Danish Council on Climate Change.

April 2024

Scenarios of Future Land Use in Denmark

How to accommodate goals for climate change mitigation, the aquatic environment, and biodiversity

English Summary

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Scenarios of Future Land Use in Denmark
How to accommodate goals for climate change mitigation, the aquatic environment, and biodiversity

Published 23 April 2024

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Danish Council on Climate Change.

Scenarios of Future Land Use in Denmark - How to accommodate goals for climate change mitigation, the aquatic environment, and biodiversity

Summary for policymakers

Denmark's limited land area must accommodate cities and infrastructure, agriculture and forestry, nature, and all the other activities and interests associated with land use. At the same time, the way in which we use land in Denmark is crucial for our ability to meet our goals for climate change mitigation, the aquatic environment, and biodiversity, among others. These are goals Denmark has set for itself or that stem from requirements from the EU and international agreements.

This summary reports on a Danish Council on Climate Change (DCCC) analysis that examines how Denmark can meet the goals for land use most efficiently. The analysis shows that measures to improve the aquatic environment and increase biodiversity will result in significant climate-related benefits. Therefore, politicians in this area should integrate Denmark's green goals in the coming years. The main conclusions of the analysis are summarized below.

The study examines three scenarios for future land use

Denmark has separate political goals on climate change mitigation, the aquatic environment, and biodiversity. These include:

- Reducing greenhouse gas emissions from land use
- Obtaining good ecological status in the Danish aquatic environment
- Conserving 30 percent of land area for biodiversity purposes

Land use in 2050 can take on many different forms, depending on political ambitions in relation to the environmental goals. To illustrate possible future land use, the DCCC has formulated three scenarios in this analysis, each fulfilling different political goals. The three scenarios are summarised in table 1.

Table 1 Scenarios in the study

Scenario		Description
Climate scenario		Obtaining net-zero emissions from the areas
Climate and aquatic environment scenario		Net-zero GHG emissions and fulfilment of the EU Water Framework Directive along with national goals for afforestation and unmanaged forest
Biodiversity and aquatic environment scenario		Biodiversity and aquatic environment goals along with national goals for afforestation and unmanaged forest

Source: The DCCC

The scenarios are analysed using the TargetEcon model, developed by researchers at the Department of Food and Resource Economics at the University of Copenhagen. The model is used to collate land use patterns in Denmark and to

estimate the costs of changing land use to meet the various goals for climate change mitigation, the aquatic environment, and biodiversity. Changes in land use, called transition elements in this analysis, can, for example, include the establishment of catch crops, afforestation, designation of unmanaged forest areas or the conversion of carbon-rich soils to wetlands. Note that, while afforestation and designation of unmanaged forest are goals in themselves, they are also classified as transition elements in the TargetEcon model when their effect on other goals is to be estimated.

Four take-home messages:

1. Biodiversity and the aquatic environment should guide spatial planning

Biodiversity and the aquatic environment must be conserved in specific areas in Denmark to yield the greatest benefits for society. For example, effective measures for conserving biodiversity require setting aside areas for nature precisely where animals and plants benefit most from it. This demands larger coherent areas with conservation features such as unmanaged forests. The greatest benefit for the aquatic environment occurs when forests and wetlands are established in locations where there is a need for reducing nitrogen leaching. In contrast, for climate change mitigation, the location of forest planting is not as crucial – the important aspect to meeting climate goals is to increase forestation regardless of location.

When land use is planned with biodiversity and the aquatic environment in mind, significant climate gains are also achieved. This means society can advantageously coordinate land use based on biodiversity and aquatic environment goals. The designation of areas should be done centrally but implemented locally.

The timing of initiating individual measures on land use also has significant importance in achieving synergy between different policy areas. This means that the efficiency of transition measures depends on how quickly they are initiated and implemented and not only on the type of transition elements and their location.

2. Biodiversity and forests should occupy more of the landscape

If the Danish goals for climate change mitigation, the aquatic environment, and biodiversity are to be achieved, areas must be dedicated to these purposes. This means that agriculture should occupy less space in the Danish landscape than it does today – but agriculture and the food industry do not necessarily need to occupy less space in the national economy if the sectors can successfully transition towards a greener future. Currently, agriculture covers the majority of the Danish landscape. This provides a certain level of economic activity and employment in the sector but also puts pressure on the climate, the aquatic environment, and biodiversity.

The analysis shows that the goals for climate change mitigation, the aquatic environment and biodiversity can all be achieved if the area used for agricultural production is reduced by approximately one-third, and at the same time, more unmanaged forests are created in the existing production forests. The released agricultural land will primarily be converted into protected nature areas such as grasslands, natural forests, and wetlands, but a massive afforestation effort will also significantly increase the total area of production forests.

3. The costs of a coordinated effort are modest

From a societal perspective, the lost earnings in agriculture and forestry are relatively modest when the goals for climate change mitigation, the aquatic environment and biodiversity are to be met. When land use is planned with a focus on achieving biodiversity and aquatic environment goals, the total direct costs amount to approximately DKK 2.8 billion annually in terms of lost revenue, primarily from reduced food production and reduced amounts of feed for livestock production.

At the same time, a significant climate benefit of almost 7 million tonnes of CO_2 equivalents per year is achieved. This corresponds to a total direct cost of approximately DKK 400 per tonne of CO_2 equivalent. Additionally, the significant societal benefits of an improved aquatic environment and increased biodiversity are not included, which would reduce the net social costs if they were included. Likewise, the cost estimations in the analysis do not include the increased recreational opportunities in nature that might arise from land-use changes, which, if included, would also reduce the costs from a socio-economic perspective.

4. Regulation of the areas should be based on three pillars

Major changes to the Danish landscape require comprehensive regulation to harvest the synergies highlighted by this analysis. The DCCC proposes some principles as a basis for further work and to inform the ongoing politically "tripartite discussions" on a CO_2e tax on agricultural emissions:

- **Designation of areas.** Considerations such as the aquatic environment and biodiversity require geographic focus. The Danish Environmental Protection Agency has designated areas that are particularly critical to the aquatic environment, but a similar designation for biodiversity is lacking. A targeted effort to enhance nature and wildlife requires the designation of coherent areas that have special value for this purpose. Therefore, the government should ensure that areas reserved for biodiversity are designated promptly to allow for comprehensive spatial planning.

- **Targeted efforts.** The designated areas should form the basis for targeted efforts to promote the desired land use for the benefit of the aquatic environment and biodiversity, among other things. This can include schemes that promote afforestation or coherent natural areas through subsidies, auction schemes, or better coordination among different types of land funds. The schemes should reward efforts where synergies are greatest. For example, forests should be planted especially where this also benefits the aquatic environment. Many of these elements already exist in current regulations and should be continued and strengthened. It is also important that the schemes are designed to encourage prompt action.

- **Greenhouse gas tax.** In Denmark an expert group on a green tax reform presented models in February 2024 for how to tax a large portion of emissions from agriculture and land use.[1] The DCCC sees no hindrance to implementing one of the expert group's models as soon as possible. A tax on emissions from agriculture, especially livestock and fertilizers, will promote structural change and more efficient land use with less feed production, more afforestation, and carbon-rich land withdrawal.

This is an abbreviated translated version

This report is an abbreviated version of the original Danish report. The original report was published in April 2024. This translated version aims to bring the conclusions of the Danish Council on Climate Change (DCCC) to a broader audience. However, this is a summary of the original report. If you find that some information is missing, or you would like to learn more about the conclusions, assumptions or methodology, please reach out to the secretariat of the DCCC. We would be pleased to help. You can reach the secretariat at mail@klimaraadet.dk

1. Introduction, conclusions and recommendations

In this analysis, the DCCC examines how we can most effectively meet the various demands placed on the Danish land area in the future. Currently, 72 percent of Denmark's land area is used for agriculture and forestry, see figure 1. The analysis focuses on these areas because this is mainly where emissions from land use originate, and where significant changes can be made to benefit water quality and biodiversity. In this section the purpose and scope of the analysis is described. This is followed by a presentation on the analysis scenarios and results. Lastly, a plan for future Danish land use is discussed.

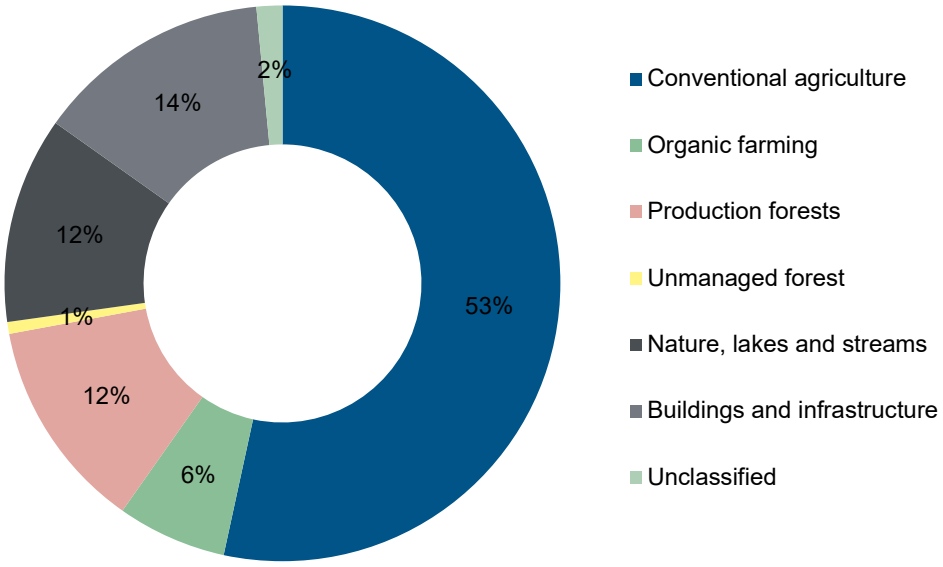

Figure 1: Land use in Denmark today divided into categories.

Source: The DCCC on the basis on calculations in Levin, 2019, Nord-Larsen et al., 2023, and Biodiversitetsrådet, 2023.[2, 3, 4]

1.1 Purpose and scope of the analysis

Denmark needs to initiate policies supporting efficient land use

Denmark's land area is 4.3 million hectares. This land area has to accommodate cities and infrastructure, agriculture and forestry, biodiversity, and all the other activities and interests associated with a society.

In this analysis, the DCCC takes a closer look at agriculture and forestry, which together cover 72 percent of Denmark's total land area. The analysis focuses on production areas, which are areas where there is intensive production of agricultural and forestry products. Activities in these production areas are crucial for addressing three major climate and environmental challenges facing Denmark in the coming years. The tasks are:

- Limiting greenhouse gas emissions in accordance with the targets of the Danish Climate Act[5]
- Ensuring good ecological status in the Danish aquatic environment
- Providing space for diverse biodiversity in line with the EU's strategy goal of ensuring that 30 percent of the EU's land area comprises effectively managed and coherent protected areas

These three tasks are all major challenges, not least because the solutions significantly affect the way we currently use agricultural and forestry land.

This analysis examines synergies in land use

This DCCC analysis investigates what Denmark's land use might look like in 2050 if we are to fulfil the goals for climate change mitigation, the aquatic environment, and biodiversity. A wise solution to meeting the goals should exploit the fact that some types of land use can contribute to multiple goals simultaneously when they are placed correctly in the landscape. This creates synergies. These synergies will also limit the costs of addressing the goals.

The primary aim of the analysis is to show the changes in land use that Denmark face. For example, this includes the amount of agricultural land that needs to be converted to other uses to achieve our goals for climate change mitigation, the aquatic environment, and biodiversity. Such conversions could include converting agricultural production to forest production or protected nature. Additionally, the analysis discusses which policy instruments and measures can support land use that should ensure the fulfilment of goals for climate change mitigation, the aquatic environment, and biodiversity. The analysis also indicates which mechanisms politicians should be aware of to achieve the greatest possible synergies.

The analysis primarily focuses on climate change mitigation, biodiversity, and the aquatic environment

In addition to the focus of this analysis, there are also many other objectives and considerations associated with land use, both today and in the future. Table 2 shows the objectives and considerations that are covered by this analysis. The main focus of the analysis is on the goals for climate change mitigation, the aquatic environment, and biodiversity. In addition, the political goals for afforestation with new production forests and the conversion of existing production forests to unmanaged forest are included. The reason for including these other policy goals is that these goals are largely aimed at achieving the three goals that are the primary focus of this analysis.

Table 2 Delimitation of the analysis in relation to goals, considerations, and other types of land use.

Objectives and considerations analysed in high detail in the analysis	Objectives and considerations treated in less detail in the analysis	Land use types and issues not addressed in the analysis
• Greenhouse gas reductions on land areas • Fulfilment of the EU Water Framework Directive • EU target for protection of biodiversity in 30 percent of Denmark's land area • National goal for afforestation • National goal for conversion of existing production forests to unmanaged forest	• Protection of drinking water • Doubling of the organic area • Placement of solar energy parks • Food production	• Settlement and infrastructure • Climate adaptation • Raw material extraction • Discharge of chemicals into the aquatic environment • Loss of phosphorus to the aquatic environment • Recreational areas • Onshore wind farms • Use of marine areas

Source: The DCCC.

The analysis uses a net-zero target for land-based emissions of greenhouse gases

Land use activities have consequences for the climate as they result in emissions of greenhouse gases when the soil is cultivated (for example, carbon-rich soils) and when crops are fertilized. At the same time, land areas may also provide uptake and storage of carbon from the atmosphere in forests and in some soils.

The goal for greenhouse gas reductions mentioned in Table 2 is formulated in the analysis as a target of net-zero emissions from the Danish land area. This corresponds to a reduction of approximately 6.5 million tonnes of CO_2 equivalents in 2050 assuming unchanged policies. Denmark has an overall net-zero target for all greenhouse gas emissions in 2050 under the Climate Act, but the target is not distributed across sectors. However, it is likely that the land sector will need to contribute negative emissions in 2050. This is because, as mentioned, Danish land areas have

significant potential to sequester carbon in forests and soils. The net-zero target for land-based emissions set out in this analysis can therefore be seen as minimum requirements of emissions from land use.

The analysis does not include emissions from animal production

This analysis estimates direct emissions of greenhouse gases from the land areas, for example from carbon-rich soils, from crop residues, from artificial fertiliser, and from use of manure. The emissions also includes the effect of uptake of atmospheric CO_2 by forests, and carbon storage in some soils. Emissions from the agricultural livestock sector or associated industries are not included. For instance, this means that costs and emissions associated with livestock production are not included in the results. However, it is important to be aware that changes in agricultural land use can affect livestock production. Therefore, the changes may also have indirect effects beyond those included in the analysis results.

1.2 Analysis scenarios and results

Land use in 2050 can take on many different forms, depending on which political goals are pursued. To illustrate future land use, the DCCC has formulated three scenarios in this analysis, each fulfilling different political objectives. These are described in Table 3.

Table 3 The three scenarios in the analysis

Scenario		Description
Climate scenario		Net-zero emissions from the areas
Climate and aquatic environment scenario		Climate and aquatic environment objectives along with goals for afforestation and unmanaged forest
Biodiversity and aquatic environment scenario		Biodiversity and aquatic environment goals along with goals for afforestation and unmanaged forest

Note: Afforestation and unmanaged forest are included in both the climate and aquatic environment scenario and the biodiversity and aquatic environment scenario as goals. Additionally, they are also transition elements that the model can choose to fulfil the goals.

Source: The DCCC.

Since there is no specific Danish implementation of the EU's biodiversity strategy regarding the target of ensuring that 30 percent of Danish land area comprises effectively managed and coherent protected areas, an outline from the Danish Biodiversity Council is used instead to address how the goal can be met in the Danish land area. It is assumed that Denmark must ensure that 30 percent of its land area comprises effectively managed and coherent protected areas.

Climate scenario focuses solely on climate change mitigation

The first scenario of the analysis has a singular focus on reducing greenhouse gas emissions. It identifies land use that achieves a reduction of 6.5 million tonnes of CO_2 equivalents from land areas at the lowest possible cost.

The reduction in greenhouse gases in the scenario is primarily achieved by establishing production forests on agricultural land. The changes result in a total direct cost of DKK 110 per tonne of CO_2e reduced. The costs of the analysis consist of the difference in annual economic earnings between the new and the old activities on the areas.

The scenario shows that focusing only on climate change mitigation only contributes, to a limited extent, to the aquatic environment and biodiversity goals. The scenario achieves 42 percent of the necessary nitrogen reductions for the aquatic environment that are required to meet the Water Framework Directive by 2027. Additionally, only about 30,000 hectares out of approximately 630,000 hectares are designated for cessation of agricultural and forestry production to meet the

EU's biodiversity strategy of ensuring that 30 percent of Denmark's land area are protected areas with no production activity.

Figure 2 shows that the climate scenario does not fulfil the biodiversity and aquatic environment goals. This is illustrated with the green line. There are two reasons why a singular focus on climate change mitigation only contributes to increased biodiversity to a limited extent and fails to meet the aquatic environment goals:

- **Type of transition elements.** Some transition elements, such as afforestation, provide a climate effect without contributing to other goals. Afforestation of agricultural land can improve the aquatic environment and carbon sequestration but requires appropriate geographic placement to achieve this. Moreover, new afforestation cannot be counted as biodiversity protection according to the EU's biodiversity strategy.
- **Placement.** The effect on greenhouse gas emissions is independent of where in Denmark a change inland use takes place. Therefore, changes in land use in a pure climate scenario are placed where costs are lowest. However, the effect on nitrogen emissions and biodiversity depends heavily on geographic location, limiting synergies in a climate-focused approach.

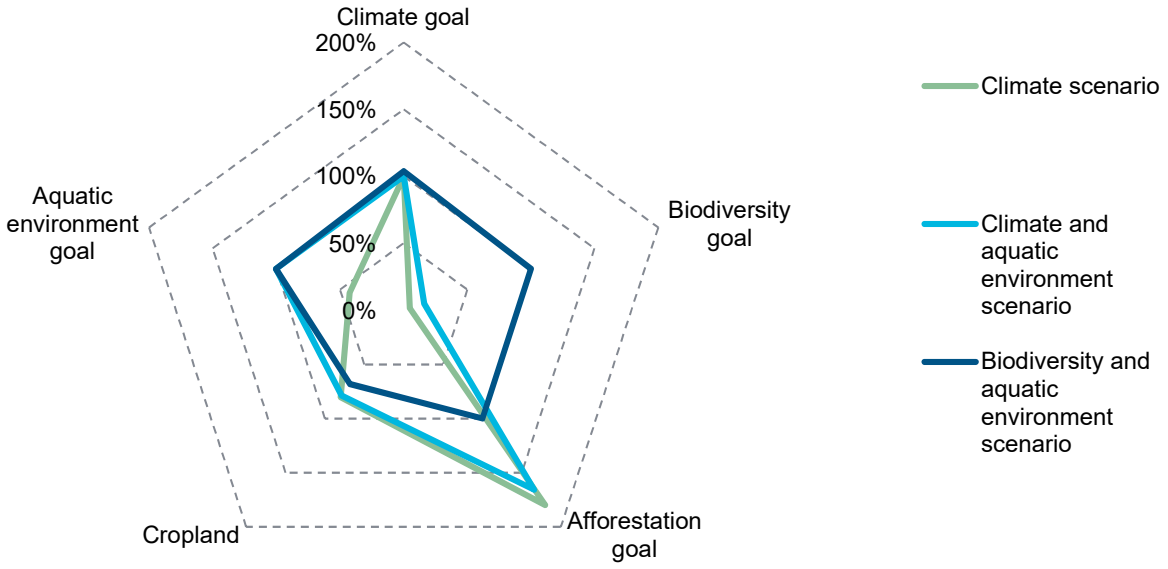

Figure 2 Comparison of the three scenarios in the analysis across goals and changes in agricultural and forestry areas

Note 1: The biodiversity goal is the area that is taken out of production in the scenario and is located within the designated biodiversity area. With an allocation of 30 percent of Denmark's area, equivalent to 1.26 million hectares, 623,228 hectares of land currently in intensive agricultural or forestry production would need to be taken out of production. The percentage is calculated in relation to the 623,228 hectares.

Note 2: The aquatic environment goal is measured as the reduction in nitrogen emissions contributed by the scenario, out of a target in the aquatic environment plans of 12,955 tonnes of nitrogen.

Note 3: The percentage contribution to the climate goal is calculated based on the number of tonnes of CO_2e contributed by the scenario in 2050 compared to an emission of CO_2e from the areas in 2050 of 6.5 million tonnes of CO_2e. The climate goal is used as an illustrative goal for the areas.

Note 4: Cropland is the proportion of agricultural land that remains under cultivation compared to the agricultural land in cultivation today. Thus, for example, in the climate scenario, 80 percent of agricultural land will still be under cultivation.

Source: The DCCC.

Coordination of climate change mitigation and the aquatic environment

The second scenario, like the climate scenario, is based on a reduction of greenhouse gas emissions of 6.5 million tonnes from Danish land areas. The scenario also includes a requirement that the reduction target for nitrogen emissions to the aquatic environment be met. The nitrogen target ensures that Denmark complies with the EU's Water Framework Directive. Finally, the scenario includes the government's desire to establish 250,000 hectares of new forest as well as political agreements on more unmanaged forest.

In this scenario, the direct cost increases to DKK 176 per tonne of CO_2e reduced. The difference from the climate scenario is that, in addition to reducing greenhouse gases, the reduction target for nitrogen emissions to the aquatic environment is also achieved. This is illustrated with the light blue line in figure 2. Furthermore, the area protected for biodiversity triples compared to the climate scenario, partly due to the increased area of unmanaged forest. The increase in cost should be seen in light of these additional benefits.

Coordination of measures on land use is necessary for this scenario to efficiently meet both the objectives of water quality and climate change mitigation. In this scenario, the establishment of production forest occurs in areas where there is also a need to improve the aquatic environment. Since a significant portion of the aquatic environment objectives can be achieved through afforestation, synergy arises in this scenario since an intervention can contribute to multiple objectives when placed geographically correctly. The climate scenario does not take this into account.

Coordination of biodiversity and the aquatic environment

The third scenario incorporates the EU biodiversity target. The scenario must meet the politically set goal for the aquatic environment, the EU biodiversity target, as well as the announced goals for afforestation and transition of existing production forests to unmanaged forest. This is illustrated with the dark blue line in figure 2.

However, the scenario does not include an actual climate target. Nevertheless, the scenario provides a significant climate benefit of 6.8 million tonnes of CO_2e as a consequence of the measures needed to meet other objectives. It thus achieves a higher climate effect than the pure climate scenario which targets reductions of greenhouse gas emissions of 6.5 million tonnes CO_2e. Greenhouse gas reductions come from both the cessation of agricultural production on areas reserved for biodiversity and from increased afforestation with production forests, which, simultaneously help the aquatic environment and serve as carbon sinks.

The costs of this scenario are significantly higher than in the other scenarios, namely DKK 409 per tonne of reduced CO_2e. This is mainly due to 30 percent of Danish land area being reserved for biodiversity. This will require the cessation of production on significantly more agricultural areas compared to the other two scenarios. When biodiversity guide which areas to take out of production, a number of synergy effects are achieved, which also help to fulfil the objectives for an improved aquatic environment and reduced greenhouse gas emissions.

The synergy effects can be seen in the result of the analysis that shows that coordinating the initiatives to reach the various goals can reduce costs by 8-20 percent compared to not coordinating the initiatives. Another important conclusion is that a policy focused solely on climate change mitigation does not have significant effects on the aquatic environment and biodiversity, but a policy focused on biodiversity and the aquatic environment will result in significant climate benefits.

Long-term planning is important

Danish land areas are facing significant changes, regardless of which political goals need to be fulfilled. Figure 3 shows land use in Denmark in 2050 in the climate scenario, climate and aquatic environment scenario, and biodiversity and aquatic environment scenario compared to today.

When land use change initiatives are implemented, the opportunities for achieving synergy between different policy areas must be used. Not only do the types of transition element and where they are placed matter, the speed at which they are initiated and carried out matter too. This is especially true for afforestation and removal of carbon-rich soils, which need to be initiated quickly to contribute as much as possible to future climate goals. Additionally, the benefits, especially for biodiversity, accrue over many years. The long-term perspective also speaks for a swift initiation of efforts.

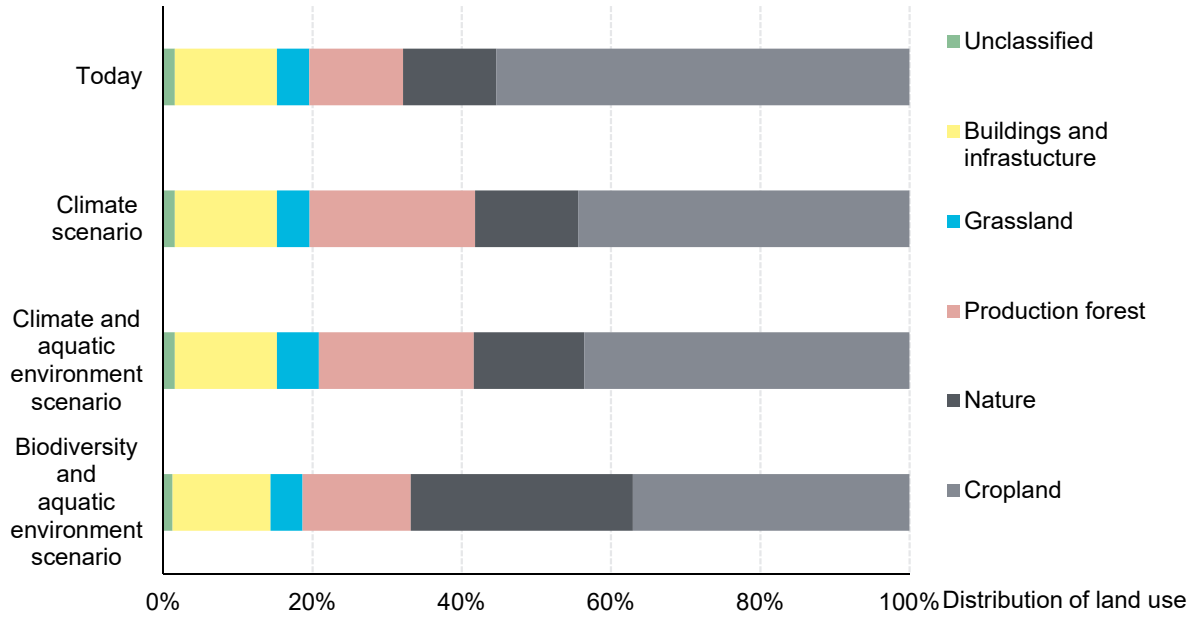

Figure 3 Danish land use distribution today and in 2050 in the three scenarios of the analysis

Note 1: The Danish Biodiversity Council has estimated that 1.6% of Denmark's area is protected today. The 1.6% is included in the category "Natural areas, rivers and lakes including unmanaged forest". [6]

Note 2: Unclassified denotes areas for which the datasets used do not contain information about land use.

Source: The DCCC.

1.3 Plan for Danish land use

Denmark can look forward to a changed landscape

For Denmark to meet the political goals for climate change mitigation, the aquatic environment, and biodiversity, Denmark will need to have a more varied landscape by 2050. The landscape will need to reflect the fact that land use will have to cater to more interests than it does today; at present, the landscape is primarily characterized by land use that cater to the interests of agriculture, and to some extent forestry production. For example, while forests in 2050 will still be mostly production forests, there will be more forest and some of the forests that already exist today will have been left to grow as unmanaged forest. There will still be a predominance of cultivated fields, but most river valleys and other areas of carbon-rich soils will no longer be cultivated. There will be more large areas reserved for nature and biodiversity, providing a foundation for more varied wildlife and plant life.

There is a need for comprehensive regulation

This is far from the first time that significant changes are needed in the management of Denmark's land area. The land ownership reforms at the end of the 18th century marked the beginning of major and decisive changes in ownership and property structure in agriculture, which still leave their mark on the landscape today. The many different desires and political objectives for the Danish land area mean that the Danish land use must undergo yet another major change. This DCCC analysis shows that the key to fulfilling these political objectives in a meaningful way is efficient and coordinated planning.

Geographical designation must consider the aquatic environment, biodiversity, and drinking water

If the aquatic environment and biodiversity are to be significantly improved, geographically targeted measures are required. Such measures should be based on the designation of areas where there are specific considerations for the

aquatic environment, biodiversity, drinking water, and similar concerns. In Denmark, we have long known which areas are particularly important for the protection of the aquatic environment, whereas the geographical overview is lacking for other areas.

For example, if nature and biodiversity are to be protected, the designated nature areas for protection must be coherent. Such coherent designation is precisely what the Danish Biodiversity Council has provided as an example for use in the DCCC analysis. Such a designation should be made on the basis of a national position on biodiversity in Denmark and on the basis of the overall biodiversity goals of the EU.

Subsidies and projects should ensure efforts are targeted geographically

Measures can be targeted geographically for goals that, unlike climate change mitigation, require geographically specific initiatives. This is already happening to some extent today, and it is crucial that this effort continues based on better mapping material. Measures can be directed towards creating changes in specific areas or even among specific landowners. Below we list a number of possibilities that can be included in future land use policy:

- **Increased conversion of agricultural land from production.** More projects need to be initiated to increase the amount of agricultural land that is converted to land use that helps achieve the goals for the aquatic environment and biodiversity. These projects should be targeted on the land areas where the effects on the aquatic environment and biodiversity are greatest. To ensure momentum in these efforts, resources need to be allocated both for carrying out projects, for example, by supporting municipalities and other project owners, and also for purchasing land and providing subsidies to landowners who are willing to contribute their own land. These efforts can be supported by subsidies under EU environmental schemes and through a land fund that should collaborate with existing funds.

- **Subsidies for voluntary efforts.** Subsidies are a central tool when efforts need to be targeted. Subsidies are often used in connection with voluntary schemes designed to compensate for the costs associated with opting into the particular scheme. They are typically co-financed by EU agricultural schemes and must be approved by the EU Commission. In Denmark, subsidies are usually designed such that all parties opting into a given scheme receive the same subsidy per hectare (or similar unit). Subsidies that are distributed based on an auction system can be more precise in terms of covering the individual costs of participating in a scheme. However, they can also be administratively more challenging. While subsidies can be geographically targeted, there is also a need to develop models that ensure quick adoption of land use change initiatives by relevant stakeholders.

- **Requirements on the use of specific technologies.** Regulation of the use of specific technologies, on the conversion of cultivated land, or similar initiatives are alternatives to voluntary subsidies. Requirements can come with or without compensation. In relation to agriculture, there are several requirements linked to the payment of general EU agricultural support. These include, for example, cultivation obligations, reduced nitrogen allocation for fields, spraying records, or fallow land requirements. There have been attempts to introduce targeted area requirements, such as cultivation-free buffer zones along lakes and streams. However, if requirements are to be introduced without compensation, they must apply indiscriminately. This means that targeting requirements geographically typically involves a need for compensation.

- **Conditional payment of agricultural subsidies.** One way to combine requirements with financial incentives is to make the payment of agricultural subsidies conditional on specific measures. Since 2023, for example, all farmers have been required to set aside four percent of their agricultural land as fallow. It could also be imagined that drainage was prohibited in areas with carbon-rich soils, or that farmers must have a certain amount of carbon-storing crops in their crop rotation. This is done, for example, in the new organic farming guidelines by requiring that fifty percent of the crops be particularly carbon-binding.

A greenhouse gas tax is an important climate change mitigation instrument for land use

An important driving force behind the climate-related transformation of agriculture and forestry should be a tax on CO_2e emissions, as is the case in all other sectors. Introducing a tax in agriculture and forestry is more complicated than in other sectors. But it is a task that can be solved, as shown by the Danish expert group on a green tax reform that

presented models in February 2024 for how to practically tax a large portion of emissions from agriculture and other land use types.[7] The great advantage of the tax is that it provides a clear incentive for action for those affected, and everyone faces the same incentive to reduce CO_2e emissions. When it becomes more expensive to cultivate the land, for example, because there is a tax on fertilizers, it will also encourage changes in land use, which will facilitate some of the land changes outlined in the analysis.

Fact box 1: Description of objectives included in the three scenarios of the analysis

The objectives described here are not a part of all scenarios, but are included in various combinations.

Aquatic environment

Denmark is committed to fulfilling the EU Water Framework Directive and ensuring good ecological status of water bodies before 2027. To do this, Denmark has to reduce its nitrogen emissions by 12,955 tonnes in the agriculture and forestry sectors. This number is based on figures from Aarhus University. The reductions are distributed across different focus areas, each of which must deliver on a specific nitrogen reduction target. The reductions targets are described in the river basin management plans for 2021-2027.

Unmanaged forest

The Danish Parliament has worked out various political agreements that together aim to ensure 75,000 hectares of unmanaged forest. As a result, the Danish Energy Agency's Climate Status and Projection 2023 assumes that 61,445 hectares of existing production forest will be converted to unmanaged forest before 2050.

Afforestation

In the governmental framework of 2022, *Responsibility of Denmark*, the government aims at afforesting 250,000 hectares, although without a time horizon. The long-term goal towards 2050 is therefore set at afforesting with 250,000 hectares of production forest.

Greenhouse gases

As an illustrative target, the analysis uses a goal of ensuring emissions from Danish land area are net-zero by 2050. This corresponds to a reduction of 6.5 mil. tonnes CO2e in 2050 compared to today. This is based on the Danish Energy Agency's *Climate Status and Projection 2023*. Thus, it is not a politically adopted climate target.

Biodiversity

The EU biodiversity strategy has various targets. One of the central targets is ensuring that 30 percent of the EU's land area and 30 percent of its sea area comprise effectively managed and coherent protected areas by 2030. If the target of 30 percent protected land area is to be applied to Denmark, 623,228 hectares of intensive agricultural or forestry production must be converted to protected areas with no production activities. The target for biodiversity is therefore the conversion of 623,228 hectares of agricultural or forestry production land use to protected areas with no production activities, as recommended by the Danish Council on Biodiversity. As Denmark is yet to make plans for how this target is to be fulfilled, and to which degree and with what financing, the target year in the model is set to 2050.

Fact box 2: Analysis method, costs, areas, and greenhouse gas emissions

The analysis method and the data used are described in Chapter 6 in the report. This box provides a brief insight into the land model used in the analysis and describes the costs, areas, and greenhouse gas emissions calculated and used in the analysis.

The TargetEcon Model

The analysis uses a model to map and follow land areas and illuminate the costs of changing land use to meet various goals. The model was developed by researchers at the Department of Food and Resource Economics at the University of Copenhagen. The model is called TargetEcon and can calculate the impact of land use change in a specific location in the country on greenhouse gas emissions (measured in tonnes of CO2e), nitrogen emissions to the aquatic environment (measured in tonnes of N), and biodiversity protection (measured in a specific number of hectares). Changes in land use, called transition elements in this analysis, can, for example, include the establishment of catch crops, afforestation, or the conversion of carbon-rich soils to wetlands.

The model optimizes land use to meet various targets at the lowest possible cost. The model's computational unit is fields and small forest plots. The optimization of the model is based on information about the current income and use of each unit, including whether production is organic or conventional, and whether and how much livestock and artificial fertilizers are used. The model also uses information about, among other things, the soil's ability to retain nitrogen and soil type.

Costs

The costs assessed in the analysis are referred to as direct costs. They consist of the lost income from a change in land use and are based on current prices for inputs, capital and labour, food, and timber products. Prices are market prices and adjusted to 2023 price levels. The costs are assumed to be externally given and thus do not account for the potential impact of changed land use on food prices or wage levels in agriculture.

Land conversion results in societal benefits that are not subtracted from the costs in this analysis. The potential benefits are associated with the altered cultural landscape, including benefits such as an improved aquatic environment, the recreational value of unmanaged forests and other natural areas, and increased biodiversity. All these benefits have a socio-economic value that would significantly reduce the total costs if included.

Areas

The areas in the TargetEcon model include all Danish agricultural land in rotation. These are areas where crops are produced and where soil is regularly tilled. The agricultural areas in the model account for nearly 2.4 million hectares. This corresponds to 92.8 percent of the total Danish agricultural area and 55 percent of Denmark's total area. The agricultural areas that are extensively cultivated are not included in the model. In addition, the model includes all areas with production forests as well as unmanaged forests. In total, the forested area covers over 0.5 million hectares and represents 13 percent of Denmark's area.

Greenhouse gas emissions

The model is updated with the latest emission data and estimates of the effects of reduction measures. Thus, the results are aligned with the data from the recent greenhouse gas inventories. The model only includes effects directly related to the production areas. This applies to greenhouse gas emissions, but also to costs, nitrogen emissions, etc. This means that, in broad terms, the model takes into account greenhouse gas effects resulting from: 1) carbon stocks, 2) nitrous oxide emission from plant residues and fertilizers, and 3) emission of methane from carbon-rich soils.

2 References

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