas of land that are adjacent to waterways (20m from the shoreline). These areas are often managed to provide a buffer and reduce the impact of human activities on the surrounding environment. Forested areas are removed from timber production for the purpose of enhancing carbon sequestration and preserving biodiversity. The measure allows for natural regeneration and restoration of forest ecosystems.

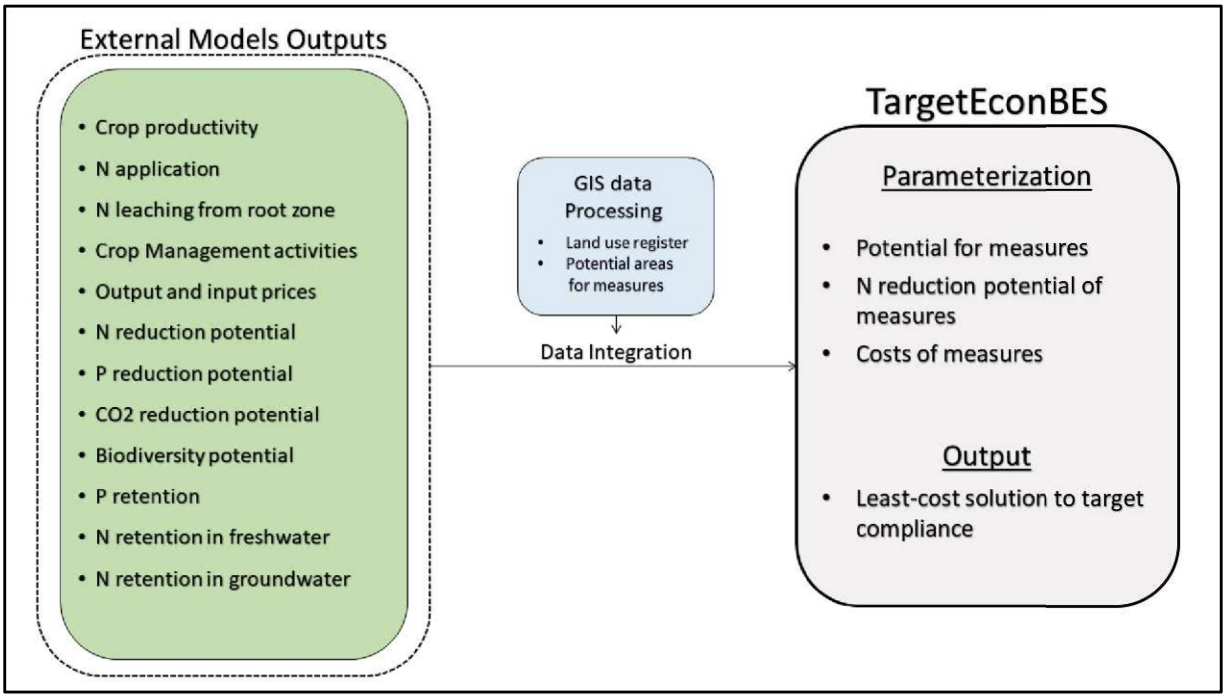

Figure 1 - Integrated modeling approach. Outputs from external models, parameters sourced from scientific publications and reports, are integrated, compiled, and treated as inputs to TargetEconBES; the inputs are parameterized and merged within a GIS of land-use register data; TargetEconBES then integrates the inputs to calculate the least-cost solution to target compliance.

Table 1 - Description of measures, its costs, effects, and potentials. Table translated from Termansen et al., 2023.

Measures	Characteristics	Cost	Effects	Potential
Afforestation	Afforestation of agricultural land in rotation.	Lost contribution margin + establishment and operating costs. Income from forest.	N: difference between initial situation (2013-18) and forest level (8 kg N/ha). C: Avg. Per year accumulation in biomass over a rotation. Stopping C emissions from agriculture. B: Number of hectares set aside with biodiversity potential.	The potential is agricultural land in rotation on high-lying soil. The potential is limited so that areas where afforestation is undesirable in the municipalities are deducted from the potential.
Buffer zones	Targeted wide and dry buffer zones (Eriksen et al 2020) along streams/lakes. 10- and 20-meter zones[1], 2 meters of mandatory strips are deducted.	Lost contribution margin for part of the field, crop rotation 2013-2018. 2-meter strips are deducted (when established).	N: reduction calculated for buffer area C: Effect as for reduction on the specific area, i.e. CO_2 e effect for the area set aside for the buffer zone. B: Effect as for set-aside on the specific area, i.e. number of hectares with biodiversity potential that have been set aside for the buffer zone.	River maps used; 2 meters strips deducted on the basis of maps from 2014. Potential for buffer zones of 10 and 20m is calculated on the basis of Geodata for streams.
Land retirement high-ground[2]	Permanent set-aside of land	Loss of contribution margin from field, crop rotation 2013-2018	N: difference between initial situation (2013-18) and natural level (12 kg N/ha) C: Cessation of emissions from agricultural production on the specific area. B: Number of hectares set aside with biodiversity potential.	All fields in rotation which are not defined as low ground.
Land retirement low-ground	Active retirement[3]	Loss of contribution margin from field, crop rotation 2013-2018, and cost of looping drains (DKK 1016/ha)	N: 40 kg/ha to coast (no retention) C: Cessation of emissions from agricultural production on the specific area B: Number of hectares set aside with biodiversity potential.	Low ground: >6% organic matter 174,666 ha, but then only in rotation considered as potential (93,188 in rotation, 81,478 outside rotation).
Wetlands	Establishment and maintenance	Establishment and maintenance costs (Eriksen et al 2020), lost contribution margin.	N: 190 kg N/ha for clay soil, 120 kg N/ha for sandy soils C: Cessation of emissions on the actual area[4] B: No effect assumed	Mini-wetland map The wetland potential is shallow ground in river valleys.
Removal of production forest	Permanent removal of forested areas from timber production	Loss of future income from timber production.	N: No effect; C: CO_2 content in biomass that will not be harvested from 2020-2030. B: Hectares set aside with biodiversity potential	Forested areas with timber production

[1] Only 20-meter zones are considered in the present report.
[2] Land retirement effects for high and low grounds are merged and given as total effect per field in this report.
[3] Defined as "set-aside of agricultural land in rotation/permanent grass or permanent grassland/natural areas where groundwater levels are raised by drains and ditches being closed and the areas thereby making the areas more moist/wetter" (Ministry of the Environment, 2021). In the model, only areas within rotation can be set aside.
[4] The C-effect may be flawed as it is not included in the estimate that the area gets wet, only that it is taken from agricultural use. The effect of set-aside on lowland and wetland land has been calculated considering the specific carbon content of the field, which is high on the land that is included as potential for both low-ground land retirement and wetlands.

Table 2 – Data sources. Adapted from Hasler et al., 2022.

Data Description	Spatial unit	Year	Source(s)
Crop composition	Field parcel	2014-2018	Basemap 03 (Levin, 2019) and field parcel maps from 2014-2018 (Danish Agricultural Agency 2014-2018)
Dominant soil type	Field parcel	2018	Soil map and map of soil organic carbon (Adhikari et al. 2015, Gyldenkærne and Greve 2015)
Average gross margin based on crop composition and dominant soil	Field parcel	2014-2018	SEGES: gross margin budgets. Farmtalonline.dlbr.dk
Fertilizer application at field level. Livestock production.	Field parcel	2018	Danish General Agricultural Register. Data from the Husbandry register annually collected by Danish authorities for cross-compliance control of Danish farmers. Data from fertilizer accounts (Danish Agricultural Agency, 2018).
Nitrogen retention	Catchments with a mean size of 15 km2 (ID15)	2021	Højberg et al., (2021)
Leaching coefficients. Kg N from the root zone.	Per crop, use of manure, soil type and whether the farm is organic.	2018	Data delivered by Hans Estrup Andersen, Department of Bioscience, AU (pers. com). Leaching estimated according to (Børgesen et al., 2009)
GHG reduction (CO_2 equivalent)	Field Parcel	2018	Nielsen et al., 2022; Gyldenkærne, S., pers. Communication; Thomas and Martin, 2012
BioScore	Field Parcel	2018	Termansen et al., 2017; Ejrnæs at al, 2021; Bladt, 2022
Spatial definition of catchments & water bodies	Catchments and water bodies	2020	Basic analysis for river basin management plans (The Danish Environmental Protection Agency, 2020)

5. Data sources

The data sources include several datasets that provide information on various aspects of ecosystem services in Denmark, as well as agronomic data. These datasets include:

- The crop composition data used in this study provides information on the types of crops grown in different field parcels in Denmark between 2014 and 2018. This data was sourced from two datasets, the Basemap 03 dataset (Levin, 2019) and field parcel maps from the Danish Agricultural Agency from 2014 to 2018.
- The dominant soil type data used in the study provides information on the types of soil found in different field parcels in Denmark in 2018. This data was sourced from soil maps and maps of soil organic carbon (Adhikari et al. 2015, Gyldenkærne and Greve 2015).
- Average gross margin data provides information on the average gross margin for different crops grown in different field parcels in Denmark between 2014 and 2018. This data was sourced from two datasets, the SEGES gross margin budgets and Farmtalonline.dlbr.dk.
- The fertilizer application and livestock production data provide information on the use of fertilizers and the production of livestock in different field parcels in Denmark in 2018. This data was sourced from two datasets, the Danish General Agricultural Register and data from the Husbandry register collected annually by Danish authorities for cross-compliance control.
- The nitrogen retention data used in the study provides information on the amount of nitrogen retained in different catchments in Denmark in 2021. This data was sourced from Højbjerg et al. (2021).
- The leaching coefficients data used in the study provides information on the amount of nitrogen leached from the root zone in different field parcels in Denmark in 2018. This data was sourced from Hans Estrup Andersen at the Department of Bioscience, AU and was estimated according to Børgesen et al. (2009).
- The spatial definition of catchments and water bodies data used in the study provides information on the spatial boundaries of catchments and water bodies in Denmark in 2020. This data was sourced from the basic analysis for river basin management plans from the Danish Environmental Protection Agency (2020).

5.1 GHG Reduction Calculation Method

The effect of land use change measures on greenhouse gas (GHG) emissions is estimated as changes in emissions measured as CO2 equivalent (CO2 eq.) from the starting point to the conversion of agricultural land to permanent grassland, wetlands, and buffer zones. The approach is to estimate the climate emissions from all fields for current production and emissions after conversion.

The calculations are based on crop distribution and fertilizer application for 2018 at the field level. The estimation of changes in emissions follows the approach used in national emission inventories, but here the emissions are calculated at the field level. The potential for carbon sequestration in soil is calculated using the latest available maps and data on the prevalence of organic soils. Integration of spatial data on standing biomass has also been used to improve the mapping of biomass growth in forests. The carbon sequestration is calculated with a 10-year perspective. Biomass is converted to dry weight of tree biomass measured in tons by using the specific density of the individual tree species. There is no change in carbon sequestration in soil for forests (Nielsen et al. 2022; Thomas and Martin 2012; NordLarsen et al. 2009).

5.2 Biodiversity Potential Calculation Method

To determine the potential for biodiversity conservation through land retirements, two criteria were chosen based on the BioScore map. The first criterion was based on the BioScore for forest decision units, with a threshold value for identifying land withdrawals in forests based on the BioScore. For each of the forest units, the average BioScore was calculated. This method is based on the work of Termansen et al. (2023), and the BioScore map for 2021 was used (Ejrnæs et al., 2021; Bladt, 2022). The BioScore ranges from 0-20 and is weighted so that areas with the most threatened species, the most secure site records, and the smallest total ranges have the highest score. Areas with a BioScore higher than a threshold value of 6 within the nationally prioritized areas (over 8 outside) were considered as possible candidates for land retirements.

The second criterion was based on the BioScore map without resetting for agricultural areas. A version of the BioScore map was created where agricultural land in cultivation is not reset. This mapping can therefore be used as an indicator of the potential increase in natural content, that can be created if agricultural land is withdrawn from cultivation.

Identification of potentially suitable areas is based on the difference between this BioScore map with and without withdrawal of the field. A threshold value of 2 was used to determine the potential for biodiversity. For each of the 379,056 fields in cultivation that can potentially be withdrawn, the average potential for biodiversity was calculated. This method is based on the work of Ejrnæs et al. (2021) and Bladt (2022).

6. Results

The results of our analysis provide relevant information for the cost-effectiveness evaluation of the measures at the field parcel level for the three project areas. However, we did not present an optimization in the results section due to the lack of specific targets for each individual region. National or proportional targets are commonly used in policymaking and planning to set specific goals for achieving environmental objectives.

However, applying these targets to regional planning could potentially be misleading since it does not account for the unique needs and priorities of each area. To avoid this issue, we have presented the costs and effectiveness of the measures separately for each project area, without optimization, to allow stakeholders and project leaders to make informed decisions based on their own objectives and circumstances. This approach ensures that the measures implemented are tailored to the needs of each region, leading to more effective and sustainable outcomes.

To facilitate the interpretation of our results and assist decision-makers in making informed choices regarding future actions, we have provided graphical representations of the costs and effectiveness of the measures at both the field parcel level and across the three project areas.

The figures presented below provide a concise and accessible overview of the results, allowing stakeholders and project leaders to compare the potential, costs, and effectiveness of the various measures presented.

The figures presented will display, for each of the project areas:

- The fields with increased biodiversity potential if afforestation, land retirement or buffer zone (effect on buffer area) is implemented. The selection shows fields with a positive "BioScore", as defined in Termansen et al., 2023.
- The forest areas that have biodiversity potential (BioScore>0) if permanently removed from timber production.
- The CO2 reduction, per hectare, when taking an agricultural field out of production. The color gradient, from green to red, represents the relative values for the specific area.
- The reduction in nitrogen leaching levels, per field, resulting from the implementation of relevant measures. Nitrogen leaching is reported as the amount reaching coastal waters after N retention. The color gradient, from green to red, represents the relative values for the specific area.

The costs associated with implementing each measure. The color gradient, from green to red, represents the relative values for the specific area.

6.1 Lake Byn

Figure 2 - Agricultural fields with the potential to increase biodiversity if afforestation, land retirement or buffer zone (effect on buffer area) is implemented.

Figure 3 - Forested areas with potential for increase in biodiversity if wood production ceased.

Figure 4 - CO2 reduction per ha when taking an agricultural field out of production. Add 929 to the value if the land is to be reforested.

Figure 5. total cost, in DKK, per field of implementing a buffer zone on 20 m bordering waterways

Figure 6 - Total N reduction, KgN per field, from implementing a buffer zone of 20m bordering waterways. Considering N retention to coastal waters.

Figure 7. Total cost, in DKK, of implementing afforestation.

Figure 8. Total N reduction, in KgN per field, from implementing afforestation. Considering N retention to coastal waters.

Figure 9. Total cost, in DKK per field, of taking land out of production (land retirement).

Figure 10 - Total N reduction, in KgN per field, from taking land out of production (land retirement). Considering N retention to coastal waters.

Figure 11. Total cost, in DKK per field of restoring wetlands.

Figure 12 - Total N reduction, in Kg N per field, from restoring wetlands. Considering N retention to coastal waters.

6.2 Island of Endelave

Figure 13. Agricultural fields with the potential to increase biodiversity if afforestation, land retirement or buffer zone (effect on buffer area) is implemented.

Figure 14. Forested areas with potential for increase in biodiversity if wood production ceased.

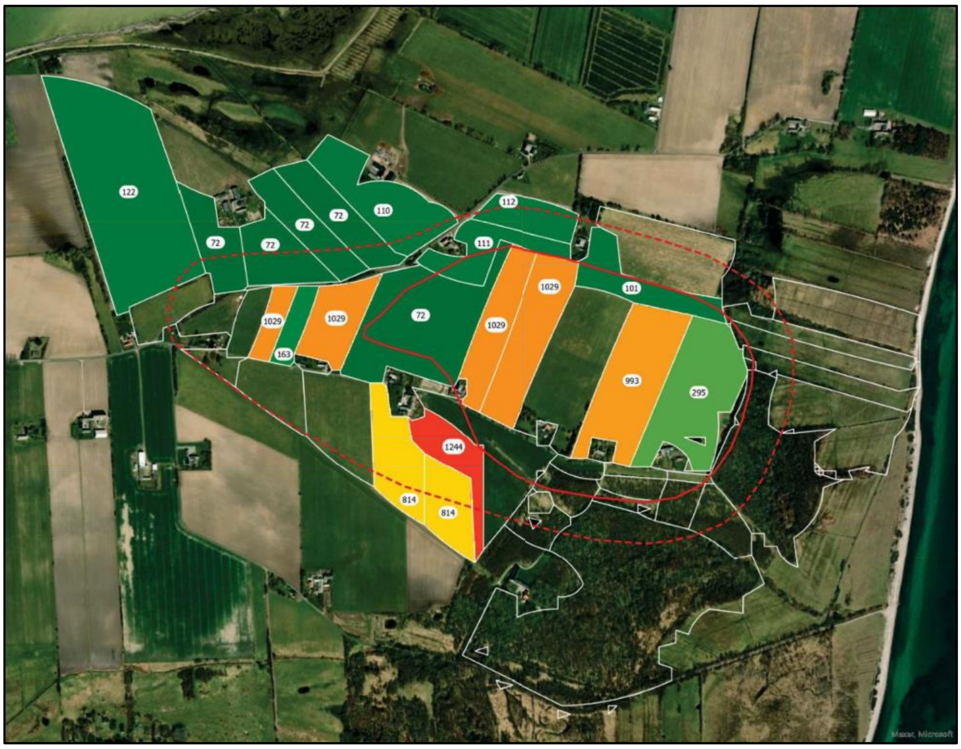

Figure 15. CO_2 reduction per ha when taking an agricultural field out of production. Add 1615 to the value if the land is to be reforested.

Figure 16. Total N reduction, KgN per field, from implementing a buffer zone of 20m bordering waterways. Considering N retention to coastal waters.

Figure 17. Total N reduction, in Kg N per field, from implementing buffer zones of 20m bordering waterways. Considering N retention to coastal waters.

Figure 18. Total cost, in DKK per field, of implementing afforestation.

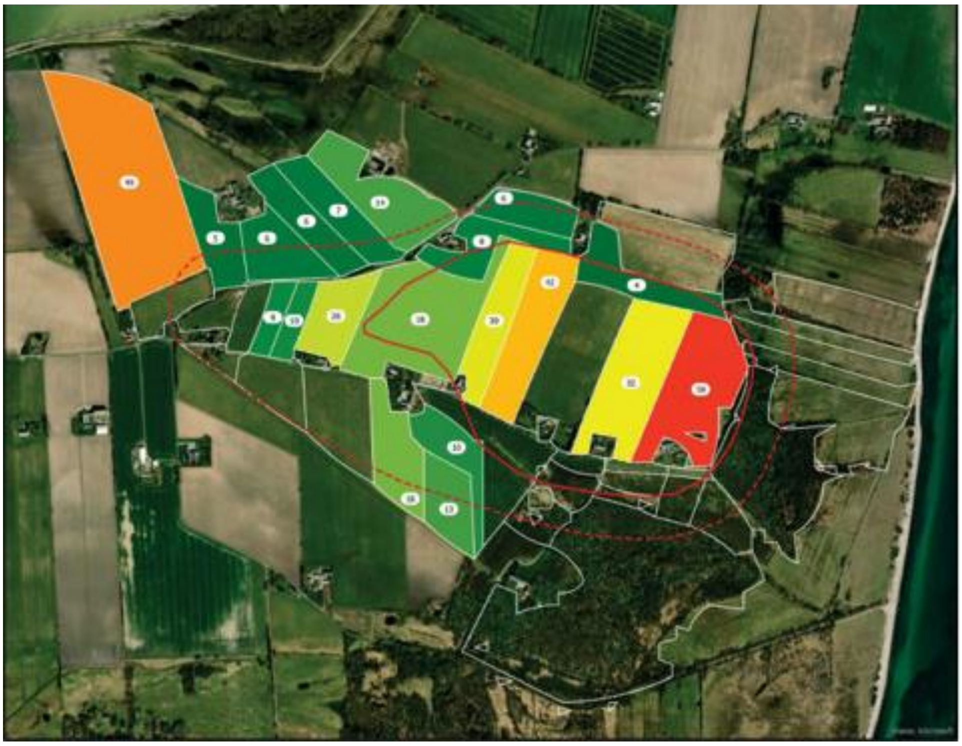

Figure 19. Total N reduction, in Kg N per field, from implementing afforestation. Considering N retention to coastal waters.

There is no potential for restored wetlands in the Endelave area, so the is no calculations for that.

6.3 Aastrup Fen

Figure 20. Agricultural fields with the potential to increase biodiversity if afforestation, land retirement or buffer zone (effect on buffer area) is implemented.

Figure 21. Forested areas with potential for increase in biodiversity if wood production ceased.

Figure 22. CO_2 reduction per ha when taking an agricultural field out of production. Add 1615 to the value if the land is to be reforested.

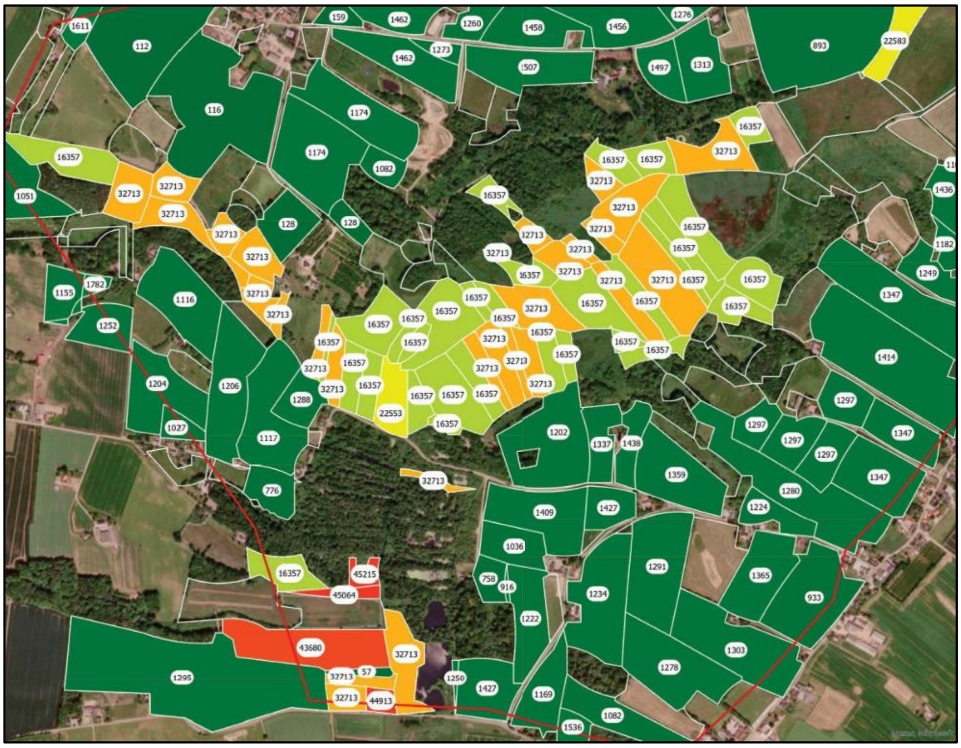

Figure 23. Zoomed in area of Figure 12 for better visualization.

Figure 24. Total cost, in DKK per field, of implementing the buffer zone measure.

Figure 25. Total N reduction, per field in Kg N, of implementing the buffer zone measure. Considering N retention to coastal waters.

Figure 26. Total cost, in DKK per field, of implementing afforestation.

Figure 27. Total N reduction, in Kg N per field, from implementing afforestation. Considering N retention to coastal waters.

Figure 28. Total costs, in DKK per field, of taking out land of production (land retirement).

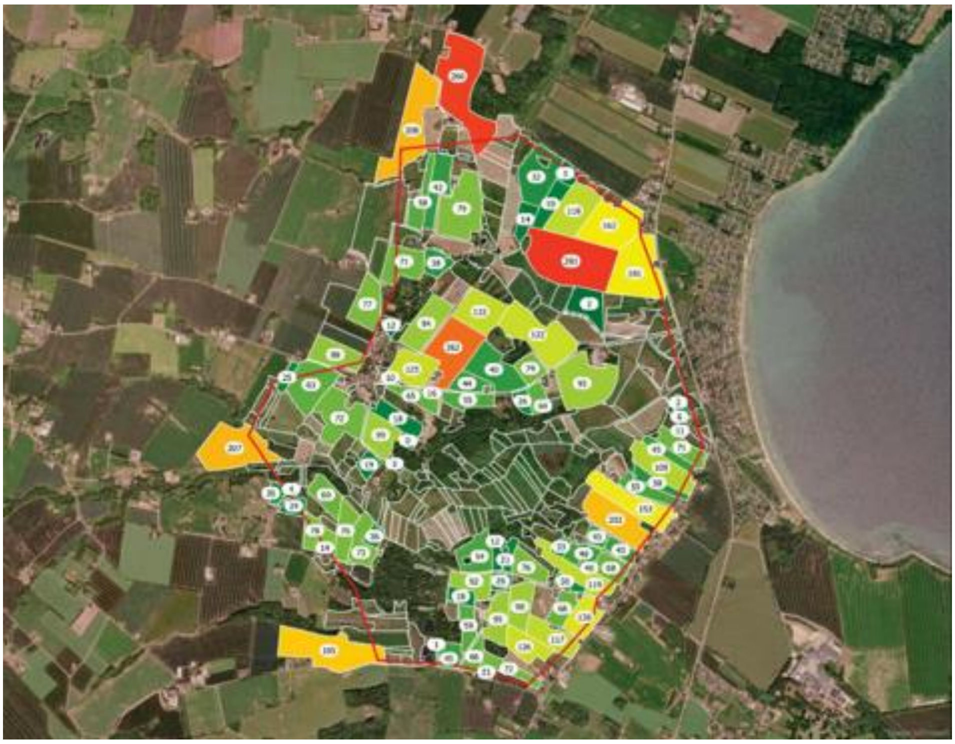

Figure 29. Total N reduction, in Kg N per field, from taking land out of production (land retirement). Considering N retention to coastal waters.

Figure 30. Total N reduction, in Kg N per field, of restoring wetlands.

Figure 31. Total N reduction, in Kg N per field, from restoring wetlands. Considering N retention to coastal waters.

7. Conclusion

The report provides relevant information for the cost-effectiveness evaluation of various agro-environmental measures across three project areas in the BioScape project. Our analysis aims to provide stakeholders and project leaders with insights into the costs and effectiveness of different measures and their potential for implementation. The results are presented in a graphical format to facilitate their interpretation, and to assist decision-makers in making informed choices about future actions.

It is essential to recognize, that the implementation of agro-environmental measures is a complex and ongoing process, that requires ongoing monitoring and evaluation to ensure their effectiveness and sustainability. Our analysis has highlighted the potential for implementing various measures to improve biodiversity, reduce carbon emissions, and prevent nitrogen leaching.

It is important to recognize the limitations of the analyses, which include the lack of specific measures for each region, and that the results are potentially affected by uncertainty of the data quality to be used for the calculations, related to the model used. We believe, despite possible limitations, that the analyses provide a reasonable starting point for further discussion and investigation. We also believe the analyses are a useful tool in the work with the landowners in the BioScape project.

With the calculations, the report and its results will be a useful tool for stakeholders and project managers to evaluate the feasibility and effectiveness of various agri-environmental measures. Our hope is that the report will encourage further dialogue and collaboration between stakeholders to develop and implement effective and sustainable measures that will benefit both the environment and the agricultural sector.

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