Biodiversity impact assessment of future biomass provision for biofuel production

Phase 1 of a new study, undertaken with Fraunhofer Institute in collaboration with Imperial College Consultants, has been completed to assess the biodiversity impact of the cultivation of energy crops for biomass production in marginal (unused, abandoned and degraded) lands

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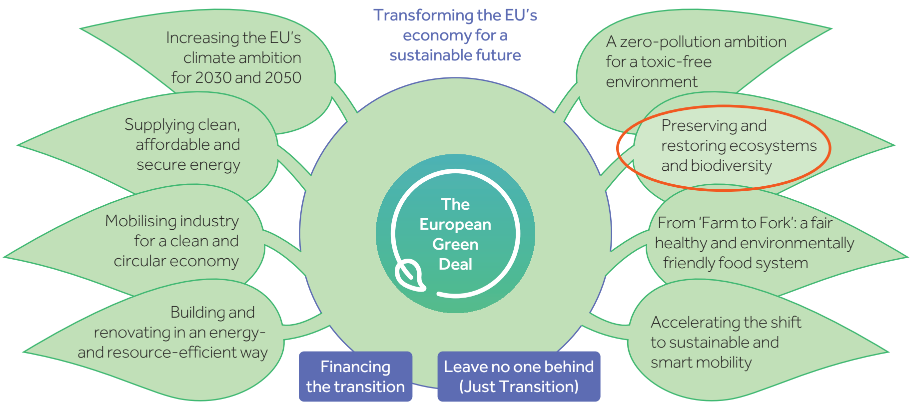
Phase 1: Biodiversity in marginal lands

Introduction

Sustainable biomass feedstock availability and its impact on biodiversity, the protection and recovery of which is one of the main pillars of the European Green Deal as shown in Figure 1, have been raised by different stakeholders as a justification for minimising the role of biofuels in the decarbonisation of the transport sector.

Figure 1: The European Green Deal[1]



In 2021, Concawe contracted Imperial College London Consultants to conduct a study on biomass availability for every EU country + UK by 2030 and 2050.[1] To comply with the sustainability standards, the study was focused on the advanced biofeedstocks (non-food or feed crops) listed in Parts A and B of Annex IX in the Renewable Energy Directive II (RED II). The future biomass potential was estimated for three different biomass mobilisation scenarios:

- Low scenario: farming and forest practices kept at 2020 levels.
- Medium scenario: improved agricultural/forest management in selected countries in the EU with high biomass availability.
- High scenario: strong management practices and increased availability through research and innovation in all EU countries.

According to the findings of this study, the total theoretical sustainable biomass availability potential by 2050 ranges from 408 to 533 Mtoe, depending on the applied scenario. The amount of sustainable biomass that can be used for biofuels production after deduction of the quantities of biomass allocated to other bioenergy sectors such as power and heating as given in the Impact Assessment by the EU Commission[2] amounts to 101–252 Mtoe. This amount of sustainable biomass (as listed in RED II Annex IX, parts A and B) is shown to be more than sufficient to satisfy the potential demand for biofuels in the transport sector in 2050 according to Concawe's low-carbon scenarios.[3]

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640&from=ET

Nevertheless, to guarantee the availability of such biomass for biofuels, additional R&D efforts and the implementation of improved management practices in forestry and agriculture will be required. The supply chain also needs to be developed to mobilise these very important volumes of biomass to the transformation points.

An important element for the acceptance of sustainable biofuels potential is the premise of not harming, or guaranteeing a minimal impact on biodiversity. Biodiversity has been considered in the study on biomass availability by Imperial College London Consultants, based on two principles:

1. Conservation of land with significant biodiversity values.
2. Land management minimising the effects on biodiversity.

However, Concawe wanted to fine-tune this assessment and better understand how biomass removal for biofuels production affects the biodiversity of natural habitats. We therefore decided to commission a study with Fraunhofer, in collaboration with Imperial College London Consultants, to evaluate more precisely and quantify the impacts on biodiversity.

Scope

In this study on the impact on biodiversity, published in 2022, Fraunhofer Institute focused on assessing the impact on the biodiversity of unused, abandoned and degraded lands as a result of the cultivation of energy crops (choosing Miscanthus crop as a representative example). The definitions of these types of marginal land, as given in RED II, are:

- Unused land: areas which, for a consecutive period of at least five years before the start of cultivation of the feedstock used for the production of biofuels, bioliquids and biomass fuels, were neither used for the cultivation of food and feed crops or other energy crops nor any substantial amount of fodder for grazing animals.
- Abandoned land: unused land, which was used in the past for the cultivation of food and feed crops but where the cultivation of food and feed crops was stopped due to biophysical or socioeconomic constraints.
- Degraded land: land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded.

This study on the impact on biodiversity focused on Germany and Bulgaria as representative examples of two EU countries with high biomass potential but with significant differences in infrastructure, policy drivers and innovation.

Biodiversity assessment methods

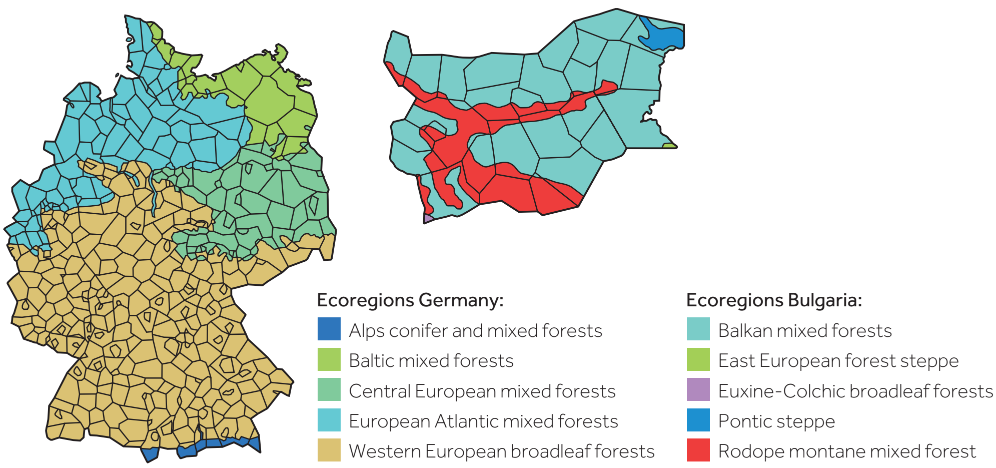
The impact on the biodiversity of a land is defined as the change in the biodiversity quality between the final (after land use) and the pre-use (reference) state. Currently there is no accepted method of reference to quantify the biodiversity quality. For this reason, Fraunhofer used two different recognised biodiversity assessment methods:

1. Biodiversity Impact Assessment (B.I.A.), a method by Lindner (Fraunhofer's methodology).
2. Potentially Disappeared Fraction of species (PDF), according to Chaudhary & Brooks (International Institute of Applied Systems Analysis (IIASA[2]) methodology)

Biodiversity Impact Assessment (B.I.A.) method by Lindner (Fraunhofer's methodology)

The B.I.A. method developed by Fraunhofer quantifies the impact on biodiversity quality using different land-use parameters of various importance. The biodiversity quality calculated with this method can become region-specific by multiplying it with a region-specific weighting factor (ecoregion factors). The different ecoregions in Germany and Bulgaria are shown in Figure 2.

Figure 2: Ecoregions in Germany and Bulgaria



As the concept behind this method is to quantify biodiversity quality as a consequence of land use, this method can be successfully implemented to calculate the biodiversity value of marginal lands in 2050 after their use for biomass production but not for the current (reference) state. To quantify the current biodiversity status, the hemeroby concept is deployed. Hemeroby is a land classification system used to assign biodiversity values to lands depending on the degree of anthropogenic interaction that takes place.

[2] International Institute for Applied Systems Analysis (IIASA) is an independent international research institute with National and Regional Member Organisations in Africa, the Americas, Asia and Europe. https://iiasa.ac.at/

The structure of the hemeroby framework together with the definition of its classes is shown in Table 1. The classification of the marginal land types in the hemeroby list, based on their definitions in RED II and other agricultural directives, was indicated by Fraunhofer and is presented in Table 1. Although the definitions between the hemeroby system and the directives match well for abandoned and unused lands, degraded land can take a broad spectrum of definitions, with hemeroby level V being considered as the best fitting one (set as the base case), and levels IV and VI to be alternative matching options that were considered in this study as part of a sensitivity analysis.

Table 1: Fitting of unused, abandoned and degraded lands to the different hemeroby classes according to their definition in RED II and agricultural directives by the EU Commission

Hemeroby Class	Class name	Different types of land use; indicative examples, to be defined by measurements
I	Natural	Undisturbed ecosystem, pristine forest, no utilisation
II	Close-to-nature	Close-to nature forest management, no thinning
III	Partially close-to-nature	Intermediate forest management (moderate thinning, natural assemblage of species); highly diversified agroforestry systems, low input
IV	Semi-natural	Semi-natural forest management (regular thinning, exotic species); close-to-nature agricultural land use, extensive grassland, orchards, highly structured cropland with low input
V	Partially distant-to-nature	Mono-cultural forest; intermediate agricultural land use with moderate intensity, short rotation coppices
VI	Distant-to-nature	Distant-to-nature agricultural land use
VII	Non-natural artificial	Long-term sealed, degraded or devastated area

Base case
(classification by Fraunhofer as being the most fitting):

- Unused land: Hemeroby class II
- Abandoned land: Hemeroby class III
- Degraded land: Hemeroby class V

Sensitivities
(to capture uncertainty in the classification):

- For unused and abandoned lands, the hemeroby levels II and III fit quite well ⟹ No sensitivity
- Degraded land however showed a broader spectrum of definition ⟹ Sensitivities to levels IV and VI

Potentially Disappeared Fraction of species (PDF) according to Chaudhary and Brooks (IIASA methodology)

This method, developed by IIASA, quantifies the effect on biodiversity in terms of the potentially disappeared fraction of species (species lost per m^2) based on the type and intensity of land use. For this reason, species-area relationships are used to calculate species loss for every ecoregion and land use. To make values specific to the two countries, region-specific factors are used. It should be noted that, compared to the B.I.A. methodology, this method is less rigorous as it requires less detailed input data.

Table 2: Land classification according to the PDF method

For the calculation of the current biodiversity state, degraded lands are classified as: Base case = natural habitat/regenerative vegetation (according to original methodology); Sensitivity case 1 = intense cropland; Sensitivity case 2 = light urban area (sensitivities suggested by IIASA's representatives in an ad-hoc meeting)

Broad land use type	Management type	Details
Natural habitat	None	Little or no human disturbance (pristine state).
Regenerating secondary vegetation	None	Little or no human disturbance.
Managed logged forests	Minimal use (Reduced impact logging (RIL) forests)	Forests managed with RIL techniques designed to minimise impacts on biodiversity.
	Light use (Selectively logged forests)	Forests where only selected commercially valuable trees are harvested at a time such that the disturbance is not enough to markedly change the nature of the ecosystem.
	Intense use (Clear-cut forests)	Forests with extractive use, with even-aged stands and clear-cut patches. The disturbance is severe enough to change the nature of the ecosystem.
Plantation forests	Minimal use	Extensively managed or mixed timber plantations in which native understorey and/or other native tree species are tolerated, which are not treated with pesticide or fertiliser, and which have not been recently (< 20 years) clear-felled.
	Light use	Monoculture timber plantations of mixed age with no recent (< 20 years) clear-felling.
	Intense use	Monoculture timber plantations with similarly aged trees or timber plantations with extensive recent (< 20 years) clear-felling.
Pasture	Minimal use	Pasture with minimal input of fertiliser and pesticide and with low stock density (not high enough to cause significant disturbance or to stop regeneration of vegetation).
	Light use	Pasture either with significant input of fertiliser or pesticide, or with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation).
	Intense use	Pasture with significant input of fertiliser or pesticide, and with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation).
Cropland	Minimal use	Low-intensity farms, typically with small fields, mixed crops, crop rotation, little or no inorganic fertiliser use, little or no pesticide use, little or no ploughing, little or no irrigation, little or no mechanisation.
	Light use	Medium intensity farming, typically showing some but not many of the following: large fields, annual ploughing, inorganic fertiliser application, pesticide application, irrigation, no crop rotation, mechanisation, monoculture crop. Organic farms in developed countries often fall within this category, as may high-intensity farming in developing countries.
	Intense use	High intensity monoculture farming, typically showing many of the following features: large fields, annual ploughing, inorganic fertiliser application, pesticide application, irrigation, mechanisation, no crop rotation.
Urban	Minimal use	Extensive managed green spaces; villages.
	Light use	Suburban (e.g. gardens), or small managed or unmanaged green spaces in cities.
	Intense use	Fully urban with no significant green spaces.

Base case
Best fitting classification for degraded land

Sensitivity analysis:
alternative degraded land classification

The primary drawback of this method is that no differentiation in the current (reference) biodiversity quality between degraded, abandoned and unused lands can be considered. For this method, the closest land use type to all these lands is either the natural habitat or the regenerating secondary vegetation class (see Table 2 on page 8), which implies that even where there is minor human interference biodiversity loss will occur. After an ad-hoc discussion with IIASA's representatives, their recommendation was to run sensitivity analyses considering degraded land as intensive cropland, as well as light urban area classes.

Biodiversity assessment results

To assess the impact that Miscanthus cultivation for biomass production has on the biodiversity of unused, abandoned and degraded lands, the B.I.A. and PDF methods described above were applied. As previously mentioned, B.I.A. has the potential to give more precise results as it is based on more detailed input data compared to PDF. For the analysis with both methods, the production yields of biomass from Miscanthus in 2050 given by the high biomass availability scenario of Imperial College Consultants were used in order to identify the largest positive or negative impact on biodiversity.

B.I.A. method

For the B.I.A. method, the biodiversity quality change is expressed by the biodiversity value increment (BVI), defined as follows:

BVI = biodiversity quality (current, 2020) - biodiversity quality (after land use, 2050)

Given this definition, a positive impact on biodiversity corresponds to negative values for BVI while the opposite happens in the case of biodiversity loss.

As described in the methodology, for the analysis using B.I.A., a base case was set, for which the current biodiversity status of degraded land is matched to hemeroby level V (partially distant-to-nature). Although this level seems to be the best fitting to the different definitions assigned to degraded land, due to the broad spectrum of these definitions, the hemeroby classes IV (semi-natural) and VI (distant-to-nature) were also considered in a sensitivity analysis as alternative options. For unused and abandoned lands, the definitions given in the directives are well established and there is no uncertainty regarding their matching with hemeroby levels.

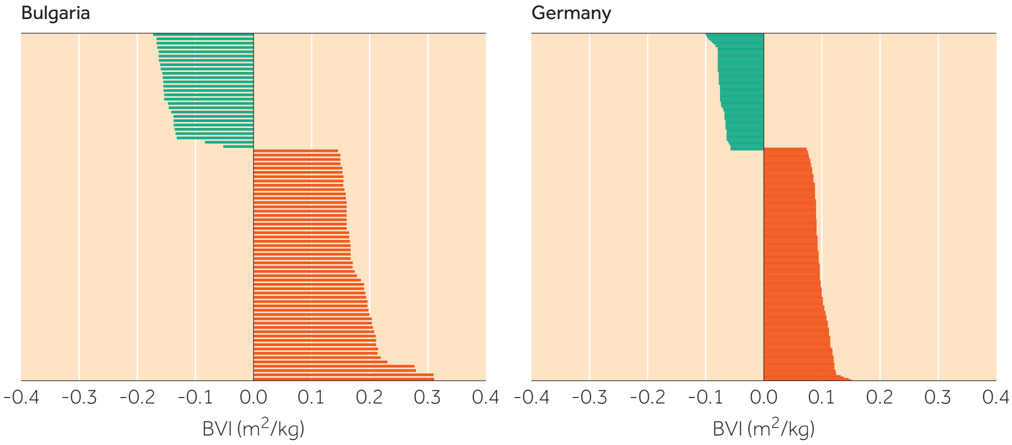
Base case

To conclude the impact of Miscanthus cultivation on the biodiversity of marginal lands, the biodiversity value increment per kg of Miscanthus in all the NUTS 3[3] regions in Bulgaria and Germany is shown in Figure 3. It can be clearly seen from the figure that, in both countries, some regions demonstrate a negative BVI (which means a biodiversity improvement) while others show a positive BVI change (which means a biodiversity loss).

[3] NUTS 3 regions = 'small regions for specific diagnoses' as defined in the European Union's NUTS (Nomenclature of territorial units for statistics) 2021 classification. https://ec.europa.eu/eurostat/web/nuts/background

This is explained by the fact that, in the regions that experience biodiversity improvements, degraded lands currently exist in which the cultivation of Miscanthus is shown to enhance local biodiversity. On the other hand, the opposite happens in areas that are rich in unused and abandoned lands; in these areas, such human interference leads to biodiversity losses.

Figure 3: Biodiversity value increment (BVI) per kg of Miscanthus (from 2020 to 2050) in all the NUTS 3 regions in Germany and Bulgaria as a result of Miscanthus cultivation in marginal (degraded, unused and abandoned) lands

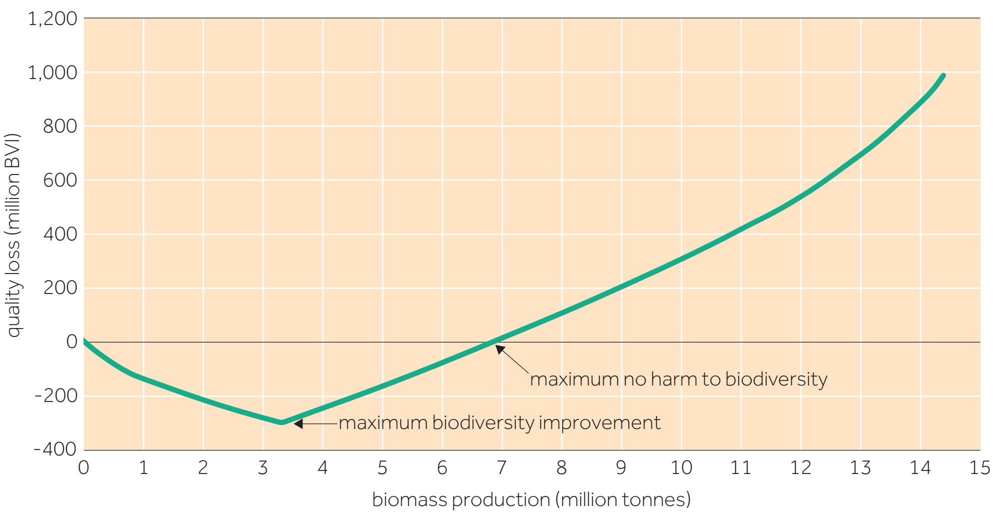


BVI < 0 means biodiversity benefits. This concerns regions with degraded lands.

BVI > 0 means biodiversity damage. This concerns regions with abandoned and unused lands.

To determine the maximum amount of biomass that can be sustainably produced from energy crops in Germany and Bulgaria combined, the cumulative biodiversity quality loss in marginal lands as a function of the biomass produced in the two countries is given in Figure 4. The highest amount of biomass produced annually in the two countries, as calculated in the high biomass availability scenario of Imperial College Consultants, is equal to 14.4 Mt.

Figure 4: Cumulative biodiversity quality loss (from 2020 to 2050, using the B.I.A. method) versus cumulative biomass production as a result of Miscanthus cultivation in marginal lands



Note: the cumulation goes through all the NUTS 3 regions in Germany and Bulgaria, starting with degraded and continuing with abandoned and unused lands.

The cumulative biodiversity loss curve starts with the areas that are rich in degraded lands, and by aggregating biodiversity benefits, the BVI expectedly decreases (biodiversity improves) up to a Miscanthus production of 3.3 Mt/year, which is equal to 23% of the total biomass that can be produced in the marginal lands of the two countries. Then, by adding the biodiversity losses of areas with abandoned and unused lands, the BVI curve starts to follow an upward trend and reaches a break-even point at 6.9 Mt/year (48% of the total biomass availability potential). Consequently, this is the maximum amount of biomass that can be produced in the two countries combined without harming marginal lands' biodiversity. Higher biomass production rates could potentially damage biodiversity.

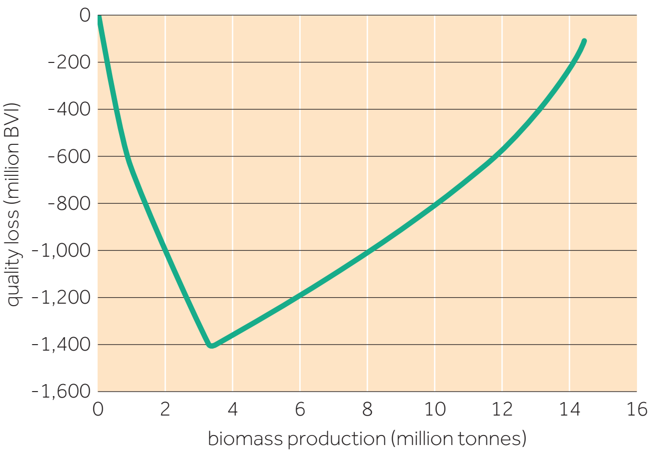
While the quantity of Miscanthus that could be produced according to the high scenario (14 Mt/year) of the Imperial College Consultants study introduces a negative impact on the biodiversity of marginal lands in Germany and Bulgaria, this is not the case for the other scenarios: the low scenario, which corresponds to a production rate of 3 Mt/year, is possible with a positive impact on biodiversity, and the medium scenario, corresponding to a production of 7 Mt/y, can be achieved with no harm on biodiversity. As the low and medium scenarios have shown the potential to satisfy the demand for biofuels in the transport sector estimated in Concawe's low carbon scenarios, this study indicates that they can achieve it in a non-harmful or even restorative way for the biodiversity of marginal lands.

Sensitivity analysis

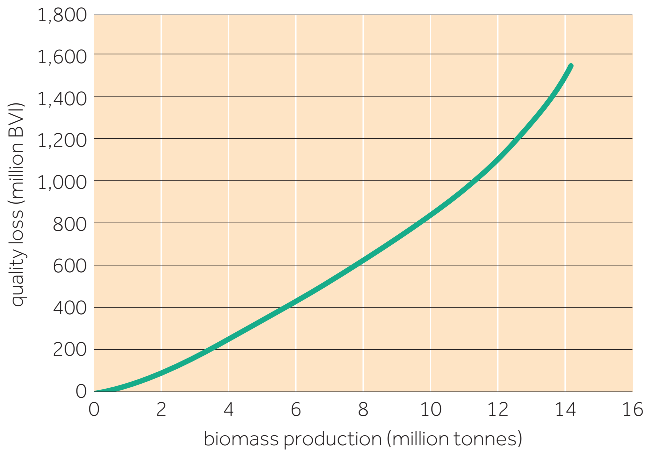
For the two sensitivity cases, in which the distant-to-nature and semi-natural hemeroby classes were used to calculate the current biodiversity status in degraded lands, the impacts of biomass production on biodiversity in the two countries are shown in Figure 5. In contrast to the base case, the biodiversity is either not harmed (distant-to-nature case), even with the maximum production of the high scenario of the Imperial College Consultants study, or is always damaged regardless of the degree of biomass removal (semi-natural case).

Figure 5: Cumulative biodiversity quality loss (from 2020 to 2050) versus cumulative biomass production, as a result of Miscanthus cultivation in marginal lands for (a) Hemeroby class VI and (b) Hemeroby class IV, used for the calculation of the current biodiversity value in degraded lands

a) Hemeroby class VI (distant-to-nature)
Negative values: no harm to biodiversity



b) Hemeroby class IV (semi-natural)
Positive values: always potential harm to biodiversity



Potentially Disappeared Fraction of species (PDF) method

For the PDF method, similarly to B.I.A., the biodiversity quality change is expressed as the deviation of the potentially disappeared fractions from the current state to the future:

PDF = PDF (current, 2020) - PDF (current, 2050)

This means that a negative PDF value implies a biodiversity improvement, whereas a positive PDF value implies a biodiversity loss.

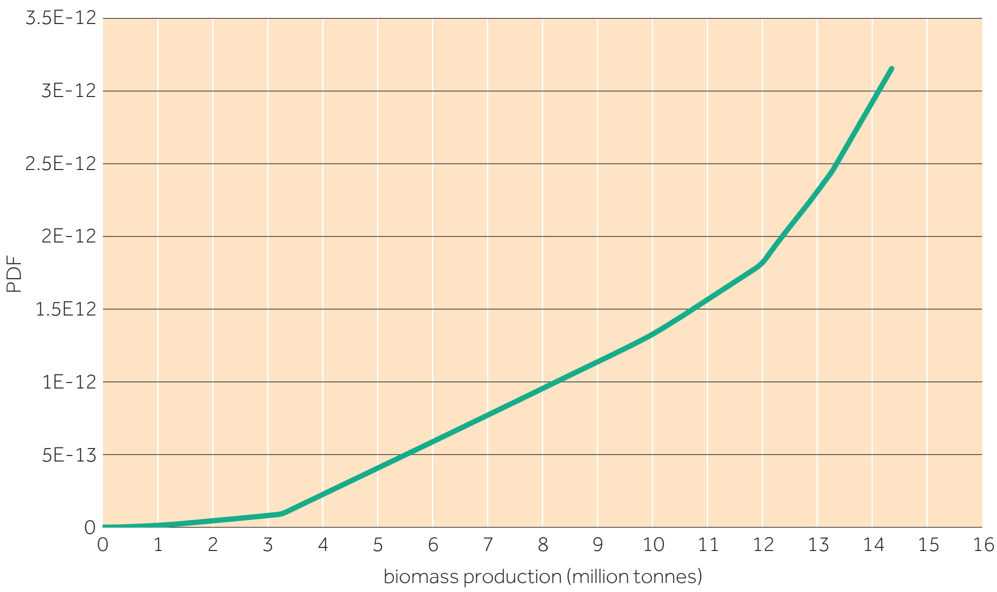
As elaborated in the methodology, a base case and two sensitivity cases were established for the application of this second biodiversity assessment method. For the base case, an analogy between the natural habitat class used for the PDF method and the current status of degraded lands was considered. For the sensitivity cases, after an ad-hoc meeting with IIASA and following their indications, it was noted that, due to the broad spectrum of definitions usually given to degraded land, there could be an analogy between the degraded land and the intensive cropland or the light urban area class of the PDF concept.

Base case

For the base case, using the PDF method, regardless of the type of marginal land being considered, even very small amounts of biomass produced have a negative impact on biodiversity quality (positive PDF values). This is not necessarily related to any vulnerability of those lands, but to the inherent inadequacy of this method to provide a representative land-use classification for the initial status of marginal lands. As the closest characterisation in the PDF concept is the natural habitat class (zero interaction with humans), the consequence (see Figure 6) with this method is that even the smallest interference results in a biodiversity loss.

Figure 6: Cumulative biodiversity quality loss (from 2020 to 2050, using the PDF method) versus cumulative biomass production in marginal lands

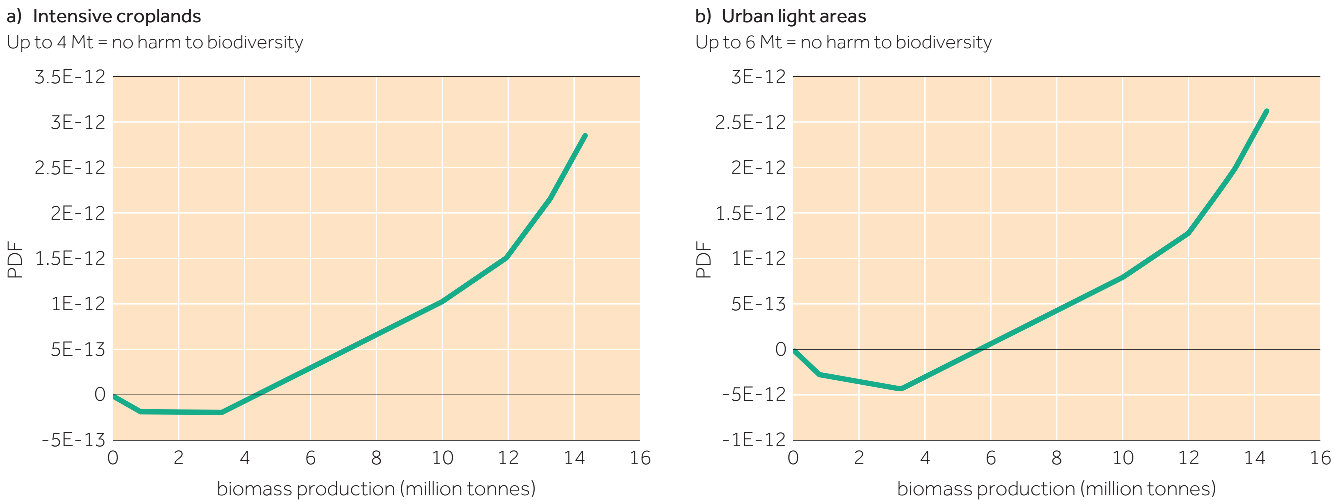
Note: the cumulation goes through all the NUTS 3 regions in Germany and Bulgaria, starting with degraded and continuing with abandoned and unused lands.



Sensitivity analysis

In the two new sensitivity cases shown in Figure 7, the current human presence is more intense compared to the natural land class assumed for degraded lands in the base case. It therefore follows that the biodiversity quality is of a much lower standard, and using these lands for biomass production up to a certain limit may have a positive impact on biodiversity.

Figure 7: Cumulative biodiversity quality loss in Germany and Bulgaria combined (from 2020 to 2050, using the PDF method) versus cumulative biomass production in marginal lands, with degraded lands to be identified as (a) intensive croplands and (b) urban light areas



Conclusions

The primary conclusions from this study conducted by Fraunhofer Institute are summarised as follows:

1. The results show that, according to Fraunhofer Institute's B.I.A. method (base case), the cultivation of Miscanthus for biomass production on degraded lands can lead to a biodiversity improvement.
2. Using the Fraunhofer Institute's B.I.A. method (base case) and the Imperial College's biomass availability potential results, the study shows that, in the marginal lands of Germany and Bulgaria combined:
   - Up to 3.3 Mt biomass (23% of the biomass availability potential in these lands and 5% of the total biomass potential for bioenergy coming from the agricultural sector as calculated by Imperial College, and equivalent to the quantities produced in their 'low scenario') can be produced that could improve the biodiversity in marginal lands in the two countries.
   - Up to 6.9 Mt of biomass (almost half of the biomass availability potential in these lands and 11% of the total biomass potential for bioenergy coming from the agricultural sector as calculated by Imperial College, and equivalent to the quantities produced in their 'middle scenario') can be produced without harming the biodiversity in marginal lands in the two countries.
3. Both the B.I.A. and PDF methods show that different conclusions can be drawn with different definitions of the current state of land (especially for degraded land). A detailed inventory and definitions of the state of land need to be developed at the EU level.

This study also demonstrates the importance of establishing a method of reference to quantify the impact on biodiversity of biomass production and the need to have a better definition of the precise status of the lands in Europe.

As a next action, Concawe is aiming to conduct another study in which the focus of biodiversity impact assessment will be shifted from unused, abandoned and degraded lands to forests. According to the Imperial College biomass availability analysis, 40–45% of the estimated biomass potential for bioenergy in Europe in 2050 comes from forests; this demonstrates the importance of assessing the imprint that biomass production leaves on the biodiversity of these habitats.

References

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