

**STAR-ProBio**

**Sustainability Transition Assessment and Research of Bio-based  
Products**

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## Deliverable 7.2

### Land Use Changes applied to case studies

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## Abstract

Land use change effects induced by policies for the promotion of bio-based products have become one of the most important aspects for the development of a sustainable bioeconomy policy framework. The topic has first become relevant because of biofuel policies introduced by different countries and regions on a global level.

Recent adaptations in EU biofuel policies have shown a diversification of strategies regarding iLUC mitigation and the general reduction of potentially negative impacts from EU biofuel policy targets. The recently passed recast of the EU renewable energy directive (RED 2) introduces a differentiation between high and low iLUC risk biomass as well as biomass and biofuels from “additionality” measures, which are also considered as low iLUC risk. A meaningful implementation of this concept into the policy framework for biofuels or even the EU bioeconomy requires appropriate and robust tools, which can be used to make the necessary differentiations regarding iLUC risks and can verify potential claims for low iLUC or additional biomass. Furthermore, it seems important to constantly monitor the effects of the RED 2 framework including, different elements for the differentiation and promotion of biomass and biofuels according to their iLUC risk.

STAR-ProBio WP 7 is contributing to this general development, by providing a risk assessment tool, which can be used to support low iLUC risk certification, as well as the development of iLUC mitigation strategies on a producer level. This tool could be integrated in certification schemes and modules for low iLUC risk certification. Furthermore, producers of biomass or bio-based products can use it to understand the potential impact of possible additionality measures on their specific iLUC risk. Based on the outcome of this assessment, a producer might develop strategies regarding the selection and implementation of additionality measures into their operation.

This report summarises the solutions for low iLUC risk certification developed by STAR-ProBio WP7.

## Suggested citation

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## Summary of Deliverable 7.2

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Over the recent years, the general attention towards the EU bioeconomy has increased significantly. Pinned to this are high expectations for potential contributions of the bioeconomy to topics such as the reduction of GHG emissions, product innovation, creation of income, etc. However, the project of developing a coherent policy framework for a growing, sustainable bioeconomy is complex, since it builds on different sectors (e.g. agriculture, forestry, energy, etc.), which are all related to specific challenges.

Regarding the potential challenges related to the sustainability of a growing bioeconomy, existing examples and lessons learned from its different sectors and development in the past can be very useful. A prominent example is the development of the EU biofuels sector. This example clearly underlined, that the development of complex interconnected economic sectors in the bioeconomy needs to be monitored and accompanied in order to avoid negative trade off effects, which might influence areas of social or environmental sustainability. One of the biggest issues related to the development of the EU biofuels sector and the development of an increasing target for EU biofuels was the potential displacement of existing uses of biomass or agricultural land. Those effects, which cannot be measured directly (they have to be modelled), are referred to as indirect land use change (iLUC) effects. In that sense, the introduction of a target for a market share of a specific bio-based product (e.g. a biofuel) can induce replacement effects which might result in land use change (e.g. from forestland into agriculture) in other parts of the world. So far, mainly because of the existing policy instruments, the issue of iLUC is associated mainly with the development of biofuels and bioenergy. However, depending on the development of the EU bioeconomy as a whole and with the introduction of respective mechanisms for the promotion of bio-based materials, the issue of replacing existing uses of biomass might also become relevant for the EU bioeconomy as a whole.

Existing studies and models to quantify iLUC effects associated with specific policies or policy targets are useful instruments to inform policy makers about the potential impact of their general strategies and future targets. STAR-ProBio WP 7 is working to complement these approaches, by providing specific tools and solutions for producers of biomass or bio-based products. These tools are meant to quantify individual risks of producers and to understand the potential impact of specific production measures, which could reduce the iLUC risk.

In that sense, STAR-ProBio WP 7 is contributing to the current policy framework of the EU Commission, which has started to work on a general differentiation of the iLUC risk of different types of biomasses and has introduced the concept of low iLUC risk biomass in its policy framework for biofuels (i.e. with the RED 2).

Throughout the project duration of STAR-ProBio, and especially during the work on Task 7.1, it became obvious, that a meaningful contribution of Task 7.2 to the topic of iLUC mitigation could not be to develop another iLUC quantification model. Instead, we focussed to support and complement the current strategy of the Commission, which aims to differentiate between high and low iLUC risk feedstocks and on strategies supporting the development of iLUC mitigation measures. In that sense, this report presents two complementary concepts, for solutions to assess and certify low iLUC risk biomass.

The first solution is an iLUC risk assessment tool, which can be applied and used by producers of biomass and bio-based products as well as by certification schemes and bodies. Based on the individual, actual values of the specific producer, the tool allows calculating a baseline iLUC risk. Furthermore, the user can use the tool to calculate, how his risk changes, when introducing different improvements into his process.



This assessment tools and the solutions produced under WP 7 are closely linked to the work in STAR-ProBio WP 2, WP 4, WP 5 and WP 6, aiming to use a common set of input data for the assessment. This ensures a generally low burden and effort for potential users of the iLUC risk assessment tool and the respective iLUC indicator in WP 8 as well as in certification schemes and assessment frameworks outside the project (compare (Marazza, Balugani, Stefan, Vincent 2018)).

The iLUC risk tool has been successfully demonstrated with the example of the STAR-ProBio case studies.

The second solution focusses on these measures for improvement and their verification by a certification body. For this purpose, we have focussed on the concept of additionality, which has been introduced also by the Commission with their Delegated Act on the determination of low and high iLUC risk feedstock. Based on STAR-ProBio Deliverable 7.1 and a comprehensive review of existing literature, the current status of existing approaches and methodologies for low iLUC certification has been summarised and discussed in this report.

Both of the solutions presented as an outcome of STAR-ProBio Task 7.2 can support a meaningful implementation of low iLUC certification as a part of the RED 2 framework, which requires robust tools and verification approaches in order to avoid free riders (i.e. projects certified as low iLUC without introducing effective additionality practices). Otherwise, a low iLUC framework would lose integrity and acceptance and fail to create the necessary incentives for good projects.

The review and discussion of existing approaches for low iLUC risk certification shows shortcomings in all available methodologies. Furthermore, existing approaches differ significantly regarding the level of complexity and the potential effort needed for a robust verification. Thus, it seems highly relevant, that the Commission provides more guidance and minimum requirements for low iLUC risk certification than currently included in the existing, respective Delegated Act of the RED 2. Since it seems especially important to avoid the certification of free riders and a potential “race-to-the-bottom”, where existing certification schemes compete on the market with respect to their individual low iLUC risk certification approach, it seems necessary that policy makers define a robust set of “baseline” certification rules. In that sense, it seems important, that out of the existing approaches, a robust set of rules is being selected and defined. This framework of rules needs to be constantly monitored and updated. Comparable to the criteria of GHG mitigation for biofuels, whose methodology and background data is also frequently updated, this approach seems more promising than to wait for a “final” methodology that overcomes all existing shortcomings for low iLUC certification (e.g. the issue of a baseline yield).

The definition of such a framework of certification rules should be able to account for the most relevant additionality measures to be expected. In that sense, especially measures to increase agricultural yields and to use currently unused resources such as residues and wastes as well as unused land seem highly relevant. Especially for the latter, clear definitions are necessary in order to avoid a potential shift of negative impacts into areas of social sustainability or biodiversity. As pointed out already by other authors (e.g. (Malins 2019)), the already existing UM CDM Additionality Tools provide an excellent framework of orientation for the verification of additionality in the certification of projects. The CDM Additionality Tool follows a different objective than additionality demonstration under the EU RED framework. In that sense, the different steps for additionality demonstration need to be adapted (as it seems, also not all of them are relevant (e.g. step 1) to low iLUC risk certification.

In that sense, as a next step, it seems necessary to test the real life implementation of the existing certification approaches, including the iLUC risk tool, in a series of pilot certification projects. Based on these projects, a starting set of rules and guidelines for low iLUC risk certification can be developed.



# 1 Introduction

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Land use change effects induced by policies for the promotion of bio-based products have become one of the most important aspects for the development of a sustainable bioeconomy policy framework. The topic has first become relevant because of biofuel policies introduced by different countries and regions on a global level. Assessments conducted by Searchinger et al., Fargione et al. and several others have flagged the high risks for increasing pressure on natural areas as a consequence of a policy induced, additional demand for biofuels and the respective areas for crop production (Fargione, Hill, Tilman, Polasky, Hawthorne 2008; Laborde 2011; Laborde, Padella, Edwards, Marelli 2014; Searchinger, Heimlich, Houghton, Dong, Elobeid, Fabiosa, Tokgoz, Hayes, Yu 2008).

Consequently, policy makers started working on mitigation measures and introduced actions, which aimed to avoid or reduce negative impacts, associated to biofuels being produced and used as a consequence of, for example, EU biofuel policies. In that sense, the EU Directives 2009/28/EC (RED), 2015/1513 and the the revised renewable energy directive 2018/2001/EU have set a specific focus on the definition of sustainability criteria, including requirements and thresholds for the GHG mitigation potential of a biofuel as well as the definition of areas not suitable for the production of biofuel feedstock. While these measures do in general address the risk of direct land use change scenarios, they are, alone, not appropriate to tackle the risk of indirect land use (iLUC) change effects resulting from an increasing use of biofuels (or bio-based products).

Throughout the recent years, a large number of literature was published on iLUC and iLUC estimations (Laborde 2011; Valin, Peters, van den Berg, Frank, Havlik, Forsell, Hamelinck 2015). Several authors have conducted estimations and assessments related to the GHG emission implications from iLUC scenarios resulting from EU biofuel targets (10% of renewable energies in the EU transport system in 2020 as in the EU RED; and 14% until 2030 as defined in the recast of the EU RED) (European Commission 2009, 2018). The assessments available have been important and useful to support the impact assessment for EU policies, especially in describing the existing dynamics (e.g. regarding trade flows, land demand and land use change) of the affected markets and the potential change induced by policy targets, which can create additional demands.

Recent studies reviewing iLUC modelling work show that the different models not only produce very different results, but also have different assumptions and set up, so that estimated iLUC effects vary widely across approaches, making it difficult to use them for policy making (Mulligan et al. 2010; Marelli et al. 2011; Edwards et al. 2010) and (Woltjer, Daioglou, Elbersen, Ibañez, Smeets, González, Barnó 2017).

Even though the general results regarding the magnitude of GHG emissions from iLUC differs between the various studies available, two broader, general conclusions can be derived:

1. The associated iLUC risks and the emissions from iLUC seem to differ significantly between biofuel feedstocks and technology pathways, which are suitable to fulfil a policy target (for biofuels).
2. The iLUC risk and the associated impact of a biofuel (or a bioeconomy) policy is determined by both the overall demand for biomass induced by the policy and the type of biomass (and conversion technology) to satisfy the target.

Thus, the observation from available literature can provide policy makers with the scientific fundamentals to develop well-balanced targets and strategies. Furthermore, in case the models used for the estimation of iLUC effect allow for more differentiated answers, also, more detailed and educated LUC mitigation strategies and policies can be developed.





With the 2015 amendment of the EU RED directive, and the EU RED recast for the timeframe of 2021 to 2030, the EU Commission has adapted its policy framework for the promotion of biofuels, trying to address the above-mentioned aspects. The introduction of a cap for biofuels from conventional agricultural crops was aiming to limit the overall additional demand for crops produced on agricultural land. Secondly, the commission introduced a risk-based approach, which shall allow for a differentiation of the iLUC risks of biofuels. In that sense, a specific sub-target is aiming at the promotion of advanced fuels (produced mainly from specific waste and residue categories, as defined in Annex IX, part A of the Directive 2018/2001). Furthermore, the recast of the renewable energy directive differentiates between low and high iLUC risk biofuels, including biofuels produced from agricultural cropping systems. (European Commission 2018).

## **1.1 Our approach to contribute to the assessment and identification of iLUC biomass**

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Under consideration of these developments, STAR-ProBio WP 7 has been set up to contribute to and potentially complement existing tools and approaches to assess the iLUC risks of bio-based products and support the certification of potential low iLUC risk biomass. In contrast, to several existing studies, which have been set up to assess iLUC risks on a broader, system level, our activities address mainly the producers of biomass and bio-based products. The general decision for our work towards that direction was the result of internal discussions, especially during the work on T 7.1 (review of existing iLUC models) and a reflection of current and recent policy developments (e.g. the process for the development of the RED 2). In that sense, it seemed relevant, to work on the development of indicators, tools and strategies, which can help producers of bio-based products and certification schemes to reduce individual iLUC risks.

Starting from a comprehensive review of available literature, models and approaches on iLUC assessment, which was published in the technical report Deliverable 7.1, this report will present two complementary approaches dealing with the iLUC risk of stakeholders included in the value chain of bio-based products. In that sense, the findings of Task 7.1 (i.e. the key drivers for iLUC risks associated with the production of bio-based materials) have been used to develop a set of indicators for measures and strategies to reduce iLUC risks during feedstock production and processing.

The first approach, which has been set up as a direct continuation of Task 7.1 resulted in the development of a model (Figure 1) and an associated tool, which allows estimating the individual iLUC risk of a producer of biomass or a bio-based product (see chapter 2.1). Furthermore, the tool allows understanding, how this individual iLUC risk might change in relation to specific production practices or measures, which could be implemented on a producer level, hence informing stakeholders and help in the definition of policies to reduce iLUC (Task 7.3).

The demonstration of this iLUC risk tool on the specific examples of the STAR-ProBio case studies show ways for its application on a producer level, but shows also relative differences regarding the iLUC risk of the different feedstock and product examples analysed (compare chapter 3).



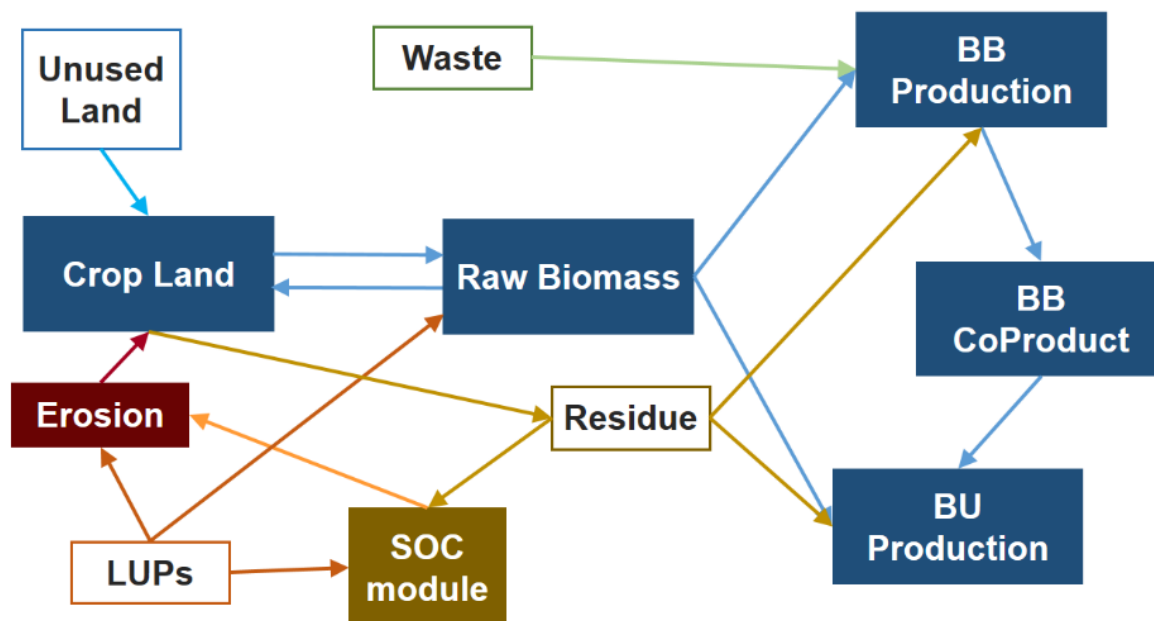
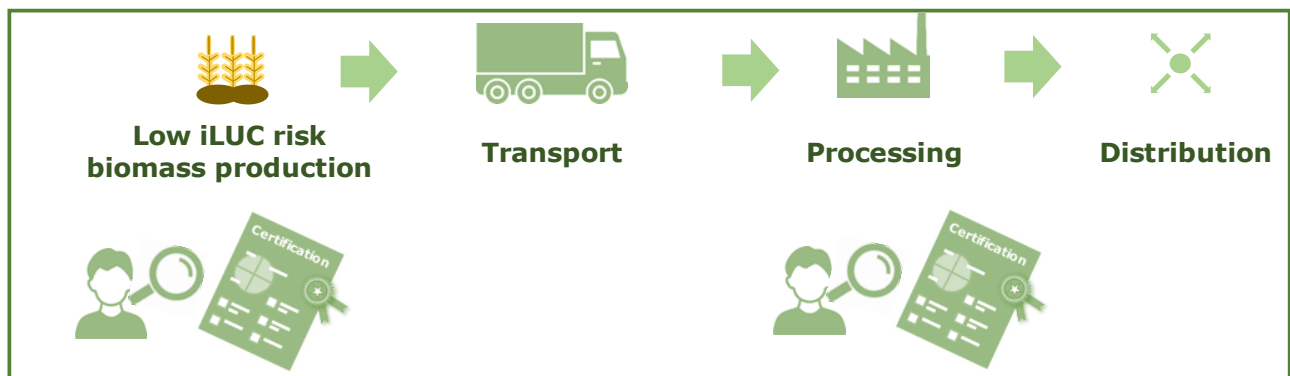
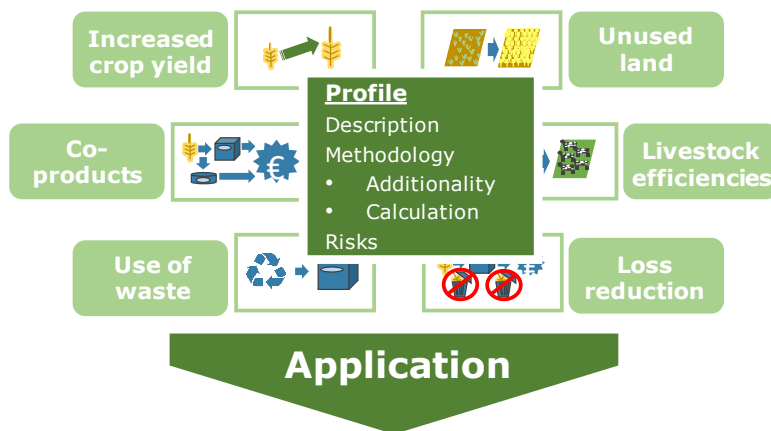


Figure 1 Schematic of the iLUC risk model; BB means Bio-Based, BU stands for "other uses" (the feed market, in the context of the model), SOC for Soil Organic Carbon. Land use practices influences agricultural yields, resistance to erosion, and SOC. SOC influence soil erosion. Erosion increases the demand for cropland, unused land can decrease it. Waste conversion to bio-based material decrease the need of raw biomass. Residues can be used to produce bio-based materials, hence decreasing demand for raw biomass; however, they are also used to increase SOC and in the feed sector. Co-products of the production of bio-based materials can be used as substitutes of raw biomass in the feed sector, decreasing the demand for raw biomass.

Secondly, Task 7.2 is summarising and tying in on existing work for the development of certification approaches, which are suitable to identify and certify low iLUC risk biomass or low iLUC risk bio-based products (compare Figure 2). This approach is mainly following the concept of additionality, which is also a strong rationale in the identification of low iLUC risk biomass and biofuels in the RED 2 directive. In that sense, Task 7.2 has reviewed, summarised and discussed existing approaches and methodologies to certify additional and low iLUC risk biomass. Furthermore, potentially relevant additionality practices and their potential integration into product certification are being discussed in this report (compare chapters 0, 4).

## Identification of additionality practices



*Figure 2 Identification and description of additionality practices for low iLUC risk certification of producers of bio-based products*

The general directive of the work presented in this report is therefore in line with the most recent discussions and developments in science and politics on an EU level.

### 1.2 The role of WP 7 in the STAR-ProBio project

STAR-ProBio is aiming to develop tools, methods and matrices for the sustainability assessment of bio-based products. Furthermore, the results of STAR-ProBio WPs 2, 3, 4, 6 and 7 will be combined in an integrated assessment tool as part of WP 8. This tool and the various results of the project shall support the sustainability assessment for bio-based products by different stakeholders of the bioeconomy. In that sense, WP7 is contributing to the goals of STAR-ProBio with the development of an indicator for the iLUC risk assessment on a producer level (and the respective methodologies to do so).

The work for the development of an iLUC risk tool and indicator is building up on the impressive work and the various existing approaches to assess iLUC effects with different combinations of models and hybrid approaches. The analysis conducted under Deliverable 7.1 has not only shown the great variety of modelling approaches, it also described the correlations and key parameters, which have been identified in the existing work on iLUC.

This first and important step in WP 7 also helped to highlight important dynamics to be considered as well as some potential connection between iLUC impact assessment and the potential identification of low iLUC risk biomass and its verification in the context of product certification. In that sense, the second contribution of the WP to the overall project is the development of approaches for the certification of additionality measures that could be suitable to provide biomass not related to an additional demand for land for its production.

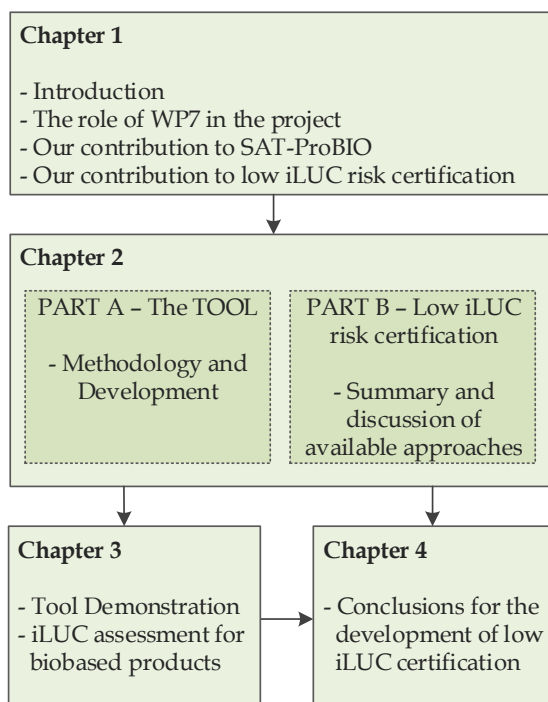
The assessment tools and solutions produced under WP 7 and presented in this report are furthermore closely linked to the work in STAR-ProBio WP 2, WP 4, WP 5 and WP 6, aiming to use a common set of input data for the assessment. This ensures a generally low burden and effort for potential users of the iLUC risk assessment tool and the respective iLUC indicator in WP 8 as well as in certification schemes and assessment frameworks outside the project (compare (Marazza, Balugani, Stefan, Vincent 2018)).

### 1.3 Structure of this document and link between the elements presented

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This document is structured as follows (compare Figure 3). Firstly, the general approach and the methodology for the development of the iLUC risk assessment tool and the review and discussion of existing certification solutions for additionality measures will be presented in the following chapter 2). The later includes a description of the potential interlinkages between both elements as well as a detailed description of the different additionality practices and potential approaches for their implementation in certification schemes.

Thirdly, the applicability of the developed iLUC risk assessment tool will be tested with the STAR-ProBio case study examples (compare chapter 3). The report ends with some conclusions towards the further development of low iLUC risk assessment and certification (chapter 4).



*Figure 3 Content, outcome and connections of the chapters of this deliverable*

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## 2 General concept and methodology

In the following two chapters, we will describe our approach for the development of the iLUC Risk Assessment Tool and the current status of additionality practices for the certification of low iLUC risk biomass.

### 2.1 Part A – The Development of an iLUC Risk Assessment Tool

#### 2.1.1 The SydILUC Model

The System Dynamics indirect Land Use Change (SydILUC) model is a dynamic causal-descriptive model that estimates future global land demand based on projection of bio-based production policies. It works on a global scale, with yearly time steps, so that the uncertainty related to land use allocation and short-time market changes are eliminated. Since it is a dynamic model, it naturally accounts for feedback loops, delay effects, and time-dependent exogenous variables. It accounts for use of co-products<sup>1</sup>, use of residues, soil organic carbon changes, use of degraded or abandoned land, market effects, changes in agricultural yields, use of waste as an alternative biomass for bio-based material production.

A simplified version of the model is visible in Figure 4 and a schematic in chapter 1, Figure 1.

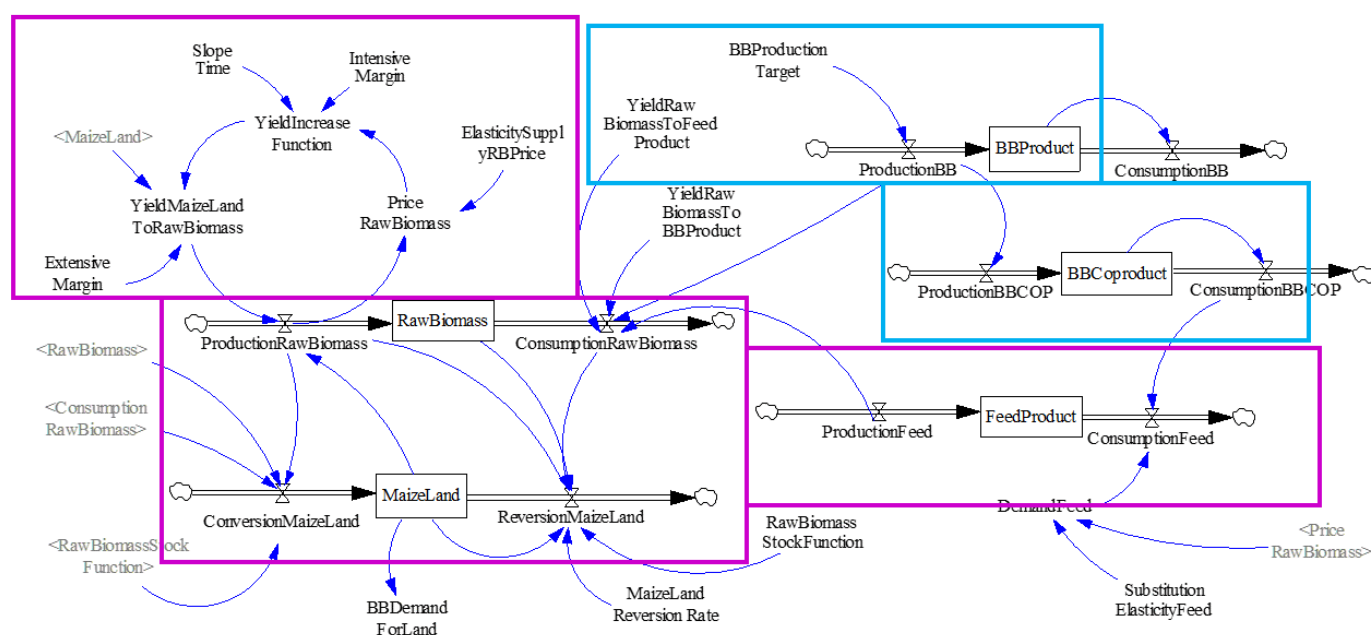


Figure 4 The simplified version of SydILUC model; the symbols are those of "System Dynamics". The light blue boxes show the part of the model accounting for different type of bio-based plastics; the purple boxes show the part of the model accounting for the type of raw biomass.

<sup>1</sup> For the sake of simplicity, the terms co-product and by-product are being used interchangeably in this Deliverable



The simplified SydILUC model shows all relevant cause effect and market relationships; these relationships have been calibrated and validated using the FAOSTAT dataset<sup>2</sup>, for the raw biomasses used in the scenarios and exercises (maize, sugar beet pulp, and soybean).

The most relevant relationships include:

- the production-driven price equation for raw biomass;
- the effect of crop price on demand from the feed market;
- the effect of crop price on yields (called *intensive margin* in iLUC literature, (Britz, Witzke 2014; Marelli, Mulligan, Edwards 2011));
- the modelled behaviour of maize yields in time;
- the future projections of global maize yields, based on literature review on maize yield forecasts (Grassini, Eskridge, Cassman 2013; Iizumi, Ramankutty 2016; Müller, Elliott, Pugh, Ruane, Ciais, Balkovic, Deryng, Folberth, Izaurrealde, Jones, Khabarov, Lawrence, Liu, Reddy, Schmid, Wang 2018);
- and the effect on global yields of increasing the extension of land cultivated for maize production (called *extensive margin* in iLUC literature, (Hertel, Lee, Rose, Sohngen 2008)). The variables related to the different bio-based plastics are (light blue box in Figure 4): (i) target production of the bioplastic (in Mt, EU values); (ii) fraction of relevant co-products resulting from the production of the bio-based plastic; (iii) the actual yields of bio-based plastic materials from the feedstock. The data used for PBS and PLA inside the model was condensed from various documents, and was revised together with University of Santiago de Compostela, Spain, to be consistent with the LCA approach used in WP 2 (Figure 5 and Figure 6); the data for the bio-PUR production was provided by DBFZ, Germany. All the relevant parameters used in the model, together with their source and metadata, can be found in the files "iLUC model - semantics - PBSparameters\_v12\_EB.xlsx" and "iLUC model - semantics - PLAParameters\_v12\_EB.xlsx" as supplementary materials, provided on the STAR-ProBio homepage.

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<sup>2</sup> Data is taken from: <http://www.fao.org/faostat/en/#data> (visited: 30.01.2020)

PBS

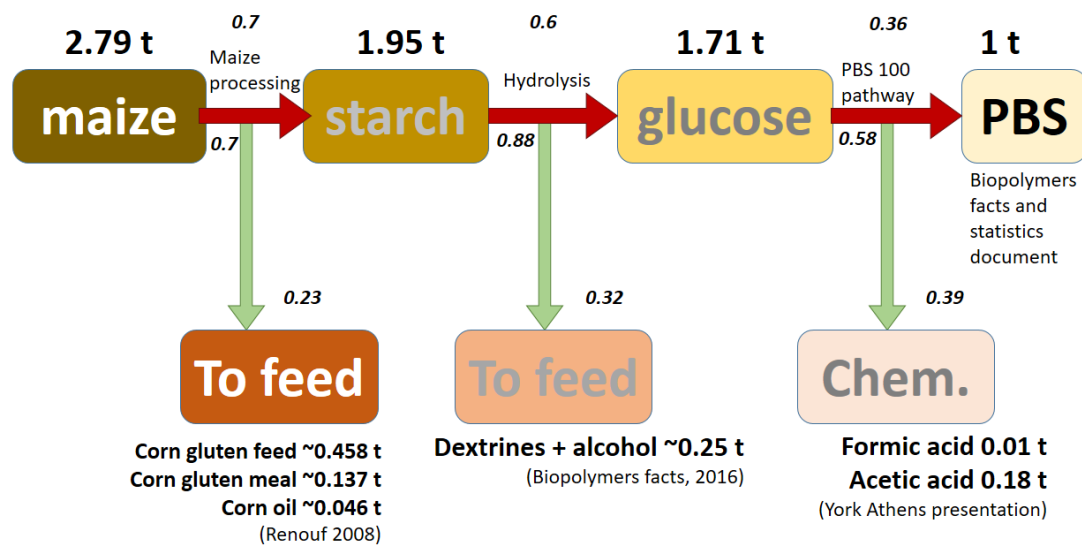


Figure 5 PBS production from maize, yields of the macro-processes and main co-products that could be used on the market.

PLA

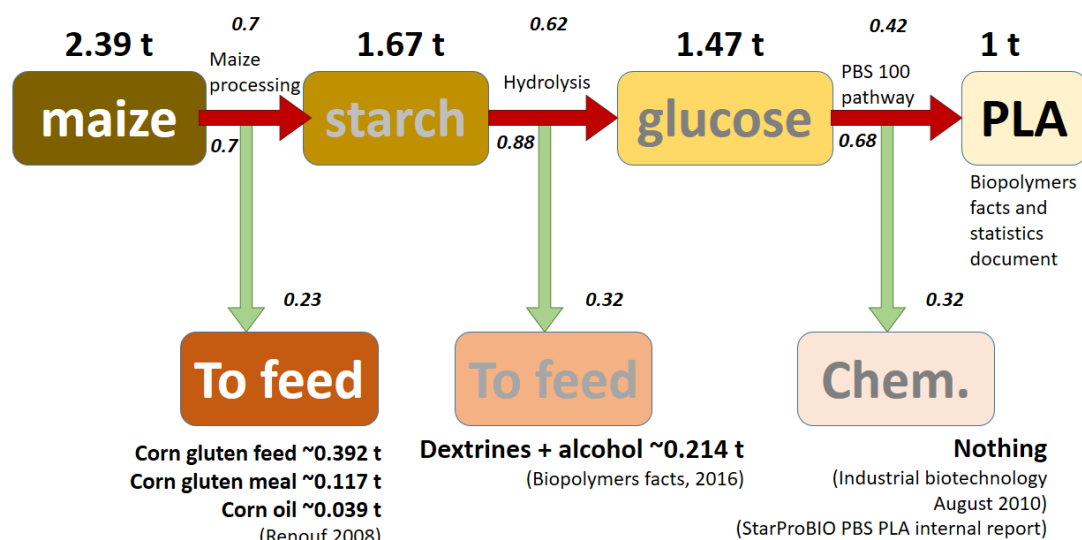


Figure 6 PLA production from maize, yields of the macro-processes and main co-products that could be used on the market.

The model was implemented in a system dynamic framework, and was later calibrated and validated using FAOSTAT data. A number of simulations were conducted using the validated model in order to estimate the iLUC risk related to the increase in production of the bio-based plastics considered for the case studies in the STAR-ProBio project. These simulations are the core for the following inclusion of land use practices shown in section XX and, later, the parameterization needed to get a useful assessment tool for the STAR-ProBio project.



It is important to remember that, at this stage, the model is:

- global (the whole world production is taken into consideration to avoid problems in prediction of land increase due to import-export effects, the so called “shift of the burden”);
- available for maize, sugar beet and soybean, with maize being the most relevant crop for bio-based materials production at the moment.

In the examples below, only maize will be addressed for brevity.

#### 2.1.1.1 Development of the model

The model was developed starting from the main structure of iLUC models emerged from the JRC. study on iLUC (Edwards, Mulligan, Marelli 2010; Marelli, Mulligan, Edwards 2011; Mulligan, Edwards, Marelli, Scarlat, Brandao, Monforti-Ferrario 2010) and from the literature review conducted in Deliverable 7.1. The most relevant and common features across different models were adapted to the system dynamic framework and implemented on a first approximation based on the maize market. Maize was selected as the first crop analysed since a wealth of literature already exists on the topic. The first version of the working model (SydILUC model 21) included the processes of *intensive margin*, the change of agricultural yields influenced by changes in crop price, and of *extensive margin*, the change of agricultural yields influenced by expansion of cropland on less suitable land. Moreover, the co-product utilization was included.

After calibration and test of the market relationships using FAOSTAT dataset and market data, temporal trends in agricultural yields and silos functions to account for the adjustment of maize market to changes in maize stocks were introduced in the SydILUC version 29. The model behaviour in time was then, extensively calibrated and validated in order to test its predictive capability. The output of WP 2 LCA analysis on PLA and PBS production from maize was, then, used to adapt the model to the specific scenarios (SydILUC versions 32 and 33), and local sensitivity analyses were conducted on both to study their behaviours. Residue use, waste, erosion and SOC were included in version 34. A modified version of the model, reducing its parameter dimensionality and adapted to account for low iLUC risk practices, was developed (version 35) and used to obtain the iLUC risk tool. Finally, two other biomasses (sugar beet and soybean) and one additional biomaterial (bio-PUR) were included in the model and implemented the iLUC risk tool.

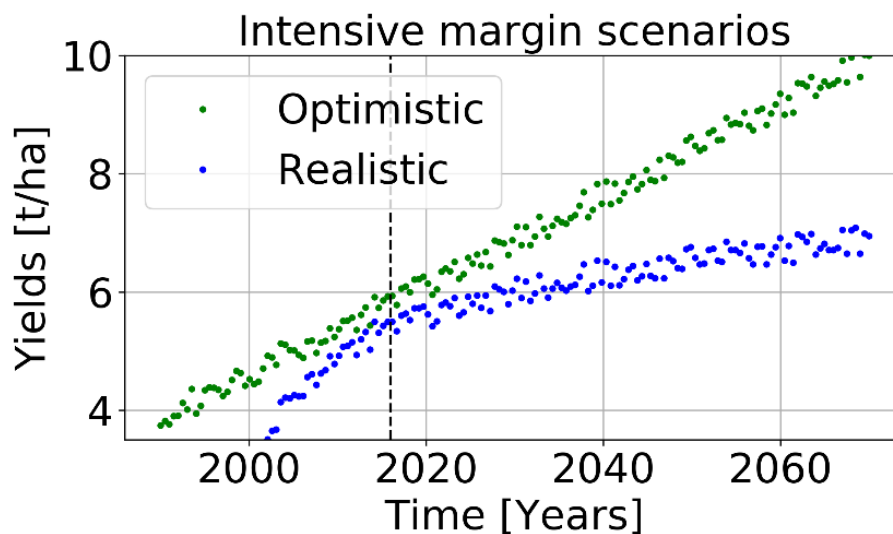
### MAIN PROCESSES MODELLED IN OF THE SYDILUC MODEL

The price of maize on the global market is mainly driven by the production (supply driven); this is due to the high demand rate for a global crop with increasing population and changes in diets. The actual price of the main global crops is somehow controlled by an oligopoly of global cereal traders, and influenced by national subsidy policy, so that it remains mostly stable (Murphy, Burch, Clapp 2012). From FAOSTAT yearly data, however, a correlation can be found between global supply of maize (production plus stock) and maize price; hence, a dependence was derived using econometrics functions for the global yearly price of maize dependent on stock and production of maize. Stock comes from the maize produced in one year and not used; production adjusts yearly to stock quantities so that the maize in the “global silos” is kept close to zero (FAOSTAT data). The Feed market behaviour is dependent on the so-called elasticity of substitution for the price of the crop transformed into feed product: an increase in feed product price makes other competing biomasses more competitive as feed.



Substitution elasticities are the percentage change in the ratio of two competing inputs (e.g. feed 1 and feed 2) used in response to a percentage change in their prices. It measures the market response to a change in price by changing demand, and are typically high for the feed sector. They are, instead, very low for the food sector, which, therefore, was neglected in the present study. Moreover, in the case of maize uses, food represent only the 20 % of total uses, while feed the 65 %.

Two relevant features coming from iLUC modelling literature are the intensive and extensive margins. Intensive margin relates to the effects of changes in crop prices on agricultural yields, the rationale being that, when higher prices are paid for the crop, then the producer is incentivised to increase yields by increasing fertilizer, pesticide and irrigation applications. However, even if this may be true at local scale, the statistical analysis on global data shows no correlation between crop prices and global yields: other important factors such as land rights, transportation, knowledge transfer, purchasing power seem more relevant in determining global yields. Agricultural sciences literature shows that global crop yields are increasing linearly in time, independently of crop prices, subsidies, incentives, changes in demand. Therefore, the time trends of crops identified in scientific literature was included in the model, e.g. Figure 7. Extensive margin represents the assumption that the most suitable land for the production of a certain crop is probably already in use, and, therefore, any expansion of crop land will be conducted on land less suitable for agriculture (or for the production of that particular crop), with the results that the global average yield of the crop will decrease. In the model the extensive margin was set in the model as (Hertel, Lee, Rose, Sohngen 2008) did: the yield of converted cropland over the initial crop land extension is only 0.66 times the normal agricultural yield.



*Figure 7 Future projection of yields as used in the SydILUC model (version 29-32) for the optimistic and realistic scenarios.*



In SydILUC version 34 use of residues, erosion and SOC changes were introduced. Agricultural residues are produced together with the main crop, but are assumed not to drive agricultural production; some examples are wheat straw, maize stover, sugar beet pulp. They are partially used in the feed sector as animal feed or as material, and partially left on the field as a source of organic carbon in the soil. Therefore, when used to produce bio-based materials, the relevant parameters are: the yields of transformation from residue to biomaterial (usually lower than the respective yields of the main crop), the effect on SOC, and the competition with the feed sector. In the SydILUC model, the competition with the feed sector is accounted with substitution elasticities for the agricultural residue relative to the feed sector. Erosion is a global issue, resulting in a net loss of soil and in land degradation. Erosion is influenced by SOC: SOC increase soil structural stability and resistance to direct erosion by wind and water. Intensive agricultural practices have high agricultural yields, but usually increase soil erosion decreasing soil resistance to precipitation events, and tend to decrease SOC; conservation agricultural practices, instead, increase SOC (by leaving agricultural residues on the field) and decrease erosion (by implementing soil protection practices). The increase in SOC due to land use practices is simplified in the model in order to account for the high uncertainty in such process; a certain land use practice can potentially: increase, decrease or not change SOC.

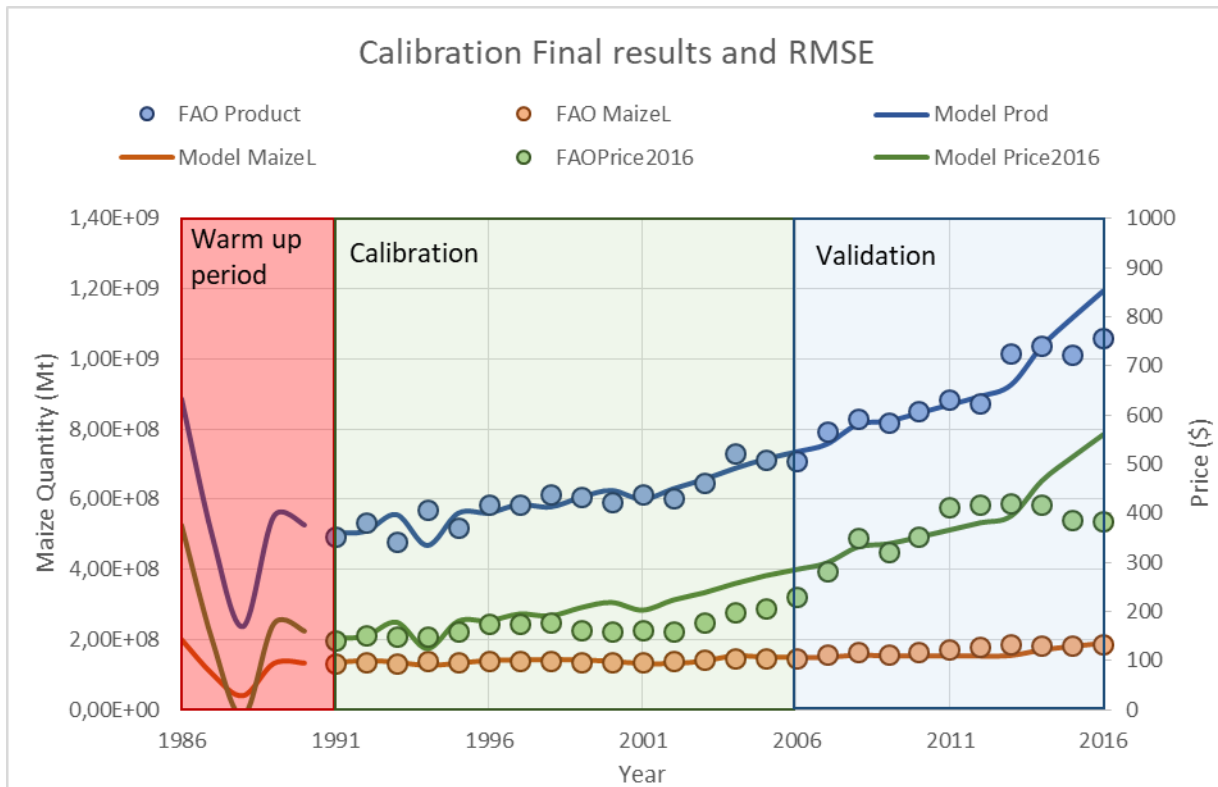
The main objective of the SydILUC model is to estimate the change in land demand caused by an increase of bio-based material production in the future. The case studies of the STAR-ProBio project focused on bioplastics, so the bio-based material taken into consideration for the SydILUC model were bioPLA, PBS and PUR. In order to test the model, it was assumed that a policy would be put in place where the fossil-based plastics in use would have to be substituted up to a prescribed percentage with bioplastics. The amount of fossil-based plastic to substitute depends, then, on: the scale of the substitution (only in EU? For the whole world?), the 10 years trend in plastic consumption changes, and the time horizon for the substitution. So, if the substitution of 50% of fossil-based plastic in the EU was the target by 2050, the amount of bioplastic to produce after 30 years (starting in 2020) of policy would be the actual use of fossil-based plastics in the EU modified by the trend (to get the fossil-based plastic used in the EU in 2050) divided by two. Some ideas of the masses involved are given in Table 1. It was assumed that the increase in bio-based plastic from actual level to target level is linear in time; this, however, can be easily changed in the model.

*Table 1 Approximate 2016 plastic production and future projections used in the model, based on "Plastics Europe" and "European Bioplastics".*

Plastic production (Mt)	E.U.	World	PBS	PLA
Actual (2016)	60	335	0.1	0.21
Future (2050)	173	1000	-	-

#### 2.1.1.2 SydILUC Model calibration and validation: example with for maize

We calibrated the model using FAOSTAT and market time-series of the main input and output variables for that part, and then validated the whole model to estimate its ability to predict future changes in land demand. There are various ways to calibrate a model; in this case we were interested in estimating the predictive ability of the model, so we decided to use the FAOSTAT time-series of global Maize price, production, stock change, uses, yields and dedicated cropland for both calibration and validation. The FAOSTAT dataset was divided into two subsets: the calibration subset consisting of years from 1991 to 2006, and the validation subset, consisting of years from 2007 to 2017. First, we used the model with the initial parameters found in the literature to predict the trends in the dataset, then we changed these parameters (and relationships) in order to get results similar to the observation in the calibration dataset, and finally we run the model for the validation period as well and compared results with observations.



*Figure 8 Results of the validation carried on the calibrated model, showing the initial warm up of the model (i.e. the time in which the model reaches equilibrium initial conditions), calibration period (showing the best fit with FAOSTAT data) and validation period (the actual result).*

Figure 8 shows that the modelled trends follow closely the observed trends, especially for the agricultural part of the model (mainly the maize land change). After an initial period of wide fluctuations, due to random initial conditions, the model equilibrates quickly to the observed values: this shows that the model is not influenced much by the initial conditions. Then, the main trends are modelled correctly, even though the model does miss the some minor fluctuations visible in the dataset. These fluctuations are likely due to exogenous variables (weather, geo-politics, and fuel prices) and cannot be modelled in our framework.



#### 2.1.1.3 Inclusion of other biomasses

In order to include other biomasses into the model, all the assumptions related to the maize market need to be tested and properly adapted. The rationale is that different crops can show different behaviours in their agricultural yields increase, residues production, transformation into bio-based material, and market behaviour. In SydILUC version 35 the most important variables influenced by specific crop characteristics are: initial cropland, the economical part (competing market, elasticities), initial yields, actual yields, yield gaps, and the silos function ("stock function in Figure 1, subsection 1.1"). In addition, the type of bio-based material obtained and the yields of production of the material change among biomasses.

##### **SOYBEAN TO 100% BIO PUR:**

Since this is a globally relevant crop that is already used for the production of bio-based materials (biodiesel), its overall characteristics are similar to those of maize. The increase in agricultural yields are linear in time, the price is supply-driven, and there is no correlation between global price and global agricultural yields. However, the market behaviour is different. In this case, the product transformed is not the soybean itself, but rather the soy oil, which is mainly used by the (inelastic) food sector. The co-product of the soy-oil production, the soy meal, is heavily used in the feed sector, instead. Therefore, in this case, the competition is with the food sector, not with the feed one. This means that the substitution elasticity needs to be adjusted accordingly. 85% of the soybean production is so processed, with only 15% used as beans.

##### **SUGAR BEET TO PLA AND PBS:**

Sugar beet, as a crop, shows a different behaviour with respect to maize and soybean, since it is more a "regional crop" (grown and used mainly in the EU) than a "global crop". The EU production is 50% of the total world production, while USA and Russia make up another 40%. This means that the global price is strongly influenced by EU control on the market (e.g. by the CAP). Moreover, trade represents less than 0.1% of the total uses (FAOSTAT), hence it can be regarded as a locally consumed/processed crop. The mean destiny of sugar beet is to be processed (95%) to sugar for the food sector; during the process a co-product is obtained, the sugar beet pulp, used mainly in the feed sector (e.g. to feed horses). Since competition with feed is preferable to competition with food (European Commission 2018), the model assumes that the raw biomass transformed into bio-based material is the sugar beet pulp (sugar could also be used to obtain bio-based materials, however). In this case, the growth in demand for sugar beet pulp does not change global production of sugar beet until it gets larger than the main sugar production. Even though prices are policy driven, yields are still increasing linearly in time.

#### 2.1.2 Translation of the SydILUC model into a user-friendly tool

A common critique of iLUC models is that they are complex and difficult to use and, as a result, are regarded as black boxes (Brandão 2015). The system dynamic framework already strives to keep dynamic models simple and easy to use; however, the SydILUC model can still look daunting for most non-experts. Therefore, it was decided to translate it to a user-friendly tool, which could be used by policy makers to assess low iLUC risk strategies, by producers to reduce their relative iLUC risk, and by auditors to rank different biomasses/bio-based material, by iLUC risk. The idea is to simulate a wide range of possible sets of inputs, e.g. different agricultural yields, different use of co-products, different types of bio-based material produced, and obtain estimates of change in land demand for each set. Then, both the input sets and the related model outputs are collected in a matrix linked to a spreadsheet.

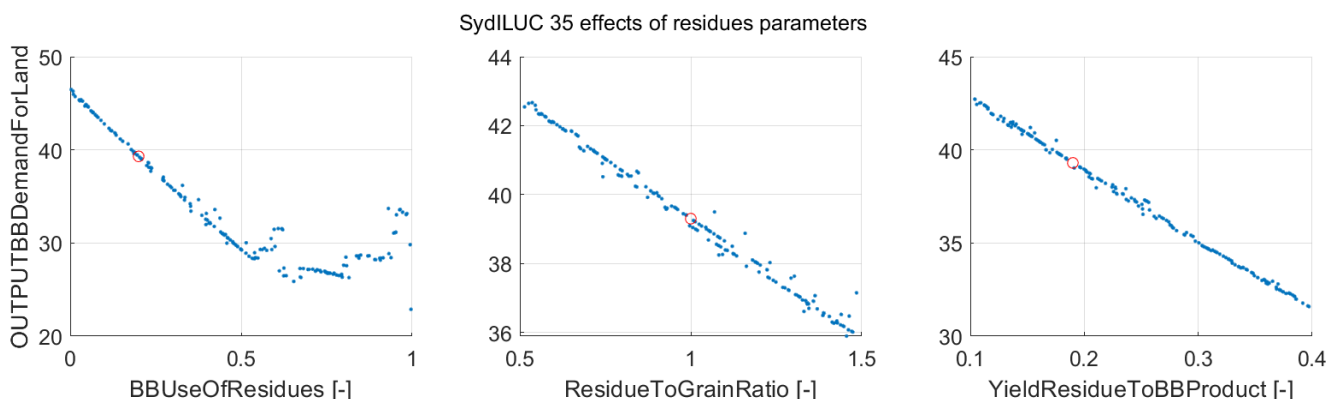


The set of model output is then binned into ten classes with equal frequency; these bins are the iLUC risk levels. When the user inserts in the spreadsheet the particular conditions of interest, the tool translates them into a set of input for the model, and locates it in the matrix, adjudicating it a change in land demand. This latter is, then, translated into an iLUC risk level. The tool user can insert data on different levels of the value chain, e.g. the crop production, the transformation into intermediate product, the bio-based industry.

The level of detail in the input data required is flexible: when less data are available, default data are assumed. Input data include the input set provided by the producers, production methods (agricultural practices, industrial synthesis, etc...) and low iLUC risk practices (additionality, unused land improvement, etc...). These input data modify the default values; the tool returns the output of the model that suits those particular conditions. Auditors can easily change the default values if more precise measurements are available using a dedicated sheet of the excel tool, to get more precise iLUC risk estimates.

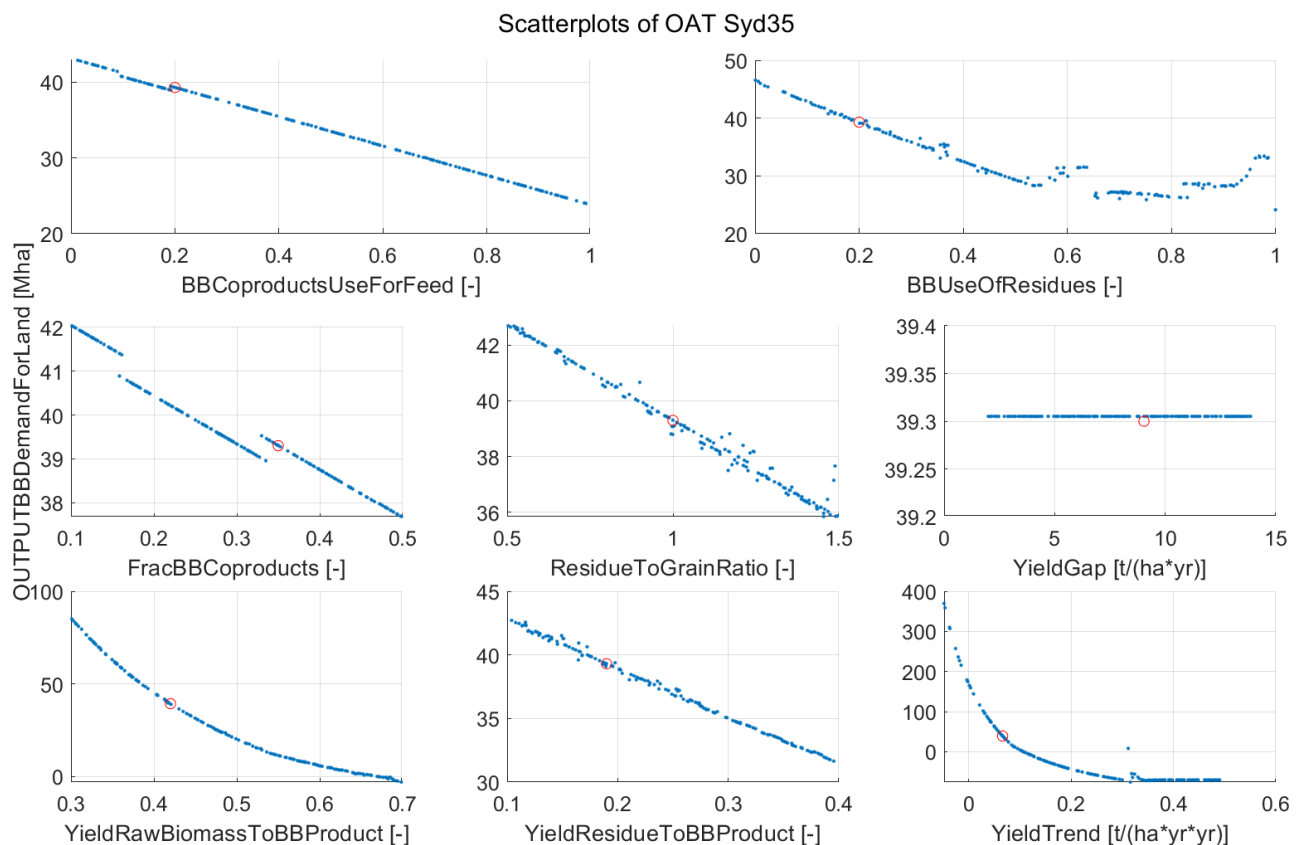
The tool has the objective of adjudicating iLUC risk levels for certain producers, and to estimate the change in iLUC risk level as a result of the implementation of certain low iLUC risk practices. Hence, the practices and the SydILUC model need to be coupled somehow, either by modifying the model to include the practices, or by calculating their effects on demand for land directly in the tool interface. Some of the low iLUC risk practices can easily be accounted in the model, like the efficiency-related practices (improved chain efficiency, additional agricultural yield increase, use of co-products in substitution of the feed). Others can be used to modify the input set, for example reducing the amount of raw biomass needed in the production of the biomaterial when waste material is used instead; or modify the change in land demand estimate, by reducing it when accounting for use of abandoned/degraded land. A more complex approach is required to account for: residues, soil organic carbon and erosion.

Agricultural residues mostly already used in the feed sector and/or are left on the agricultural field to increase SOC and as mulch to reduce soil erosion. Using them for bio-based material production is, therefore, in competition with these other uses, which have impacts on the prediction of change in land demand. The interdependencies and the feedback loops implied must, then, be included directly in the system dynamic SydILUC model (Figure 9). The residues are created as by-product of the main crop, and cannot drive the expansion of agricultural land. Residues are stored for some period, then used partly for mulch and partly by the feed sector. When their use is diverted to the production of the bio-based material, the demand of crop from the feed sector increases, or the amount available for soil protection decreases.



*Figure 9 The local sensitivity analysis on the residues flow parameters only, the output is the predicted change in demand for land at the end of the policy period (2050 in this case). The red circle indicates values used for the parameters.*

In Figure 9, the effect of the inclusion of residues in the model is shown. The relationship with the decrease of iLUC is linear, even though the effects are limited with respect to other parameters; the yield of biomaterial production from residues has also a linear dependence; the dependence on the use of residues is linear for uses below 0.5 of the total production of residues, but becomes problematic for higher values. The assumption that a depletion of residues will not drive the increase in maize land conversion results in the fluctuation seen here, as the switch in use of residues from feed to biomaterials increase the depletion of the residues, due to different yields of transformation.



*Figure 10 Complete OAT local sensitivity analysis of the SydILUC35 model accounting for residue use.*

In Figure 10, it is possible to see that the predicted change in land demand is mainly sensitive to yield trends and yields of transformation from raw biomass into bio-based product materials (an industrial value with small variation). Yield trends can change the land demand widely, even lowering it to negative values, meaning that the increase in biomaterial demand of biomass is surpassed by the increase in biomass production. Moreover, yield trends are adjustable with additional practices in agriculture, in order to reduce land demand. The yields of transformation from raw biomass to bio-based material, instead, are industrial synthesis, which have already been made as efficient as possible and, hence, show very little variation. Discover of new synthesis pathways are always possible though, so the user can change this values in the excel tool. Not much variation is expected in the next years though, since research is focusing more on different biomasses.





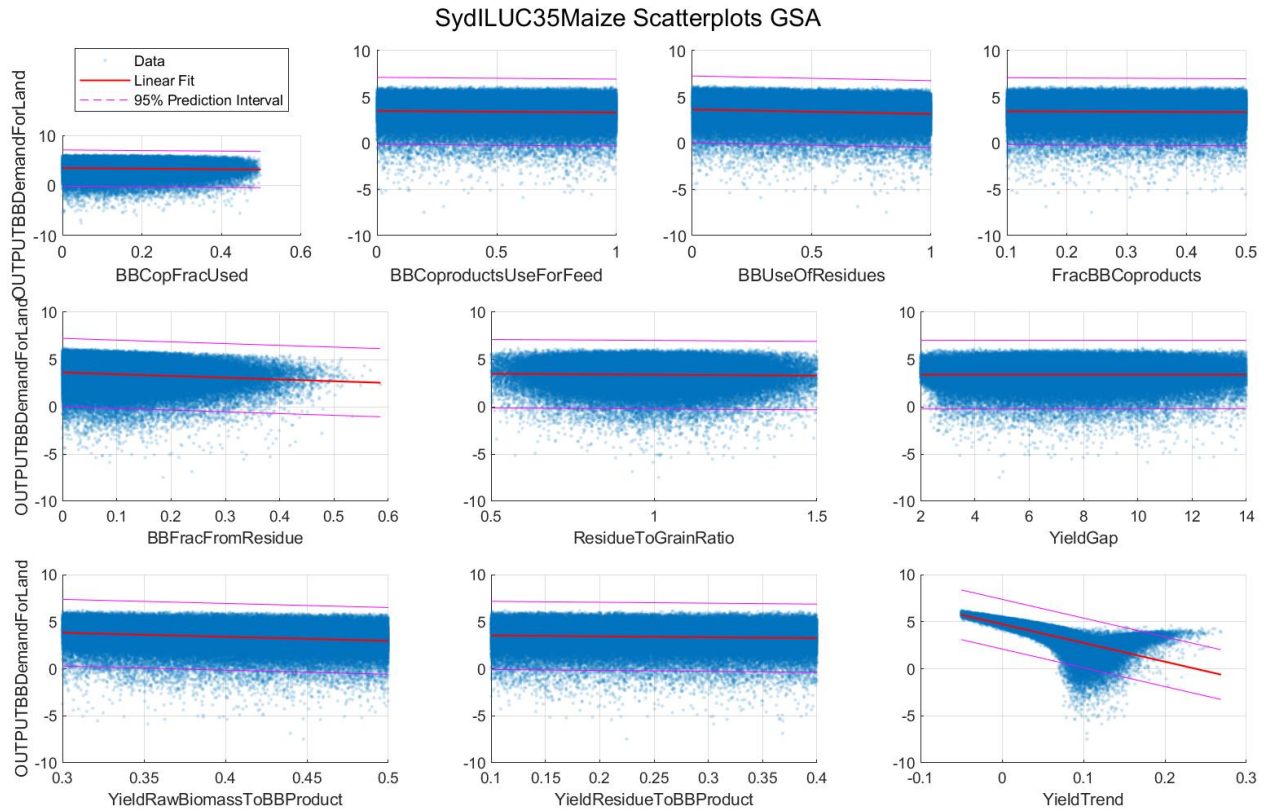
The second most important parameter having an effect on projected changes in land demand (log OUTPUTDemandForLand in Figure 10) is the use of co-products to reduce the demand of biomass for feed. Therefore, when compared with other parameters/strategies to reduce iLUC, the use of residues has certainly a role, but limited, and it makes sense only for residue uses below a certain fraction (in this case 50%) of the total residue use. A note: the fact that yield gaps have shown no effect in Figure 10 is due to the low default yield trend for maize, meaning that, in 30 years of bio-based material production increase policy, the ceiling for yield trend increase is not reached. The yield gap is more important on a country level, though, since the production of maize from rich countries appears to be close to reaching the ceiling value (i.e. to close completely the gap, with no further increase in agricultural yields).

Since the direct inclusion of erosion and SOC in the SydILUC model would result in a number of input parameters and output variability difficult to manage with an excel spreadsheet, it was decided to include them directly in the excel tool. This means that SOC behaviour and erosion are calculated directly in the excel spreadsheet from user defined land use practices and, then, used to modify the input and output of the matrix analysis performed by the iLUC risk tool. Erosion was managed by Quantis in the STAR-ProBio project, and they decided to use RUSLE to estimate it, therefore the same approach was used in the iLUC risk tool for consistency. Therefore, erosion is calculated using the RUSLE equation and using Quantis values; the change in SOC affects the K parameter (the soil resistance to erosion) using the default equations in the 1990 version of the RUSLE from USDAC (Renard, Foster, Weesies, Porter 1991). (STAR-ProBio 2018)

The eroded soil is, then, transformed into hectares of land lost due to agriculture production, and accounted for in the BB land demand output from the model. The SOC is calculated depending on a quick analysis that shows that a conservative average value for SOC increase-decrease is  $0.2 \text{ \% year}^{-1}$ ; the user defines in the tool if SOC is increasing, stable or decreasing, and this affects directly the K parameter of the RUSLE as  $K = \Delta SOC \cdot 1.8 \cdot 10^{-4}$  (Wischmeier 1959). The SOC range used in the model cannot go below 0% or above 15%. In case the user does not define the SOC change, the default is a decrease in SOC. The auditor can still input directly the change in SOC if measurements are available. The auditors have also the possibility to define their own specific values for the RUSLE equation in the default sheet of the tool.

After the set-up of the model and the tool were completed, some input variables for the model were combined in a summary variable to reduce the dimensionality of the problem. Then, the SydILUC model  $10^6$  times with different input sets covering all the possibilities, sampled with a latin hypercube method. The resulting global sensitivity analysis (GSA) of the modified version of the SydILUC model is shown in Figure 11; this analysis has also the potential to inform policy makers and stakeholders, and will be taken into consideration in Deliverable 7.3. The output was then re-sampled to reduce further the dimensionality of the matrix to a size manageable by the tool:  $10^5$  rows by 5 columns; the effect on the model output are shown in Figure 12.





*Figure 11 Global sensitivity analysis of the model adapted to prepare the iLUC risk tool matrix, with  $10^6$  simulations.*

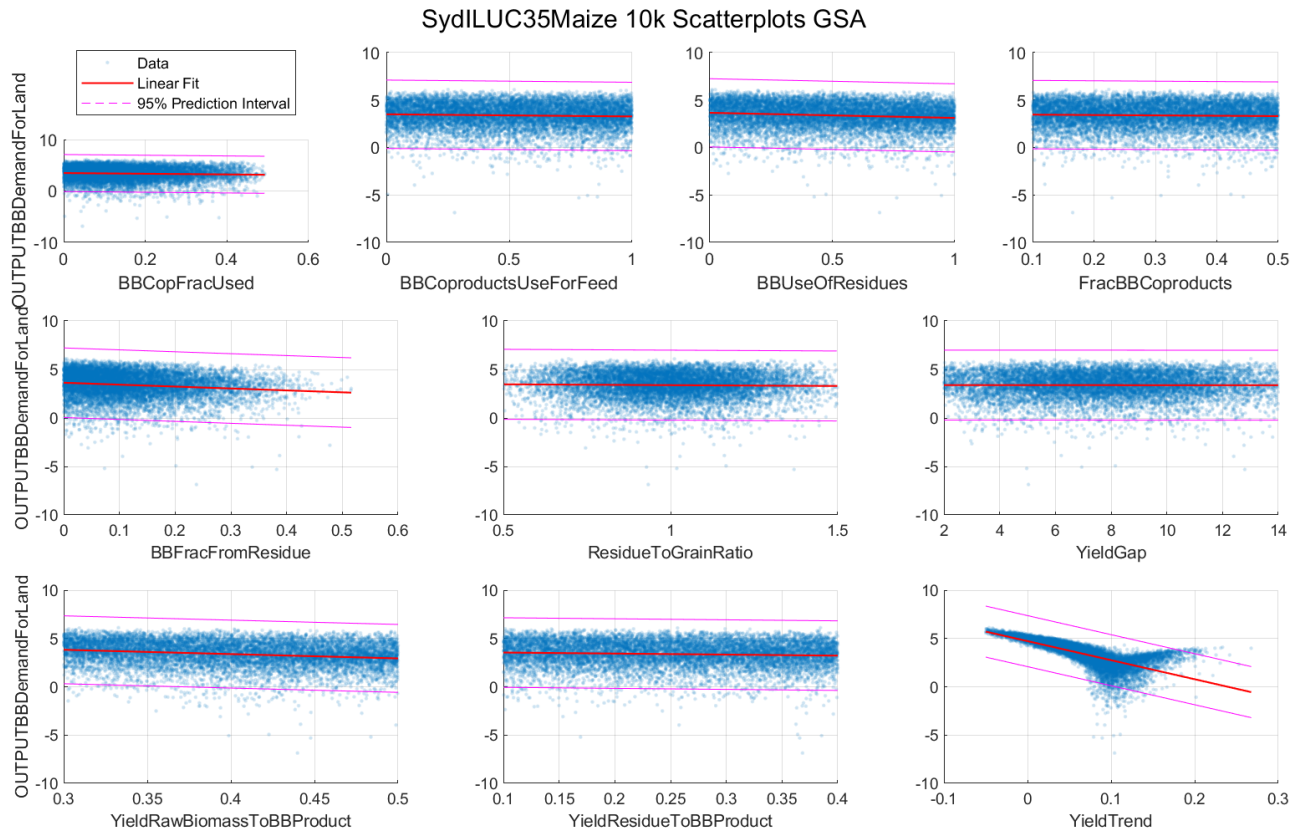


Figure 12 Same as Figure 11, but with simulations reduced to  $10^5$ .

### 2.1.3 The low iLUC risk tool

The iLUC risk tool resulting from the parameterization of the SydILUC model as presented in subsection 2.1.2 appear as a biomass-specific spreadsheet composed of 5 difference calculation sheets, of which only the first one (called "Input") is relevant for the basic user. Due to the restricted size of the SydILUC output matrix usable on Excel, the analysis had to be restricted to specific biomasses in order to retain an acceptable level of resolution; accounting for more biomasses together would result in spreading the model output on a larger parameter space, hence decreasing the overall resolution of its parameterization. In this case, an iLUC risk tool was developed for each biomass: maize, soybean and sugar beet pulp. The tool was implemented without using macros programming to enhance its transparency and usability. The objective of the tool is to help compare the relative decrease in iLUC risk of a specific production practice when low iLUC risk practices are applied.

Figure 13 shows the first page of the iLUC risk tool. On the left side of the page there is the list of input parameters to supply, divided by value chain level. Some of the inputs are chosen from a provided list (e.g. land use practices), while others have a default value if not modified. Most of the inputs required are related to the low iLUC risk practices highlighted in this deliverable. Some notes are provided to explain the type of input as well as its measurements units. On the right side of the page, the iLUC risk classes are listed and the final output of the iLUC risk calculation is given (it can take some seconds for the tool to run). Note that the iLUC risk categories are represented using the old scheme for energy consumption in the EU; this may change in response to changes in the labelling used in other working packages of the STAR-ProBio project. In the present case, A+++ means negligible risk, blue and green colours refer to very low, manageable iLUC risk, and red is the biggest class, containing all the projections of land demand overshooting a certain threshold. iLUC risk classes are derived by statistical binning of the results from the sensitivity analysis of the model, and have only a relative significance, i.e. are valid only for that particular crop. To make cross-crop comparisons, the projections of and demand should be used instead; see chapter 3 for some examples.

Crop producer			
Land use practice used	p and down slope tillir		
Yield increase	0	t/ha/yr	
Land erosion, if measured directly (optional)		t/ha/yr	
SOC change (optional)			
Crop produced on former abandoned land	0	t/yr	
Crop grown on area obtained by means of livestock improved efficiency	0	t/yr	
Country of production	Other (average)		
Crop grown	Maize		

Intermediate product producer <sup>2</sup>			
Co-products sent to the food-feed sector	0	kg of co-products created during	
Use of agricultural residues in the production	0	kg certified residues/kg intermediate product	
Yields of transformation (optional)		kg of input/kg of intermediate product	

Bioplastic producer			
Yields of production from intermediate product		kg of BB material/kg intermediate	
Yields of production from crop agricultural residue (optional)		kg of BB material/kg of residue	
Type of biomaterial produced		PBS	
Co-products sent to the food-feed sector	0	kg of co-products created during BB material production/kg of co-products	
Use of agricultural residues in the production	0	kg certified residues/kg intermediate	
Waste <sup>3</sup> used for the production of biomaterials	0	kg of BB material obtained from waste/ total kg of total BB	

iLUC Risk category	
A+++	Your risk category is: E
A++	
A+	
A	
B	
C	
D	
E	
F	
G	

<sup>2</sup> Refers to production of hydrolizate, glucose, oil etcetera from crops

<sup>3</sup> Sewage sludge, municipal solid waste, etc...

Figure 13 The input page of the iLUC risk tool.

The second page of the tool (represented in Figure 14) is dedicated to auditors it contains all the direct input to the matrix, together with the default values used. The direct input parameters are defined in the main table, on the top left; below that, a table contains all possible bioplastics parameters for the specific raw biomass considered in the spreadsheet. On the left the iLUC risk class is adjudicated depending on the predicted change in crop land demand; the classes (bins) of iLUC risk are biomass-specific, and are clearly indicated in the coloured list. At the centre of the page the iLUC risk class and the corresponding land demand change predicted are given; information on land demand change can be used to compare the iLUC risk between different biomasses by the auditors. The normal user, however, is only interested in relative changes in iLUC risks resulting from the application of low iLUC risk practices.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	variable	range	Default value	input value	Operator input	unit of measure	description	BBDemandForLand with erosion	iLUC Risk		BBDemandForLand levels	Bbdemand DIST	Risk levels	min_distBB
1	FractionBBCoproducts	0.1-0.5	0.387	0.387		[-]	TO DO	64.305505	E		-13.31969624	77.625201	A+++	7.3947283
2	UseOfBBCopForFeed	0-1	0.2	0		[-]					-0.824838326	65.130343	A++	
3	BBCopFracUsed		0.0774	0		[-]					8.252346364	56.053158	A+	
4	ResidueToGrainRatio	0.01-2	1	1		[-]					17.12829074	47.177214	A	
5	ResiduesUse	0-1	0.2	0		[-]					27.05622716	37.249278	B	
6	YieldResidueToBBProduct	0.05-0.5	0.19	0.19		[t/t]					38.21950906	26.085996	C	
7	BBFracFromResidue		0.038	0		[-]					52.09233586	12.213169	D	
8	YieldPotentialIrrigated	5-50	13.51742955	13.51743		t ha <sup>-1</sup> yr <sup>-1</sup>					71.70023316	7.3947283	E	
9	InitialYield	1-50	4.483684683	4.4836847		t ha <sup>-1</sup> yr <sup>-1</sup>					99.85856311	35.553058	F	
10	Yield Gap		9.033744869	9.0337449		t ha <sup>-1</sup> yr <sup>-1</sup>					143.280936	78.975431	G	
11	YieldTrend	0.01-0.7	0.066142358	0.0661424		t ha <sup>-1</sup> yr <sup>-2</sup>								
12	YieldRawBiomassToBBProduct	0.3-0.5	0.3598452	0.3598452		[t/t]								
13														
14														
15							testing with maizePLA values							
16														
17	Type of bioplastic	Yield Maize-Starch	Yield Starch-Glucose	Yield Glucose-BB	Yield Coproducts	Initial BB production	Yield Residue/BB							
18	PLA	0.699	0.880	0.680	0.319	0.210	0.390							
19	PBS	0.699	0.880	0.585	0.387	0.100	0.190							
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
31														

Figure 14 The "default value" page of the iLUC risk tool, dedicated to auditors using the tool.

The third page (Figure 15) is called "country matrix", and contains all the country-specific values for agricultural yield potential (irrigated, rainfed), actual agricultural yields, average country yield trends, and the R and K average RUSLE parameters. The potential yield values come from the Global Yield Gap Atlas (Grassini, van Bussel, van Wart, Wolf, Claessens, Yang, Boogaard, Groot, van Ittersum, Cassman 2015; van Bussel, Grassini, van Wart, Wolf, Claessens, Yang, Boogaard, Groot, Saito, Cassman, van Ittersum 2015) the actual yield come from the analysis of the FAOSTAT data and the RUSLE parameters from Quantis (deliverable 2.2). Since average values can be missing (in that case, the world default is applied), outdated, or not representative of the particular situation studied, they are provided here for comparison. However, the yield values should be changed in the "default values" page, not here.

The fourth page (Figure 16) is where the soil organic carbon change (SOC) and the erosion potential are calculated depending on the input given by the user about land use practices. Erosion is modified by SOC changes, as a lower SOC results in a decrease in soil resistance to erosion. The amount of land lost due to erosion is then added to the total projection of change in crop land demand.

Finally, in Figure 17 the SydILUC output matrix is displayed and used to assess the changes in crop land demand depending on the set of input provided by the user. The input values provided by the user in the "input" page are processed and aggregated in the "default value" page with the help of the "country matrix" yield values, resulting in a vector with values for each relevant parameter (the columns in the right hand side of the "matrix" page). This vector points to a point in the multidimensional parameter space; a simple calculation (left hand side of the "matrix" page) yield the closest point in the parameter space with a calculated value for crop land demand change. This value is then modified by erosion and use of abandoned/degraded land and transferred to page "default values", where it is used to calculate the iLUC risk class.



	A	B	C	D	E	F	G	H
	Country	Average carbon content in the topsoil as a % in weight	Yp	Yw	Ya	Ytrend	R	K
1								
11	Armenia	1.570E+00			4.672E+00	1.640E-01		
12	Aruba	5.700E-01						
13	Australia	6.300E-01			5.559E+00	9.671E-02	1.000E+01	3.110E-02
14	Austria	1.640E+00	1.338E+01	1.246E+01	9.725E+00	1.196E-01		
15	Azerbaijan	1.210E+00			4.555E+00	1.922E-01		
16	Bahamas	4.200E-01			7.533E+00	1.214E-01		
17	Bahrain	3.100E-01						
18	Bangladesh	1.900E+00	1.010E+01		5.838E+00	1.174E-01		
19	Barbados	1.640E+00			2.884E+00	1.188E-02		
20	Belarus	5.100E+00	1.181E+01	1.145E+01	4.931E+00	1.790E-01		
21	Belgium	1.320E+00	1.387E+01	1.258E+01	1.193E+01	-3.788E-02	1.270E+02	4.380E-02
22	Belize	1.610E+00			2.926E+00	4.868E-02		
23	Benin	8.000E-01			1.103E+00	1.683E-02		
24	Bhutan	1.150E+00			2.318E+00	3.110E-02		
25	Bolivia (Plurinational State of)	1.040E+00			2.789E+00	2.621E-02		
26	Bosnia and Herzegovina	1.310E+00	1.339E+01	6.552E+00	4.521E+00	2.504E-02		
27	Botswana	6.200E-01			1.617E-01	-6.842E-03		
28	Brazil	1.210E+00	1.249E+01	8.692E+00	4.367E+00	6.990E-02	1.020E+04	3.390E-02
29	British Virgin Islands	1.090E+00						
30	Brunei Darussalam	1.017E+01						
31	Bulgaria	1.290E+00	1.301E+01	7.329E+00	6.251E+00	3.550E-02		
32	Burkina Faso	7.600E-01	1.028E+01	6.251E+00	1.434E+00	2.521E-02		
33	Burundi	1.020E+00			1.060E+00	2.711E-03		
34	Cabo Verde	1.250E+00			2.200E-01	-5.378E-03		
35	Cambodia	9.600E-01			3.613E+00	5.958E-02		
36	Cameroon	1.080E+00			1.974E+00	2.800E-02	8.640E+03	1.500E-02
37	Canada	4.280E+00			1.001E+01	9.860E-02	5.260E+02	4.380E-02
38	Cayman Islands	3.700E-01						
39	Central African Republic	8.600E-01			1.615E+00	1.130E-02		
40	Chad	8.700E-01			8.174E-01	-5.691E-03		
41	Chile	2.230E+00			1.108E+01	1.939E-01	2.280E+02	4.380E-02
42	China		1.279E+01	1.070E+01	5.460E+00	8.968E-02	2.170E+03	4.380E-02
43	Colombia	3.820E+00			2.723E+00	3.982E-02	1.660E+04	3.390E-02
44	Comoros	1.590E+00			2.086E+00	2.670E-02		
45	Congo	1.480E+00			8.174E-01	1.073E-02		

Figure 15 the "country matrix" page of the iLUC risk tool, use to get the country average values for yield projection and erosion calculation.





	A	B	C	D	E	F	G
1	Variable	range	Default value	input value	Operator input (opzional)	unit of measurement	description
2	SOC change	{-0.2,0,0.2}	-0.2	-0.2		% yr <sup>-1</sup>	TO DO
3	R	0-22000	3988.940963	3988.940963		Mj mm ha <sup>-1</sup> h <sup>-1</sup> yr <sup>-1</sup>	
4	K	0-0.05	0.039143182	0.039683182		t h MJ <sup>-1</sup> mm <sup>-1</sup>	
5	LS	fixed	0.456	0.456		[-]	
5	C	0-1	0.38	0.38		[-]	
7	P	0-1	1	1		[-]	
3	Erosion (A)		27.05591171	27.05591171	0	t ha <sup>-1</sup> yr <sup>-1</sup>	
9							
0							
1	2010 Global crop area	178	Mha				
2	Land lost 2020-2050	0.1020978	Fraction of soil				
3	Land lost 2020-2051	18.173405	Mha				
4							
5							

Figure 16 The "erosion SOC" page of the iLUC risk tool, were soil organic carbon change and erosion are calculated (both depend on each other).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	BBCopFracUsed	BBFracFromResidue	YieldGap	YieldTrend	YieldRawBiomassToBBProduct	BBDemandForLand		BBCopFracUsed	BBFracFromResidue	YieldGap	YieldTrend	YieldRawBiomassToBBProduct	DIST	BBDemandForLand		Min_DIST	BBDemand correspondent
2	0.195081	0.208953	7.57637	0.0540558	0.338056	47.0909		0.15678276	0.1640055	0.01084186	0.002040669	0.00189908	0.579283935	47.0909		0.07504686	46.1321
3	0.38354	0.0337852	8.49018	0.103519	0.486109	-18.3126		0.60602383	0.0042876	0.00150822	0.019514972	0.06377044	0.833729608	-18.3126			
4	0.360984	0.253854	8.49444	0.0203663	0.351429	79.928		0.53683927	0.24206345	0.00148467	0.029271444	0.00028333	0.899967869	79.928			
5	0.0572843	0.304931	8.46219	0.0803255	0.425252	22.8531		0.01351885	0.34927247	0.00166754	0.002810039	0.01711227	0.619984808	22.8531			
6	0.147529	0.0363106	11.1343	-0.0137876	0.32588	258.359		0.08966504	0.00495254	0.02252316	0.089245542	0.00461456	0.45934828	258.359			
7	0.0896698	0.0468801	3.62489	0.0549398	0.422495	51.345		0.03312537	0.0082554	0.14933849	0.00175308	0.01570005	0.456259136	51.345			
8	0.00438661	0.0238162	5.78982	0.122047	0.364086	3.14284		7.9273E-05	0.00213062	0.05371588	0.043657927	7.1938E-05	0.31568281	3.14284			
9	0.017212	0.274143	10.7972	0.0649628	0.470968	17.0237		0.00122048	0.28230302	0.01587413	1.94359E-05	0.0493933	0.590601701	17.0237			
0	0.249886	0.137745	7.0641	0.0824942	0.449494	4.84476		0.25724813	0.07127101	0.01980327	0.003735087	0.03214776	0.619842924	4.84476			
1	0.10756	0.0330585	6.4987	0.0968972	0.384264	11.9871		0.04766175	0.00410514	0.03280442	0.013212785	0.00238512	0.3164952	11.9871			
2	0.167727	0.13937	11.2708	0.134137	0.463415	-21.9162		0.11589757	0.07296252	0.0255455	0.064582782	0.04290699	0.567358227	-21.9162			
3	0.0911873	0.203784	13.0784	0.0583415	0.469887	23.2331		0.03425603	0.15599165	0.08350723	0.00850065	0.04843698	0.568367814	23.2331			
4	0.00366541	0.105252	4.25648	0.118532	0.469211	-10.3313		5.5349E-05	0.04161232	0.11649834	0.03834054	0.0478437	0.494317969	-10.3313			
5	0.369428	0.118344	9.38089	0.0847774	0.338411	20.3478		0.56224809	0.05260823	0.00061515	0.004850965	0.00183771	0.788771288	20.3478			
6	0.0662082	0.052737	7.43349	0.0437518	0.47569	55.1889		0.01805893	0.01044701	0.01307192	0.007003211	0.05368029	0.319783293	55.1889			
7	0.15103	0.283419	8.74351	0.101012	0.374177	3.58681		0.09397121	0.30173044	0.00042999	0.016984875	0.00082161	0.643380228	3.58681			
8	0.280554	0.0139519	9.14193	0.0539333	0.45531	37.7404		0.32426592	0.00073119	5.9744E-05	0.002082244	0.03645426	0.602987022	37.7404			
9	0.0133565	0.0900424	8.29518	0.0840151	0.456613	15.169		0.00073494	0.03045477	0.00278444	0.004462207	0.03745618	0.275486011	15.169			
0	0.0202085	0.218096	5.13911	0.0790564	0.376858	22.9993		0.00168243	0.17867204	0.07742739	0.002329656	0.00115775	0.511145045	22.9993			
1	0.339461	0.0115492	3.47504	0.183079	0.432323	-16.765		0.4747316	0.00050103	0.15772783	0.191015497	0.02154316	0.91952114	-16.765			
2	0.0171989	0.394628	8.50216	0.0251142	0.388835	64.6465		0.00121862	0.58497458	0.00144247	0.023514264	0.00336165	0.78390789	64.6465			
3	0.0176183	0.0419106	7.29982	0.034964	0.376439	109.399		0.00127878	0.00659795	0.01534694	0.014887651	0.00110142	0.198022065	109.399			
4	0.235445	0.101934	3.35295	0.091397	0.429934	4.84113		0.22837435	0.03903007	0.16473251	0.008869045	0.01964984	0.678716295	4.84113			
5	0.0231919	0.162396	10.494	0.0307054	0.48163	57.2611		0.00221585	0.09906309	0.01088475	0.017542045	0.05932639	0.434778248	57.2611			
6	0.167861	0.395956	3.55507	0.0924624	0.364405	8.43884		0.11608283	0.58891831	0.15321884	0.009676995	8.3167E-05	0.931654515	8.43884			
7	0.0497909	0.104329	4.62845	0.0149525	0.415116	114.795		0.01021335	0.04088569	0.09906291	0.036604562	0.01221949	0.44607847	114.795			
8	0.00098018	0.306774	10.8982	0.194407	0.429457	-31.6967		3.958E-06	0.35350723	0.01774455	0.229816535	0.01938329	0.787690014	-31.6967			
9	0.274676	0.401436	9.79404	0.0717044	0.328584	29.1815		0.3108206	0.60533228	0.0029507	0.000432151	0.00390907	0.960960354	29.1815			
0	0.212123	0.421846	3.91451	0.0897293	0.342044	21.8505		0.1853719	0.66845022	0.13377385	0.007771604	0.00126754	0.998316132	21.8505			
1	0.0992193	0.0384997	2.92253	0.0570943	0.357448	71.9489		0.04055652	0.0055677	0.19064096	0.00114361	2.2986E-05	0.487782508	71.9489			
2	0.18895	0.0286336	3.93935	0.0910601	0.460557	0.301331		0.14708289	0.00307973	0.13247878	0.008673308	0.04057163	0.576095774	0.301331			
3	0.202122	0.0957451	11.6183	0.0275582	0.401656	84.884		0.16830443	0.03443454	0.0340983	0.020796268	0.0069926	0.514418252	84.884			
4	0.0279051	0.00638159	6.41491	0.113082	0.438224	-5.43805		0.00320801	0.00015297	0.03500881	0.030778462	0.02457304	0.306139343	-5.43805			
5	0.4222731	0.0185293	8.37472	-0.00891422	0.343768	247.649		0.00736201	0.00128967	0.00221699	0.078694591	0.00103391	0.300993654	247.649			
6	0.492065	0.155741	7.96965	0.0813324	0.324733	23.8668		0.99750096	0.09111022	0.00577992	0.003223186	0.00493149	1.050021797	23.8668			
7	0.116751	0.119327	6.79714	0.084271	0.315697	32.3275		0.05615515	0.05348582	0.02553522	0.004549091	0.00779629	0.384139787	32.3275			
8	0.246457	0.013405	13.6333	0.0841755	0.376497	24.2538		0.25023652	0.00067499	0.10799229	0.004542659	0.00110913	0.60378439	24.2538			
9	0.199804	0.219254	8.08076	0.0451773	0.427786	43.2556		0.16446623	0.18057443	0.00463589	0.006139874	0.01846388	0.611784523	43.2556			
0	0.192325	0.0261218	6.44294	0.0454295	0.336085	98.9305		0.15238417	0.00256311	0.0342634	0.005993043	0.0022582	0.444366882	98.9305			
1	0.0469742	0.138559	10.8832	-0.0092164	0.341988	196.256		0.00909049	0.07211584	0.01746018	0.07932952	0.00127552	0.423404714	196.256			
2	0.132803	0.143983	6.45066	0.020298	0.364075	104.588		0.07265812	0.07787241	0.03405951	0.029358857	7.1565E-05	0.462623463	104.588			

Figure 17 The "matrix" page of the iLUC risk tool, used to calculate the predicted change in crop land demand; the actual iLUC risk class, instead, is calculated in the "default value" page.



## 2.2 Part B – Certifying low iLUC Risk Biomass

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While the above presented work aims to quantify the individual iLUC risk of a producer of biomass or bio-based products, it seems an important question to discuss the potential ways and strategies to reduce this respective risk on a producer level. This follows the approach taken in the RED 2, which in general allows for the possibility that feedstock producers can demonstrate that they have avoided iLUC. This involves that the biomass or the respective products are being certified as *low iLUC risk*, by demonstrating that the production or sourcing of the respective feedstock was not associated with displacements of existing users. In March 2019 the Commission has published a Delegated Act (European Commission 2019), including a set of additionality measures, potentially suitable to supply biomass without the respective replacement effects as well as a set of general rules for the certification of low iLUC biomass.

### 2.2.1 On the general concept of additionality

The general concept of additionality in the context of low iLUC risk biomass is to provide biomass without displacing existing uses. Additionality measures and strategies as for example discussed by (Malins 2019) and (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016) or as referred to by the RED 2 can be categorised into two broader groups.

The first group of measures is aiming at the activation of unused potentials (unused land or unused biomass), following the reasoning that using these resources would not result in a displacement of existing users.

The second group addresses measures aiming at increasing the productivity of processes or value chains, meaning that more bio-based products could be produced from the same unit of biomass input. Again, according to this logic, the respective product produced would not be associated with displacement effects of potential previous users of the biomass or land.

While in theory, the general rationale seems clear, the definition of certification guidelines to appropriately certify additionality is complex, since they have to be defined in a way to avoid potential free rider risks (Malins 2019) while at the same time allows for the flexibility to deal with potential new additionality measures in the future.

Free rider risks to be addressed by low iLUC certification involves aspects such as to allow any feedstock grown on land not farmed prior to a given cut-off date to be certified (Malins 2019) or potential increases in efficiencies as results of normal variabilities in yields.

Finally, several of the additionality measures currently under discussion might be appropriate to provide biomass without causing displacement effects, however these measures might be associated with other environmental or social risks. These risks need to be analysed and understood, in order to develop a certification structure for low iLUC risk biomass, which is able to certify the qualified projects without ignoring potential negative trade-offs.

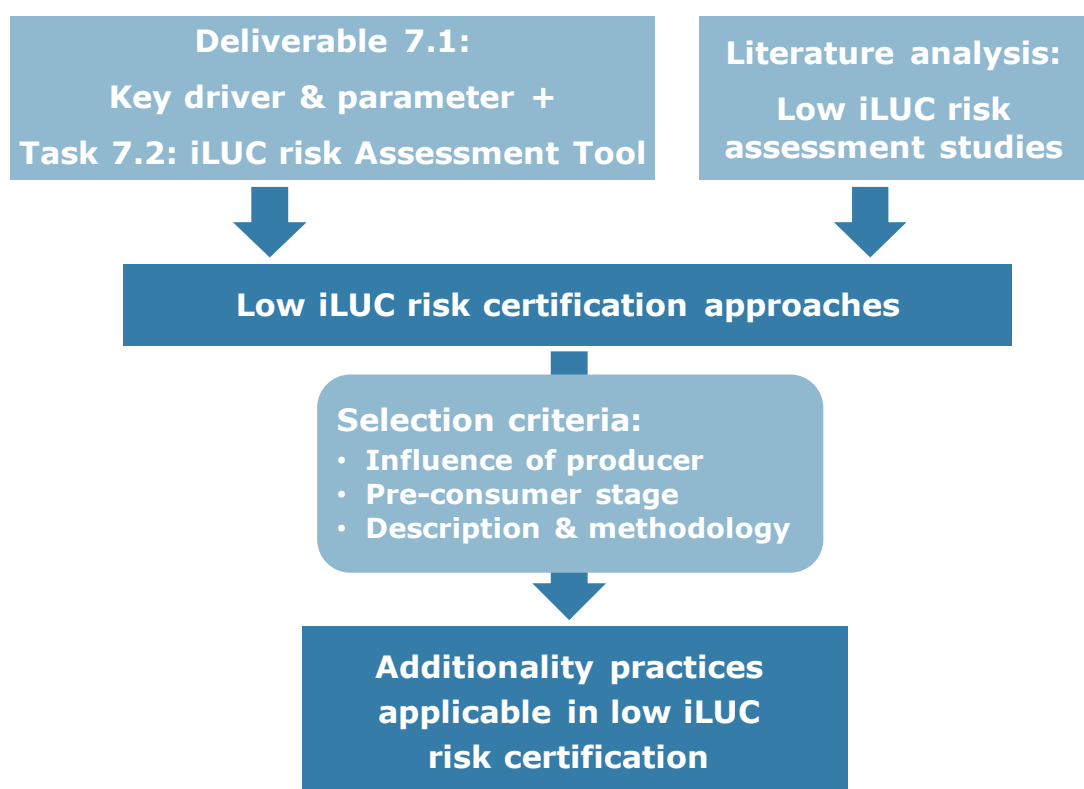
The following parts of this chapter discuss six categories of potential additionality measures and potential approaches for their application in the context of product certification. It should be noted, that by discussing measures, we are not necessarily recommending their implementation. It is more, that we try to reflect on potential ways for the certification of low iLUC risk biomass, in case one of the respective measures has been used by a producer.



### 2.2.2 Procedure for the identification of additionality practices

For the general selection of the potential additionality measures under review, we are building on existing work from (European Commission 2012, 2019; Malins 2019; Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016; RSB 2015; van de Staaij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012) as well as on the findings from T 7.1 and the work for the development of the iLUC risk tool in T 7.2. Figure 18 illustrates the methodological approach for the identification of the additionality practices.

One of the results of Deliverable 7.1 is the identification of key drivers and parameters of iLUC modelling approaches. These identified drivers and parameter set up the background for the identification of the additionality practices. Thus, the selection of the additionality practices from low iLUC risk approaches bases on the identified key drivers and parameter.



*Figure 18 Methodological approach for the identification of the additionality practices applicable in the certification process based on the identified key drivers and parameter of Deliverable 7.1 and the literature analysis of studies dealing with low iLUC risk assessments.*

The first part of the approach is complemented by the identification of practices described in existing literature on the certification of low iLUC risk biofuels. Although, these approaches were initially developed for liquid biofuels, the scope was extended to biomass in general. Besides the analysis of existing certification methodologies, approaches discussing several options for the certification of low iLUC risk biomass are examined. Further low iLUC risk assessment strategies, with a different scope than certification complement the review. These comprise i.e. methodologies to assess the iLUC risk mitigation potential on a regional scale (Wicke, Brinkman, Gerssen-Gondelach, van der Laan, Faaij 2015).

However, for the selection of the additionality practices appropriate for the certification at project or product level, some requirements or preconditions need to be met.



- The applicability of the practices needs to be in the general sphere of influence of the producer of biomass feedstocks or bio-based products. This has been reflected, in the selection of the additionality measures described in (section 2.2.4). Consequently, we do only include measures to be applied at the pre-consumer stages of the supply chain of bio-based products. The post-consumer stages are out of the influence sphere of the biomass or bio-based product producer. Furthermore, for the selected practices originating from approaches dealing with the low iLUC risk certification a detailed description and quantification methodology need to exist. Thus, we integrate practices that are eligible for the application in the certification process.
- The practices taken from regional assessment approaches have to comprise a profound description and quantification methodology, too. In comparison, these practices are not directly applicable in the certification process of bio-based products, because its purpose is an assessment at regional scale and not at the project or product level. Nonetheless, these iLUC risk mitigation options are part of this report, because they potentially can support the product certification with a regional assessment approach.

Finally, for each additionality practice potential negative trade-offs are identified. The identification bases on a literature review of relevant studies.

### **2.2.3 Framework for the certification of the additionality practices**

The integration of the additionality measures under discussion into product certification approaches requires a robust framework, with elements that allow for a transparent verification of the impact of the respective additionality measure.

The following paragraphs do describe potential elements and instruments of a framework for low iLUC risk certification. Specific examples for the application of these elements will be shown for each of the six additionality measures in this report, in section 2.2.4.

#### **2.2.3.1 *Additionality demonstration under the RED 2***

In Article 4 of the European Commissions Delegated Act (European Commission 2019) amending the recast of the Renewable Energy Directive (RED 2) (European Commission 2018), criteria for the certification of low iLUC risk biomass used for the production of biofuels, bioliquids and biomass fuels are determined. Besides the fulfilment of the general sustainability and greenhouse gas emission saving criteria, described in the directive, biomass, which is additional and therefore considered as low iLUC risk can be determined and certified, if the producer can show that it results from additional feedstock, which is a direct consequence of the application of an additionality measure. It should be noted, that the EU RED 2 refers to biomass for bioenergy. However, the same principle might be applied also for biomass used for the production of bio-based products.

In the RED 2, these additionality measures are very generally defined as: "...any improvement of agricultural practices leading, in a sustainable manner, to an increase in yield of food and feed crops on land that is already used for the cultivation of food and feed crops; and any action that enables the cultivation of food and feed crops on unused land, including abandoned land for the production of biofuels, bioliquids and biomass fuels" (European Commission 2019).



Article 5 of the Delegated Act, specifies, that an additionality measure needs to fulfil at least one of the listed conditions. The first condition says, additionality measures become financially attractive or no barrier exists, preventing their implementation due to the fact, that biofuels, bioliquids and biomass fuels produced from additional feedstock can be counted towards the targets for renewable energy. The second condition comprises the cultivation of food and feed crops on abandoned or severely degraded land. Finally, the third conditions deals with the application of the measures by small holders (European Commission 2019). This is in line with some parts of the approach to demonstrate additionality, mainly, aspects of the investment and the barrier analysis as illustrated in below. Amongst others, the concepts for the demonstration of additionality as described in the Delegated Act shows strong similarities to the general concept of additionality demonstration under the EU ETS CDM framework. Even though, the two frameworks of the ETS and the RED are completely different, and both approaches for additionality demonstration follow different objectives, some of the approaches included in the UN CDM Additionality Tool can be considered as very promising and applicable also for additionality demonstration in the context of low iLUC certification (Malins 2019).

#### *2.2.3.2 Specific Instruments for additionality demonstration in certification*

##### **iLUC MITIGATION PLAN**

An iLUC mitigation plan is a document, which shall transparently describe the approach and the additionality measure, taken by an operator for the production of a low iLUC risk feedstock. This document can be the basis for the individual low iLUC risk certification of a producer of biomass or bio-based products. Based on this mitigation plan, the respective certification scheme or certification body can accept and register the iLUC mitigation project. Therefore, the operator submits the mitigation plan for verification to the certification body, which submits it to the certification scheme. According to (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016) standardized templates for the iLUC mitigation plan need to be developed. These should at least include:

- Specific geographical location, where the application of the iLUC risk mitigation is planned;
- Level of certification (single farm or group of farms);
- Size of area, expressed as the amount in hectares impacted by the additionality practice;
- Designated target crop or crop component group (including protein);
- Detailed description of the reference (baseline) scenario;
- Specific approach to determine the above-reference (above-baseline) volumes or amounts of biomass (additionality practice)



For clarification, some of these aspects are explained according to (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016) as follows:

- **Single farm level certification:** The certification takes place on a single farm or field at the farm. The reference scenario is established at farm level as well as the implemented additionality practices and the auditing process.
- **Group certification:** The certification takes place for a group of farms, which cultivate the same target crop in the same geographical region using similar agricultural management practices. The reference scenario is established at group level and the decision for the implementation of a specific additionality practice are coordinated at the group level. However, the implementation itself and the auditing takes place at individual farm level by using a sample.
- **Target crop:** The specific agricultural crop (feedstock for bio-based product), for which the low iLUC risk certification is applied.
- **Crop component:** An elementary material contained in feedstocks, e.g. protein.
- **Reference or baseline scenario:** Scenario describing the development of the agricultural production without an (additional) demand for biofuels or bio-based products.
- **Above-reference or above-baseline production:** Volumes or amounts of biomass that can be produced with the implementation of one or several additionality practices within the level of certification. The additional biomass has a low iLUC risk.

#### CDM "TOOL FOR THE DEMONSTRATION AND ASSESSMENT OF ADDITIONALITY"

The general concept of additionality is not an exclusive achievement of the Renewable Energy Directive. The UN has published guidelines for the demonstration and assessment of additionality in the context of CDM projects, since 2006. Even though the specific objectives of additionality demonstration differs significantly under the ETS and the EU RED framework, a number of similarities in the general concept can be observed. In both concepts, one of the main criteria for the identification of additionality is that the introduction of a new benefit, which creates an additional economic value (e.g. the carbon credit under the CDM/ETS and the low iLUC certification under the RED 2) makes the project feasible. In other words, it shall be demonstrated, that the project would not have been realised, without this new incentive, stemming from the economic value, which is attached to the "additionality".

The substantial difference between both approaches is that the additionality under the CDM aims to demonstrate that an additional carbon credit has been created. Whereas under the RED 2, low iLUC certification logic, additionality refers to the provision of additional biomass. As the discussion on the issue of yield variables will show, especially the demonstration of the later can be rather complex.

However, due to the conceptual similarities of both approaches (especially the aspect of economic feasibility, which is also highlighted in the respective Delegated Act on the RED 2), different authors recommend the general application of the methodology included in the CDM Additionality Tool also to low iLUC risk projects in the bioeconomy. According to (Malins 2019), this CDM tool for additionality can be referred to as a potential gold standard, also for the certification of low iLUC risk projects.

The CDM Additionality Tool follows a stepwise approach, which is described briefly in the following.



## The CDM Tool approach (Clean Development Mechanism Executive Board 2012):

The tool was originally developed for demonstrating additionality for GHG emission reduction projects as a requirement for their approval and crediting in the context of the ETS. For this demonstration a business-as-usual scenario, the so called baseline scenario, needs to be determined. Thus, the project has to demonstrate that the reduction in GHG emissions would not have taken place in a business-as-usual baseline scenario. The baseline scenario describes the case without CDM crediting. Therefore, the CDM Tool is an instrument to ensure that reductions in GHG emissions take place, which otherwise would not have occurred (Searle, Giuntoli 2018).

The tool evaluates the additionality of projects, following a stepwise approach (illustrated in Figure 19). The general approach of the tool is structured as follows (Clean Development Mechanism Executive Board 2012):

### 1. First-of-its-kind project activity

Can the project activity demonstrate that it is the first of its kind in a certain region or country? If yes, is it therefore already to be considered as additional (i.e. not related to displacement effects).

### 2. Identification of alternatives to project activity

Identification of several realistic and credible alternative scenarios that comply with mandatory laws and regulations in a region or country for comparison with project activity. On the one hand, the identification of alternative(s) needs to be available for the project participants. On the other hand, similar project developers with comparable output (e.g. cement) or services (e.g. electricity, heat) to the CDM proposed project activity need to be available. The identified alternatives have to fulfil some requirements as follows:

- The alternatives are not registered as a CDM project activity;
- Other alternatives that deliver outputs or services with a comparable quality, properties and application area are in place;
- If possible, retain continuation of the current situation.

Subsequently, the identified alternatives need to be in compliance with all mandatory legal and regulatory requirements in the country. If an alternative cannot comply with this requirement, the CDM project needs to show that noncompliance with this laws and regulations is widespread in that country. In the case, the project cannot show that, the project is not additional. If the CDM project activity is the only alternative, which complies with mandatory requirements, it is not additional.

### 3. Investment analysis

If the project activity is less financially attractive as at least one of the identified alternatives (compare point 2), the project can be additional. In that case, the common practice analysis needs to be conducted. In the case, the project activity is the most financially attractive option a barrier analysis can be conducted (see point 4).

To conduct the investment analysis one of the following analysis methods can be selected:

- Simple cost analysis: Demonstration that at least one alternative is less costly compared to the project activities. Hence, the project can be additional.



- Investment comparison analysis: Identification of the most suitable financial indicators (e.g. internal rate of return (IRR), net present value (NPV), cost benefit ratio, unit cost of service). If one of the alternatives has the best indicator, the proposed project activity is not the most financially attractive. Hence, it can be additional.
- Benchmark analysis.

#### **4. Barrier analysis**

The objective of this step is to identify barriers that prevent the implementation of the project activity, like technological barriers and investment barriers, other than financial barriers. If the identified barriers do not exist for at least one of the alternatives, the project activity is potentially additional. For clarification, the common practice analysis needs to be conducted.

Examples for realistic and credible barriers that can prevent the implementation of the project can be:

Investment barriers (others than economic or financial barriers):

- Activities would only be implemented with grants or other non-commercial finance;
- No availability of private capital from capital markets.

Technological barriers:

- Lack on skilled, properly trained labour to operate and maintain the technology or practice, which bears a high risk of malfunctioning;
- Lack of infrastructure to maintain the technology (e.g. lack of gas distribution network);
- The technology or practice has a high risk of failure, which is greater compared to other technologies that provide comparable output or service;
- The proposed technology is not available in the region.

#### **5. Common practice analysis**

Finally, the CDM Tool does foresee an analysis evaluating, to which extent the project, which claims to be additional, represents a typical activity within its sector or region. This is a credibility check for the complementation of the investment analysis and the barrier analysis. In this sense, the project activity is compared to similar activities (i.e. technologies or practices) that are determined by several requirements. These are e.g. activities of the same scale, take place in a comparable environment, with a similar regulatory framework and geographical region. If the project activity is not a commonly used practice in regard to this analysis step, the project activity is additional.

The project needs to determine the activities (i.e. technologies or practices) to reduce GHG emissions. Furthermore, similar projects using similar technologies or practices to produce the same output or capacity have to be identified (compare to point 2). Based on this, the project calculates the share of similar activities within the sector and in the geographical area that use the same technologies or practices as the CDM proposed project. If the share is greater than 20% or if more than three similar projects use the technologies or practices, the project activity is a commonly used practice. Hence, the project is not a commonly used practice in the certain geographical area, if this share is less than 20% or less than 3 similar projects use the technologies or practices (Clean Development Mechanism Executive Board 2012; Searle, Giuntoli 2018).



## Results of the additionality demonstration

The result of the additionality demonstration is the crediting of the proposed GHG emission reduction project. This means, that the project can get certified credits for the reduced emissions. These credits can be traded within emission trading schemes. In the case of the CDM, projects with the purpose to reduce GHG emissions in developing countries can sell their credits in industrialized countries. Thus, these countries can meet a part of their emission reduction targets under the Kyoto Protocol.<sup>3</sup>

### Example for a project activity demonstrating additionality according to the CDM Tool

The example is taken from the (Clean Development Mechanism Executive Board 2012) and extended by information from a landfill gas extraction and utilization project at the Matuail landfill site Dhaka in Bangladesh (UNFCCC 01.07.2004). A project reduces the GHG emissions of a landfill by implementing measures to capture the methane and other pollutants, occurring from the deposit of municipal solid waste from private households and industry. For this purpose, the project covers the landfill and captures the gas for further treatments. This can be done by implementing extraction technologies like vertical wells, collectors + piping, condensate separator and compressors. The methane is separated from the other pollutants and used for electricity generation by gas-engines connected to electric generators and feed into local electricity grids.

In our example, this gas capture project is not the first-of-its-kind within the region of Dhaka.

According to the CDM Tool, the demonstration of additionality would involve the definition of alternative scenarios. Alternatives to the proposed project could include different ways to operate the landfill. These can be e.g. the capture of the methane, capture and flaring of the methane or capture and combustion of the methane for energy generation. This scenario analysis of the project identifies several possible alternatives and assesses the probability of each alternative scenario to take place in the future. Two of these scenarios can be identified as "most likely": "Landfill gas recovery does not take place" and "No electricity generation will occur (for example, because supply to the grid is not possible)". Due to the results of the alternative scenario analysis, the project concludes that the only likely alternative is that the current practice continues. Furthermore, the project can be additional, because no legislation exists in the location, which enforces landfill gas extraction with or without utilization.

The investment analysis concludes that the net present value (NPV) of the project is negative compared with the benchmark of interest rates available to a local investor. Thus, in comparison the project is unattractive and therefore potentially additional.

The barrier analysis verifies that the landfill gas capture project face several barriers, like economic unattractiveness, lack of technical know-how and lack of availability of equipment, why it qualifies for the common practice analysis.

If the gas capture project is additional, the common practice analysis in the last step can demonstrate. Finally, the project can demonstrate that in the whole country of Bangladesh no other landfill gas extraction and utilization project exists. If we otherwise assume, there would be minimum one other comparable similar project in the region of Dhaka, the project can be still additional compared to a business-as-usual scenario, because less than three similar projects using the technology to extract and utilize gas from landfills in the region exist.

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<sup>3</sup> Reference: Homepage of the Clean Development Mechanism: <https://cdm.unfccc.int/> (visited: 22.01.2020)



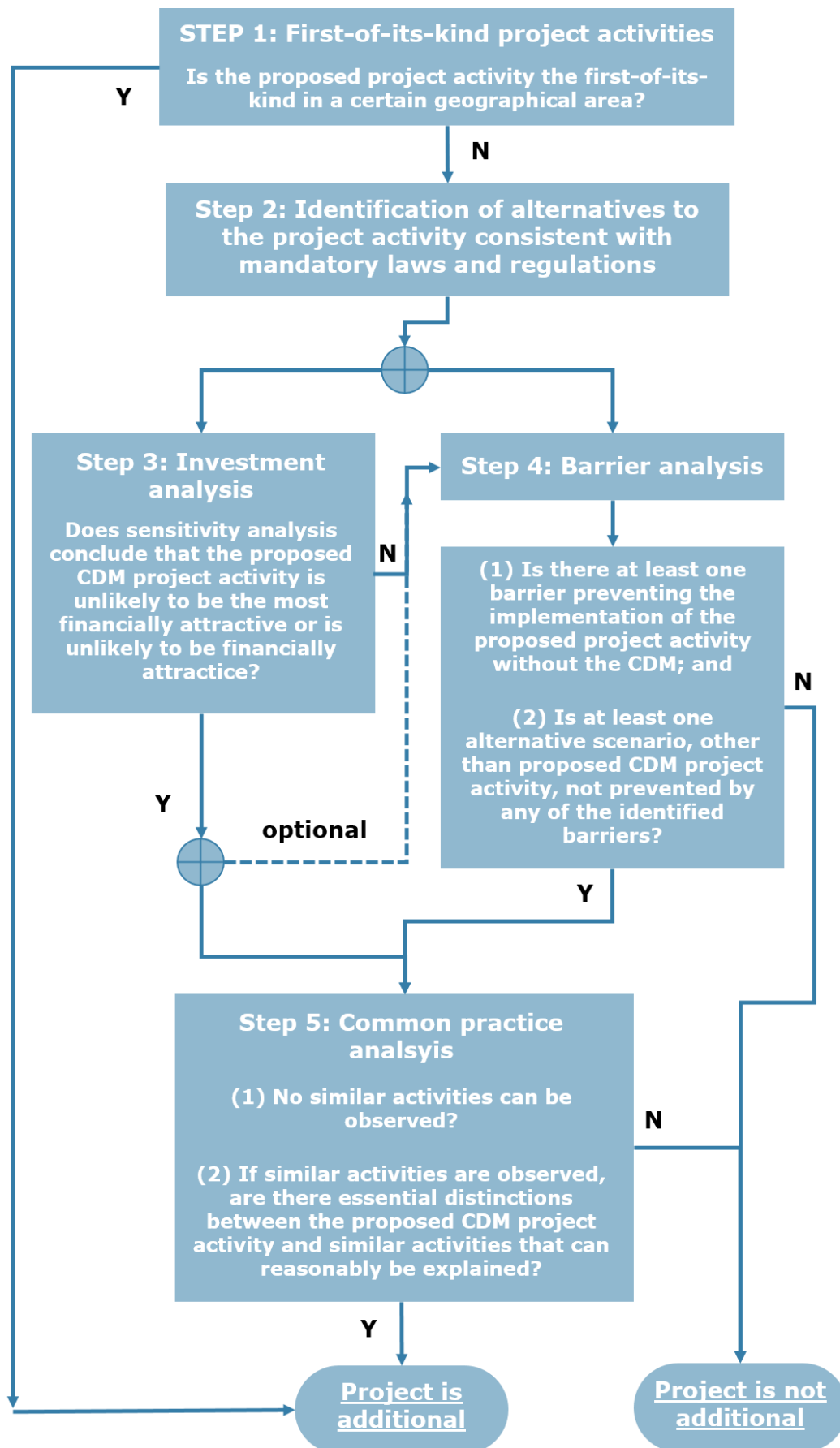


Figure 19 Step-wise approach of the CDM Tool for the demonstration and assessment of additionality (taken from (Clean Development Mechanism Executive Board 2012)).



## Benefits and challenges of the CDM Tool applied to low iLUC risk projects

The application of the CDM Tool to demonstrate that a low iLUC risk project is additional to the business-as-usual activities offers some benefits for the credibility of such projects. The tool bases on the one hand on detailed guidelines, which are publicly available. On the other hand, its applicability has already been demonstrated in the practice several times. Furthermore, it is an internationally accepted system to demonstrate that a GHG emissions reduction project is additional compared with similar projects. Challenging for the application can be that the requirements of such a system can pose a large administrative burden for feedstock producer and producers of bio-based products (Malins 2019). Furthermore, it seems unlikely that the first step (first-of-its-kind project) is really appropriate for low iLUC certification projects, because improvements like increased agricultural crop yield are part of business-as-usual activities of farms, globally. Even attempts for the cultivation of biomass on former unused land is widespread, globally. Thus, for projects taking unused resources into use, it is unlikely to find a place, where this practice was not established by a similar producer before.

### 2.2.4 Additionality practices discussed in this report

Following the approach described above, six general additionality measures, which are frequently discussed in literature and/or seem relevant for future certification projects for low iLUC risk biomass have been identified. The following Table 2 summarises the measures and provides first examples and general direction regarding their potential verification in a certification context.

In the following paragraphs, each of the six measures identified will be discussed in greater detail. Also, a more comprehensive version of this table, including additional information is included in chapter 6.1 in the Annex.



Table 2 Summary of the additionality measures described in this report

Additionality measures	Supply chain <sup>4</sup>	Application	Guidance	Reference
Increased agricultural crop yield	FP	<b>Examples for yield increase strategies</b> <ul style="list-style-type: none"> <li>Choice of crop varieties (i.e. higher yielding variety, better adaption to eco-physiological or climatic conditions)</li> <li>Sowing (e.g. improved drilling machine)</li> <li>Soil management (e.g. mulching instead of ploughing, low tillage)</li> <li>Fertilisation (e.g. optimisation of fertilisation, use of better fertiliser)</li> <li>Crop rotation (e.g. change in crop rotation, cultivation of catch crops)</li> <li>Crop protection (i.e. change in weed, pest and disease control)</li> <li>Pollination (e.g. by using bees)</li> <li>Harvest (e.g. new harvest machine, harvest at optimal time)</li> <li>Precision farming</li> </ul>	<p>Establishing a reference scenario for specific crop(s) to calculate reference yield calculating a linear trendline based on the historical yields of the last 10 years</p> <p>After introduction of a yield measure, the actual yields per crop are compared to reference yield</p> <p>Above-baseline-yield = low iLUC risk biomass (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016; RSB 2015)</p> <p>Calculation of land demand reduction (ha) that results from an above-baseline yield increase for crops, applying an improved yield growth rate (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)</p>	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016; RSB 2015)
Biomass cultivation on unused land	FP	<b>Definition according to Delegated Act complementing EU RED 2:</b> Areas, which were not used for cultivation of food and feed crops, other energy crops or fodder for grazing animals for a period of at least 5 years before the start of cultivation of the feedstock used for the production of biofuels, bioliquids and biomass fuels, e.g. degraded land, marginal land, abandoned agricultural land.	<p>Establishing the reference scenario or situation for unused land</p> <p>Requirements to demonstrate unused land reference:</p> <ul style="list-style-type: none"> <li>Regulatory assessment               <ul style="list-style-type: none"> <li>Legal right to use the land</li> <li>No traditional and /or customary land use rights</li> </ul> </li> <li>Remote sensing analysis determines the land cover and land use during the past five years</li> </ul>	(European Commission 2019; Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016)
Increased livestock production efficiencies	FP	<ul style="list-style-type: none"> <li>Increase efficiency in livestock systems on meadow and pasture land</li> <li>Growth in <b>cattle product yield</b> (higher meat or milk production per animal per year)</li> <li>Increase <b>pasture productivity</b> ( e.g. fertilization or higher productivity grasses)</li> </ul>	<p>Calculation of a land demand reduction (ha) that results from applying an above-baseline scenario for cattle density and/or productivity</p> <p>Based on land demand reduction (ha), amount of low iLUC risk biomass can be determined</p>	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012, 2012)

<sup>4</sup> Feedstock Production (FP); Biomass Conversion (BC) comprises Pre-treatment/ Pre-processing, Conversion, Formulation; Packaging (P) (In accordance to Lokesh, K., Ladu, L., Summerton, L. (2018), 'Bridging the Gaps for a 'Circular' Bioeconomy: Selection Criteria, Bio-Based Value Chain and Stakeholder Mapping', *Sustainability*, Vol. 10, No. 6, p. 1695)



		<ul style="list-style-type: none"> <li>Improved <b>feeding practices</b> (e.g. more concentrated fodder with higher protein diets)</li> <li><b>Landless</b> livestock production</li> </ul>		
<b>Improved by-products integration</b>	FP	<p>Use of <b>by-products</b> from crop production, like crop residues, e.g.:</p> <ul style="list-style-type: none"> <li>Wheat straw</li> <li>Corn stover, cobs</li> <li>Sugarcane leaves</li> <li>Thrash</li> <li>Bark branches and leaves</li> </ul>	<p>Assessment steps of by-products integration:</p> <ol style="list-style-type: none"> <li>Assessment of the amount of residues generated by crop cultivation and the removable share <ul style="list-style-type: none"> <li>Residue-to-product ratio (RPR)</li> <li>Sustainable removal fraction (SRF)</li> </ul> </li> <li>Assessment of the potential use of By-products and the rate at which they can replace other products, e.g. amount of advanced biofuels</li> <li>Calculation of land demand reduction (ha) results from using by-products</li> </ol> <p>Alternative methodology for residue integration (see use of waste)</p>	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; RSB 2015; Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staaïj, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012)
<b>Reduction of biomass losses</b>	FP	<p>Reduction of <b>food losses</b> in transport, storage, (un)loading, etc.</p> <p>Especially: reduction of <b>post-harvest losses</b></p>	Assessment of the land demand reduction (ha) generated from efficiency improvements by calculating the amount of crop prevented from being lost due to efficiency improvements in the food chain	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)
<b>Increasing use of waste</b>	FP	<p><b>Usable surplus</b> of a waste, e.g.:</p> <ul style="list-style-type: none"> <li>Biodegradable garden and park waste</li> <li>Food and kitchen waste from households restaurants, caterers and retail premises</li> <li>Waste from food processing plants</li> </ul>	<p>Assessment of the iLUC-free potential of wastes (and residues)</p> <ul style="list-style-type: none"> <li>Is the material a waste (or residue) (and not a by-product or a product)?</li> <li>Available quantity of the material which is not already used for other purposes (food, animal feed, oleochemicals etc.) in a certain region (feedstock-region-combination)</li> <li>Establishment of a waste (and residue) positive list</li> </ul> <p>Introduction of a maximum removal rate for primary land-using agricultural and forestry wastes (and residues) with specification at regional or national scale</p>	(Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013) (van de Staaïj, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012)



#### 2.2.4.1 *Increased agricultural crop yield*

As part of the group of additionality measures, aiming to increase efficiencies regarding the use of agricultural land or biomass, the topic of increasing agricultural productivity and thus, agricultural yields is discussed very frequently.

In theory, several measures or practices introduced in agricultural production systems can result in increasing yields of agricultural production systems. Following the general concept of the options to demonstrate additionality in the context of low iLUC risk certification, an operator needs to demonstrate, that the production of biomass to be claimed as low iLUC risk biomass results from the application of a yield improvement measure. In this regard, the production of the crop needs to take place at an existing cultivation site, already under production at a specific cut-off date. Furthermore, the operator needs to demonstrate, that the attained yield is a direct consequence of the application of the yield improvement measure which allows the production of biomass above a specific baseline yield (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016). Due to this concept, in theory, biomass for new or additional purposes could be produced without an expansion of the agricultural area or an increasing risk of competition between different biomass utilisations.

Examples for respective crop management measures that might lead to yield increases are an improved soil management, optimised fertilisation, changes in crop rotation, or for example multicropping measures (compare Table 14). Different authors are highlighting especially the latter as an interesting measure to increase agricultural yields and to provide low iLUC risk biomass. Related work on multicropping has for example been presented by (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016; RSB 2015).

As stated above, it is not the intention of this report to give recommendations for practices to increase agricultural yields, but to discuss how these measures could be implemented in certification.

### **APPROACHES FOR THE CERTIFICATION OF LOW iLUC RISK BIOMASS FROM YIELD INCREASES**

Following, the theoretical description of verification measures for additionality, as described under chapter 2.2.3, the definition of an iLUC mitigation plan could be a potential first step in a certification approach. In case of agricultural crop yield improvements, the iLUC mitigation plan should deal with the expected contribution of the yield improvement measure to increase the yield of the target crop, respectively. In addition, the iLUC mitigation plan describes the management practices for yield improvements, e.g. crop varieties, fertilisation, crop rotation (RSB 2015). Furthermore, an additionality demonstration needs to be conducted. The aim of the demonstration is to proof, that the claimed yield increase is not a cause of business-as-usual activities, but is additional to the yield increase without the application of the yield improvement measure. If the operator cannot demonstrate that the claimed biomass is additional, the biomass cannot be certified as low iLUC risk biomass (Malins 2019; Searle, Giuntoli 2018).

When this precondition is fulfilled, the operator can determine the amount of low iLUC risk biomass with the calculation methodologies below. In principle, the determination of low iLUC risk biomass bases on the calculation of a reference scenario in comparison to an above-reference scenario characterised by an improved yield growth rate after implementation of at least one crop management measure (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016). In theory, the difference between the calculated baseline yield and the actual yield of the farm is the amount of biomass to be considered as “additional” or low iLUC risk biomass (compare Figure 20).



For this purpose, a specific baseline yield is to be set for the certification project. Different approaches do exist for the definition of this baseline scenario, using for example static methodologies based on historical data (e.g. multiplying the average yield on a farm for the preceding five years by an annual yield growth factor derived for “similar producers” over the preceding ten year period (RSB 2015) or on model-derived yield references (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015).

### Options to demonstrate additional biomass from crop yield increase

As written under chapter 2.2.3, the demonstration of additionality could follow the basic rationale and the elements included in the UN CDM additionality assessment tool. However, the application of the requirements of such a system can be an induced additional administrative burden for operators, especially for smallholders or smallscale producers. In this sense, different alterations, or simplifications of the CDM tool approach have been developed in the past. Most of these aim for a reduction of the general complexity and the effort needed to demonstrate additionality.

#### **Example I: Emphasis on local supply chains according to (Malins 2019)**

(Malins 2019) suggests a less burdensome additionality assessment approach, laying more emphasis on local conditions. The approach bases on a direct connection between a producer of low iLUC risk biomass and a specific producer of bio-based products. By demonstrating such a connection, the reliability increases that a producer of low iLUC risk feedstock produces the biomass as a response of the demand of the specific bio-based product producer. Therefore, the common practice analysis of the CDM Tool can be applied by the biomass producer, as described below. Furthermore, to increase the credibility regarding the connection between the biomass producer and the processing unit, an agreement and the direct supply from the feedstock producer to the bio-based product producer needs to be documented.

#### Common practice analysis:

Based on the requirements of the last step of the CDM additionality assessment tool, the operator, a farm or group of farms, demonstrates that the yield improvement measure, e.g. changes in crop rotation, is not commonly used within a certain geographical area, like a specific region. Thus, the implementation of the additionality practice of increased agricultural crop yields by application of the specific yield improvement measure needs to demonstrate that less than 20% or less than three similar yield improvement measures are implemented by comparable farms to increase their crop yield. Another option is to demonstrate that the application of the yield improvement measure is less attractive due to certain characteristics, like site conditions, at the farm or group of farms intending to increase yields according to the additionality practice than on other farms in the region.



#### Documentation of statement of intent and segregated supply chain:

The common practice analysis can be complemented by a documentation of an agreement with a specific biomass conversion facility to use the low iLUC risk biomass delivered by the farm or group of farms. This agreement can document that the bio-based product producer takes the whole delivery of low iLUC risk feedstock produced by the farm or group of farms. With this commitment, a direct link between the market for bio-based products and the decision to produce low iLUC risk biomass by the farm or group of farms can be established. This can be complemented by the requirement of a segregated supply chain from the farm or group of farms to the known biomass conversion facility in a region. The combination of the documented state of intent and the establishment of a segregated supply chain directly between biomass producers and biomass conversion facilities within a certain region can on the one hand increase the interest of the bio-based product producer to support yield improvements. On the other hand, it can reduce the free-rider issue of certified biomass produced by a business-as-usual yield increase, because it is less attractive, due to higher supply chain costs, to use segregated supply chains over long distances than locally directly between farms and biomass conversion facilities.

However, this approach still implies a free-rider risk. Thus, the business-as-usual yield increase of farms, which are geographically near to or already supplying producers of bio-based products could be certified as low iLUC risk biomass.

#### **Example II: Reduction to three main steps according to (Searle, Giuntoli 2018)**

According to (Searle, Giuntoli 2018) the additionality demonstration of above-baseline yield increase projects can be reduced to the following three analysis steps, derived from the CDM tool:

##### Investment analysis:

The application of the yield improvement measure is not profitable without the low iLUC risk certification in a specific region. The rationale behind this is that low iLUC risk biomass can be sold for higher prices than non-certified biomass.

##### Barrier analysis:

Alternatively, a barrier analysis can be conducted. This analysis deals with non-cost investment barriers like the lack of knowledge on agricultural management practices, technological barriers or a lack in infrastructure.

##### Common practice analysis:

With this analysis, an operator can show that the yield improvement measure is not commonly used in the region. By demonstrating that the measure is not widely used in the business-as-usual scenario, the biomass resulting from the above-baseline scenario is additional and can be certified as low iLUC risk. If the share of similar producers using the same yield improvement measure to increase their yield in a certain region is less than 20%, the improvement measure is not a commonly used practice. Alternatively, if less than three similar projects use the improvement measure for yield increase, it is not a commonly used practice. Therefore, the yield improvement activity is additional and the resulting biomass low iLUC risk.





### **Example III: Proxy additionality assessment measures according to (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016)**

To reduce effort and costs within the certification process, (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016) propose the application of proxy additionality assessment measures. It needs to be noted that this approach is developed for the specific case of biofuels. In the case of biofuels, the increased demand is mostly policy driven. This implies that a biofuel mandate is in place in a certain geographical area, e.g. the EU. The following additionality assessment measures have a strong focus at biofuels and a binding biofuel mandate. Therefore, this approach is not directly applicable to other bio-based products without a binding mandate in place.

With this approach, probably additional feedstock for biofuel production can be identified. Thus, operators do not need to undertake a full additionality assessment following the CDM Tool (Malins 2019). Besides, the demonstration of additionally produced biofuel (feedstock) compared to a business-as-usual or reference scenario, the additional production can be linked to an overall biofuel demand. The rationale behind this approach is that the demand for biofuels is not the only driver to increase crop yields. Other sectors like the food sector drives the increases in agricultural production, too. (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016).

Examples for such proxy additionality assessment measures for biofuels are listed below (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016):

- A binding biofuel mandate exists in the region, where the low iLUC risk practice is implemented;
- More than 50% of target crop production in the region is used for biofuels;
- Investment analysis: Operator demonstrates that a business case only exists due to an incentive, e.g. provided by a low iLUC risk premium;
- Barrier analysis: Operator demonstrates that non-financial barriers exist that are lifted by actions initiated by the biofuel industry.

However, (Malins 2019) criticises that the first two measures do not ensure that a project activity is additional. For example, the first measure evaluates at least every project in North America and Europe to be additional due to the case that in these regions are biofuel mandates in place. Furthermore, the premise of a clear link between the production of the feedstock for biofuels and a biofuel demand is not assured. Thus, according to (Malins 2019) the proxy additionality measures are not robust enough and can qualify a huge amount of the global agriculture production as additional.

Besides, for the development of low iLUC risk practices for the bioeconomy, particularly the first measure is not useful. Because no binding mandate for other bio-based products exist until now.

### **Methodologies for the calculation of additional biomass from yield increases**

Over the recent years, several authors presented approaches for the calculation of yield increases resulting from additionality measures. The available approaches have been prepared for different target groups and applications. The following sections summarises the existing approaches, suitable for product certification or regional low iLUC projects.

### Example I: Historical yields linear trendline reference of one farm or group of farms (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016)

Peters et al. present a simple approach, which aims to support the certification of low iLUC risk biomass on a producer level. Following the general logic of comparing the actual yield of a producer with a baseline or reference yield, (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016) propose a baseline development based on:

- Historical yields of the last 10 years for the target crop of one farm or group of farms, which implements low iLUC risk yield improvement measure are used to determine the linear trendline;
- A statistical approach, following the "least squares" methodology, to calculate the reference baseline or trendline (preferably in Excel) and the calculation of the reference point, which is performed with the linear trendline (Equation 1).

Following this concept, any yield above the calculated reference point would be considered as low iLUC risk (compare Figure 20). Based on the calculated reference point, with the Equation 2 the amount of low iLUC risk biomass can be calculated.

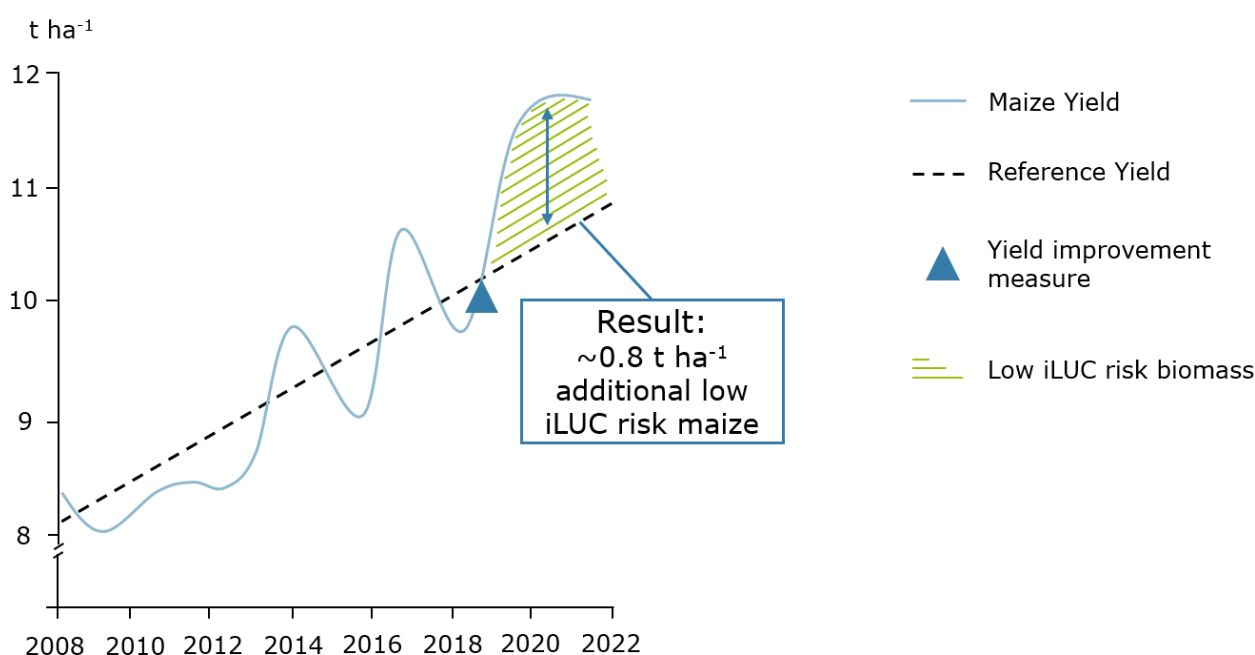


Figure 20 Example for the historical yields linear trendline reference approach to determine additional low iLUC risk biomass from yield increases by comparison of a reference and an above-reference biomass production of maize abridged from Peters et al. (2016).



### EQUATION 1:

$$Y_{\text{ref},t=x} = \text{SP} + \text{AYG} \times a$$

- $Y_{\text{ref},t=x}$ : Reference Point ( $\text{t ha}^{-1}$ )  
(Statistical point on the trendline yields in year 10, i.e. before the crop yield improvement measure is applied);
- SP: Statistical starting point ( $\text{t ha}^{-1}$ )  
(Beginning of the linear trendline 10 years before yield improvement strategy is applied);
- AYG: Annual yield growth ( $\text{t ha}^{-1} \text{ a}^{-1}$ ) of the last 10 years;
- a: Year for which the point on the linear trendline is calculated, e.g. year 1 is 10 years ago and year 10 is the previous year before crop management is applied).

Any yield above the calculated reference point is low iLUC risk.

### EQUATION 2:

$$V_{\text{low iLUC } t=x} = (Y_{t=x} - Y_{\text{ref},t=x}) \times A$$

- $V_{\text{low iLUC } t=x}$ : Volume (t) of low iLUC risk compliant biomass in year x;
- $Y_{t=x}$ : Actual yield ( $\text{t ha}^{-1}$ ) in year x;
- $Y_{\text{ref},t=x}$ : Reference scenario yield ( $\text{t ha}^{-1}$ );
- A: System boundary area (ha).

The calculated amount of biomass ( $V_{\text{low iLUC } t=x}$ ) is low iLUC risk biomass.

The potential advantages and disadvantages of this approach can be summarised as listed in Table 3:

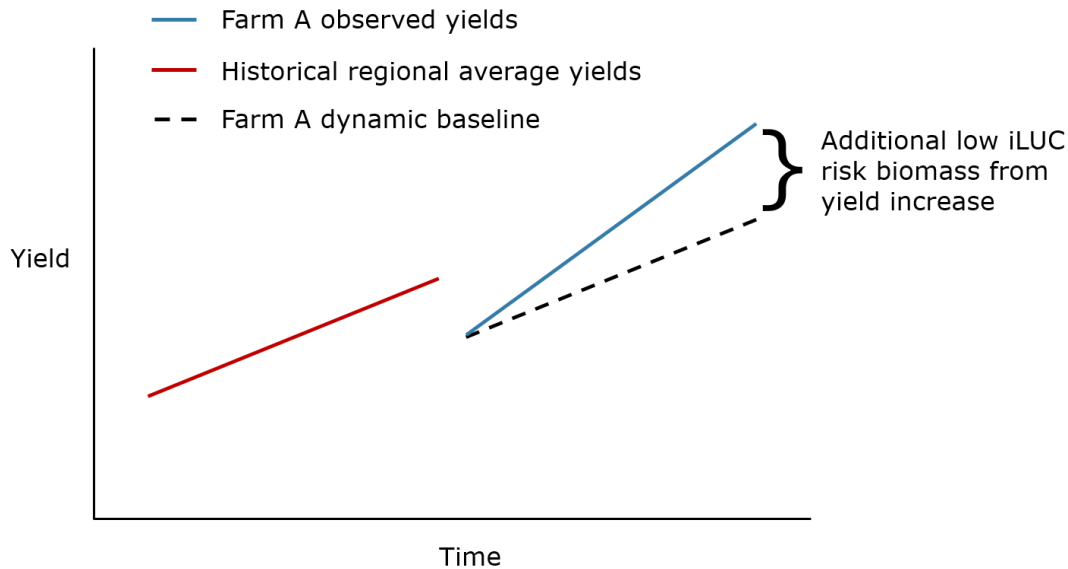
*Table 3 Advantages and disadvantages of the Example I: Historical yields linear trendline reference bases on yields of the farm or group of farms.*

Advantages	Disadvantages
Relatively low effort in calculation of yields trendline and comparison to yield above-reference point	Taking into account only historical yields and no projection of the future
Calculation with a common computer program (Microsoft Excel)	Trend could be over- or under-estimated in regard to variabilities
Use of measured yield data	Risk in over-crediting the effectiveness of specific improvements
Existing yield data of the last 10 years	

## Example II: Dynamic baseline yield scenario

To complement the methodology of the historical yields trendline reference based on the yield data of one farm or group of farms (as presented under Example I), (Searle, Giuntoli 2018) suggested to calculate dynamic baseline yields. A methodology how to calculate the dynamic baseline yield scenario is developed by (RSB 2015).

The Figure 21 illustrates the approach. Hence, the dynamic baseline (dashed line) of farm A has the starting point in the year 0. It follows the same level as the historically observed average yields of similar producers in the region (red line). The observed yields of farm A (blue line) above the dynamic baseline after year 0 can be certified as low iLUC risk.



*Figure 21 Approach to determine additional low iLUC risk biomass from yield increase with a dynamic baseline yield scenario based on historical average yields of similar producers within one region in comparison to observed yields of the yield increasing farm abridged from (Searle, Giuntoli 2018).*

The Roundtable on Sustainable Biomaterials developed an approach similar to the approach developed by (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016). However, the main difference is that the RSB calculates the baseline yield with the historical yields of the farm and from similar producers in the same region as describes above. Similarly, to the approach of Peters et al., the baseline yield is calculated over a period of 10 years. With Equation 3, the baseline yield can be determined. It even offers an option to calculate the baseline yield without the yield data of similar producers by adding a 10% factor to the baseline yield of the farm proposed to be certified (Equation 4).

### EQUATION 3:

$$Y_{\text{BASE}} = Y_{b,t=0} * Y_{gr}$$



#### EQUATION 4:

$$Y_{BASE} = Y_{b,t=0} * 1.1$$

$Y_{BASE}$ : Baseline scenario yield ( $t\ ha^{-1}$  or  $m^3\ ha^{-1}$ );

$Y_{b,t=0}$ : Participating operators reference yield at reference year ( $t=0$ ), which is the last year before yield increase measure started being implemented or 2008, whichever is later ( $t\ ha^{-1}$ );

$Y_{gr}$ : Average annual yield growth for similar producers in the region (%).

For the calculation of the participating operators reference yield, the following Equation 5 can be used:

#### EQUATION 5:

$$Y_{b,t=0} = \frac{Y_{t=-4} + Y_{t=-3} + Y_{t=-2} + Y_{t=-1} + Y_{t=0}}{5}$$

$Y_{b,t=0}$ : Participating operators reference yield at reference year ( $t=0$ ), which is the last year before yield increase measure started being implemented or 2008, whichever is later ( $t\ ha^{-1}$ );

$Y_{t=0}$ : Participating operators actual yield during the reference year ( $t=0$ ) ( $t\ ha^{-1}$  or  $m^3\ ha^{-1}$ );

$Y_{t=-1}$ : Participating operators actual yield the year preceding the reference year ( $t=-1$ ) ( $t\ ha^{-1}$  or  $m^3\ ha^{-1}$ );

$Y_{t=-2}$ : Participating operators actual yield two years preceding the reference year ( $t=-2$ ) ( $t\ ha^{-1}$  or  $m^3\ ha^{-1}$ );

$Y_{t=-3}$ : Participating operators actual yield three years preceding the reference year ( $t=-3$ ) ( $t\ ha^{-1}$  or  $m^3\ ha^{-1}$ );

$Y_{t=-4}$ : Participating operators actual yield four years preceding the reference year ( $t=-4$ ) ( $t\ ha^{-1}$  or  $m^3\ ha^{-1}$ ).

Example: If the reference year ( $t=0$ ) is 2019, then  $t=-1$  is 2018,  $t=-2$  is 2017, etc.

The average annual yield growth for similar producers in the region ( $Y_{gr}$ ) is calculated with the Equation 6.

#### EQUATION 6:

$$Y_{gr} = \sqrt[9]{\frac{T_{t=0}}{T_{t=-9}}}$$

$Y_{gr}$ : Average annual yield growth for similar producers in the region;



$T_{t=0}$ : Trend line value for similar producers in the region at the reference year ( $t=0$ ) ( $t \text{ ha}^{-1}$  or  $m^3 \text{ ha}^{-1}$ );

$T_{t=-9}$ : Trend line value for similar producers in the region nine years before reference year ( $t=-9$ ) ( $t \text{ ha}^{-1}$  or  $m^3 \text{ ha}^{-1}$ ).

It should to be noted that the calculation of the yields bases on the trendline of the similar producers and not on the actual yields. Due to the yield increases over 10 years, only 9 time steps are in place. Thus, the 9<sup>th</sup> root has to be extracted of the division of the trend line value in year  $t=0$  and the trend line value in year  $t=-9$ .

Similar farms or producer can be defined by fulfilment of the following conditions:

- Grow the same crop
- Are located in the same geographical region (e.g. NUTS2 in EU)
- Use a similar management model (e.g. smallholder, small or large scale plantation)

Besides, (Malins 2019) established a similar methodology shown in Equation 7. It proposes to calculate a “year zero” baseline yield and an annual trend yield. The “year zero” baseline yield bases on the production data of the last 10 years of the farm or a group of farms, like it is proposed by (RSB 2015).

#### EQUATION 7:

$$Y_{\text{baseline},t=x} = Y_{\text{baseline},t=0} + N \times \Delta Y$$

$Y_{\text{baseline},t=x}$ : Baseline yield in year  $x$  ( $t \text{ ha}^{-1}$ );

$Y_{\text{baseline},t=0}$ : Baseline yield in the year zero with data of the last 10 years of the farm or group of farms ( $t \text{ ha}^{-1}$ );

$N$ : Year of project implementation;

$\Delta Y$ : Annual trend yield increase ( $t \text{ ha}^{-1} \text{ a}^{-1}$ ) with regional or national data of the last 10 years of similar farms.

When calculating the annual trend yield, extreme values like the lowest and the highest yields can be excluded as well as limits for minimum and maximum yield growth can be established. The minimum yield growth can be set at zero and the maximum yield growth can be based on longer term trends (Malins 2019).

Due to the yield evolution in the lifetime of a perennial crop (e.g. oil palm), it is not appropriate to compare the yield in a certain year with a regional or national average. Therefore, the baseline yield can base on the normal rate of yield development by plantation age with a strong focus at local conditions (Malins 2019).

For this approach, potential advantages and disadvantages can be summarised as follows in Table 4.



*Table 4 Advantages and disadvantages of the Example II: Dynamic baseline yield scenario.*

Advantages	Disadvantages
Calculation of the yields baseline bases on historical yields is relatively easy	Taking into account only historical yields and no projection of the future
Inclusion of yields of the operator and similar farms in the same region	Trend could be over- or under-estimated in regard to variabilities
No computer program or other advanced technology is needed for the calculation	Risk in over-crediting the effectiveness of specific improvements
Use of measured yield data	Data gathering of similar producers can be an issue
Existing yield data of the last 10 years	

**Example III: Model-derived yield reference for regional low iLUC projects (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)**

Contrary to the first examples, which were developed for the certification of individual producers of biomass, (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015) present an approach for the development of regional low iLUC projects. The approach follows a three step logic, resulting ideally in a better understanding about the specific potentials of a region to provide low iLUC risk biomass as well as the specific additionality measures that could be implemented.

- I. In a first step, two scenarios will be developed for the respective region. The first, reference scenario focusses on the development of the biomass production (and yield development) of this region. The second scenario is used to estimate the potential demand for biomass resulting from the introduction of a regional biomass target (e.g. a quota or mandate). The difference between both scenarios is the gap between the theoretical supply and the demand side. Thus, this concept gives an idea regarding the potential iLUC risk of a region, associated with a specific biomass policy.
- II. Secondly, the potential for the supply of low iLUC risk biomass is investigated for this specific region. Thereby, the potential impact from the implementation of several regional additionality measures and the amount of biomass which could be produced consequently (low, medium and high scenario because of potential variability and uncertainty in data sets) is being calculated. Therefore, in Equation 8, the reduced demand for land resulting from the implementation of the additionality measures needs to be calculated. Based on this the potential biomass production can be calculated.
- III. Thirdly, the general potential for biomass production, including the effects of additionality measures from step two is being compared to the difference between the target and baseline scenario of step 1. This general comparison allows to discuss the general potential of a region to produce low iLUC risk biomass. This potential is described in Equation 9.

This approach can be very useful for the development of regional projects, but also as an instrument for a regional risk assessment, which could be applied by certification schemes, before entering an actual certification of specific producers within a region.





#### EQUATION 8:

$$\text{LDR}_{\text{ABY,crops}} = A_{\text{baseline}} - A_{\text{ABY}} = \sum_{i=1}^n \frac{P_i}{Y_{\text{baseline},i}} - \sum_{i=1}^n \frac{P_i}{Y_{\text{ABY},i}}$$

- $\text{LDR}_{\text{ABY,crops}}$ : Land demand reduction (ha) from above-baseline yield increase (ABY) for crops;
- $A_{\text{baseline}}$ : Area (ha) needed for baseline crop production by application of the baseline yield growth rate;
- $A_{\text{ABY}}$ : Area (ha) needed for baseline crop production by application of an improved yield growth rate;
- $Y_{\text{baseline},i}$ : Projected baseline yield for crop  $i$  ( $\text{t ha}^{-1} \text{a}^{-1}$ );
- $Y_{\text{ABY},i}$ : Projected above-baseline yield for crop  $i$  ( $\text{t ha}^{-1} \text{a}^{-1}$ );
- $P$ : Projected production (t) for crop  $i$ , as derived from the models baseline scenario.

#### EQUATION 9:

$$\text{Pot}_{\text{low iLUC risk}} = \text{LDR} \times Y_{\text{bio-based product feedstock}}$$

- $\text{Pot}_{\text{low iLUC risk}}$ : Low iLUC risk biomass production potential ( $\text{t a}^{-1}$ );
- $\text{LDR}$ : Land demand reduction generated by the low iLUC risk practice (ha);
- $Y_{\text{bio-based product feedstock}}$ : Projected bio-based products feedstock yield ( $\text{t ha}^{-1}$ ).

Potential advantages and disadvantages of this approach might be summarised as follows in Table 5.

*Table 5 Advantages and disadvantages of the Example III: Model-derived yield reference for regional low iLUC projects.*

Advantages	Disadvantages
Projects a bandwidth for low, medium and high expected annual yield growth	Modelling bases on assumptions and is therefore not applicable in all cases
Large amount of data as model input increases reliability of the projected yields	Relatively high effort in calculation of reference yield
Regional data is publicly available in databases	Uncertainty in future projections for modelling
Ties on established modelling approaches, which increases the comparability of results	Need for (expensive) model software
Comprehensive and in case studies approved methodology for iLUC risk mitigation	Bias in crediting due to over or under estimation



## Approaches to deal with the issue of yield variabilities

In existing approaches for certifying low iLUC-risk feedstock from yield increases and in the proposals presented so far, the general idea is to set up and validate a project plan, and to certify “additional”, low iLUC risk biomass based on comparison of actual achieved yields against a baseline yield prediction.

However, a number of difficulties can hinder the implementation of robust low iLUC certification based on these theoretical approaches. One of the main challenges is being imposed by normal weather-influenced yield variation. In that sense, annual yield variations in a specific region or for a specific producer can be larger than any annual marginal yield increase resulting from the implementation of a dedicated yield increasing measure. Following the simple rationale of comparing measured, actual yield to some yield baseline, this could result in over-crediting in years with good weather and under-crediting in years with poor weather.

Since, already the normal variety in agricultural yields can lead to these effects of over- or under-crediting problems, a calculation of low iLUC risk biomass from yield increases based on a simple statistical trend seems not ideal for the development of a robust approach. In that sense, the following paragraphs summarise approaches, which try to tackle this specific issue of yield variations.

### **Example IV: Crediting project implementation and outcome (Malins 2019)**

As stated before, it can be very difficult to identify clearly, whether measured yield increases are a result of the application of a yield improvement measure with the purpose of iLUC mitigation or the result of variabilities due to favourable conditions, like weather. Furthermore, unfavourable conditions can cause yield decreases, too. Consequently, both situations can influence the willingness of an operator to participate in a certification with the purpose to reduce the iLUC risk of his operations.

(Malins 2019) therefore proposes a combination of expected yield increases resulting from the project (i.e. the additionality practice) implementation and the actual yield results. The project implementation comprises the demonstration that the yield improvement plan determines reasonable expectations for yield increases. According to the (RSB 2015) these expectations can be demonstrated in several ways, e.g. by reference to scientific literature or experience from field trials. (Malins 2019) suggests to consider and credit both, the project implementation and the observed yields with a minimum of 30%, respectively. The advantage of this credit splitting is that enough credit can be generated in years with less yield due to the credit of the project implementation and enough credit for the observed yield, whereas the incentive to maximise yield improvements still exists. Furthermore, the implementation is audited after the first year with repetitions every three years. Therefore, this approach needs to be implemented as an additional auditing requirement of the respective scheme or certification body. Additionally, a project review can be undertaken at the end of the fourth year. The purpose of this review is to compare the yield development of the four years with a calculated yield trend. Thus, the minimum annual credit can be adjusted in accordance to the performance of the yield improvement measures.

### **Example V: Moving trendline (Searle 2019)**

Another, more dynamic approach to deal with the problem of yield variations is the concept of the moving trendline. This concept dynamically considers the annual yield development of a producer since the start of his certification.

The benefit of this approach is that an operator can achieve credit and low iLUC risk biomass certification in years with less yield due to poor weather conditions. Otherwise, it avoids over-crediting in years with unusually high yields caused by good weather conditions.

The general concept follows a three-step approach and is illustrated in Figure 22:

- Year one:

The amount of low iLUC risk biomass for certification will be calculated as a result of the difference between the actual observed yield and the dynamic baseline (average yield increases of other agricultural producers in the area, see Example II).

- Year two:

A trendline based on yield development during the years 0, 1 and 2 is calculated, including e.g. a low yield in year 2 due to poor weather conditions. The identified low iLUC risk biomass is the result of the difference between the predicted yield on the trendline and the dynamic baseline. Thus, in this step, for the identification of low iLUC biomass the calculated trendline does replace the actual observed yield from step one.

- Year three:

A trendline based on the yields of the years 0, 1, 2 and 3 is calculated. The low iLUC risk biomass is the result of the difference between the predicted yield on the trendline and the dynamic baseline.

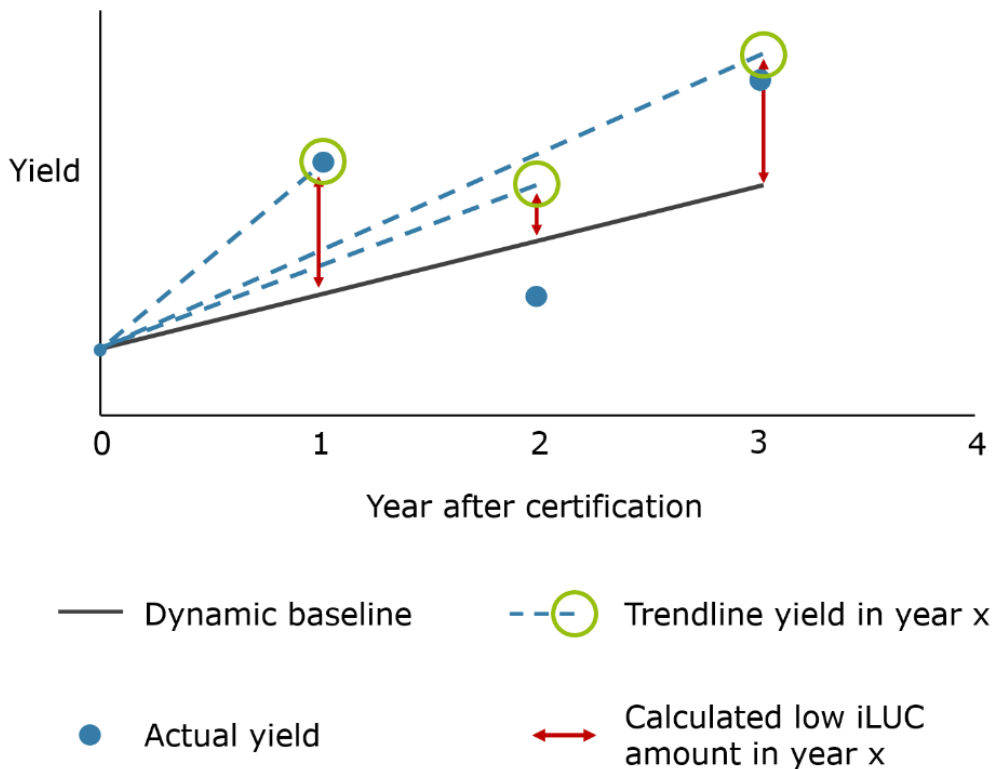


Figure 22 Schematic illustration of the moving trendline approach to calculate the low iLUC amount on the basis of the actual yield in each year in comparison to a dynamic baseline yield, abridged from (Searle 2019).



## POTENTIAL NEGATIVE TRADE-OFFS OF THIS ADDITIONALITY MEASURE

For the appropriate certification, the crop yields need to be increased without causing environmental and social risks, regarding several sustainability criteria. Therefore, in this chapter a selection of potential negative trade-offs dealing with these risks are illustrated. A list with further negative trade-offs can be found in Table 15 (section 6.2.1 in the Annex).

The increase in agricultural yields can cause e.g. biodiversity losses. The loss in biodiversity caused by increased fertilizer uses, the expansion of monocultures, and conventional intensification can effect species not only in croplands but also in surrounding habitats (Beckmann, Gerstner, Akin-Fajiye, Ceașu, Kambach, Kinlock, Phillips, Verhagen, Gurevitch, Klotz, Newbold, Verburg, Winter, Seppelt 2019; Gerssen-Gondelach, Wicke, Faaij 2017; Liu, Pan, Li 2015; Wingeyer, Amado, Pérez-Bidegain, Studdert, Varela, Garcia, Karlen 2015; Zabel, Delzeit, Schneider, Seppelt, Mauser, Václavík 2019). Furthermore, a decrease in soil functionality can be caused by an increased fertilizer use, inefficient fertilizer and pesticides use, which can lead to over-fertilized soils. The expansion of monocultures can have impacts on the soil degradation through wind and water erosion, soil organic matter (SOM) depletion and nutrient losses. An intensive irrigation can increase soil acidification as well as land degradation and erosion (Gerssen-Gondelach, Wicke, Faaij 2017; Gregory, Ingram, Andersson, Betts, Brovkin, Chase, Grace, Gray, Hamilton, Hardy, Howden, Jenkins, Meybeck, Olsson, Ortiz-Monasterio, Palm, Payn, Rummukainen, Schulze, Thiem, Valentin, Wilkinson 2002; Ju, Xing, Chen, Zhang, Zhang, Liu, Cui, Yin, Christie, Zhub, Zhan 2009; Lambin, Meyfroidt 2011; Liu, Pan, Li 2015; Smith, House, Bustamante, Sobocká, Harper, Pan, West, Clark, Adhya, Rumpel, Paustian, Kuikman, Cotrufo, Elliott, McDowell, Griffiths, Asakawa, Bondeau, Jain, Meersmans, Pugh 2016; Tian, Lu, Melillo, Ren, Huang, Xu, Liu, Zhang, Chen, Pan, Liu, Reilly 2012; Wingeyer, Amado, Pérez-Bidegain, Studdert, Varela, Garcia, Karlen 2015). An increase in GHG emissions, e.g. nitrous oxide (N<sub>2</sub>O) can result from the increased fertilizer use, mechanization and cultivation of groundwater-irrigated crops ((Brinkman, Wicke, Faaij 2017); (Hickman, Tully, Groffman, Diru, Palm 2015); (McGill, Hamilton, Millar, Robertson 2018); (Smith, Haberl, Popp, Erb, Lauk, Harper, Tubiello, Siqueira Pinto, Jafari, Sohi, Masera, Böttcher, Berndes, Bustamante, Ahammad, Clark, Dong, Elsiddig, Mbow, Ravindranath, Rice, Robledo Abad, Romanovskaya, Sperling, Herrero, House, Rose 2013)).

### 2.2.4.2 Biomass cultivation on unused land

The second potential option for the provision of low iLUC biomass under discussion is the cultivation of biomass on unused land. In theory, bringing an unused plot of land into agricultural productivity can contribute to the provision of additional biomass, without increasing pressure on existing agricultural land or replacing existing users of biomass. However, in this context it is crucial to define and determine the term of unused land in a robust manner and without unnecessary room for interpretation. There are several risks, associated with an unclear or vague definition of unused land. Consequences can be high GHG emissions or biodiversity loss due to the conversion of area with high carbon stocks or a high biodiversity values (compare section 6.2.2 in the Annex). Generally, the term unused land can describe several types of lands, including various reasons, why a specific plot is not being used for biomass production. Examples include degraded, marginal and abandoned agricultural land (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012).



In the context of a robust low iLUC certification approach, it is important to demonstrate, that the land under discussion is really unused. It is therefore important, to complement a clear definition of the term unused with a number of criteria and indicators, allowing the verification of the respective definition. This includes for example the check of regulatory criteria, dealing for example with land use rights, both with legal rights and traditional and/or customary rights. Secondly, it is important to understand, whether the land under discussion shows low carbon stocks and biodiversity value. Thirdly, it is important to check, whether the land was used for provisioning services (e.g. food, wood or fibre) (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016), recently. The identification of unused land, requires information about the location, the size, the actual uses and the suitability for the cultivation of the feedstock for bio-based products (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaïj 2015). Thus, the determination of unused land, suitable for the provision of low iLUC risk biomass cultivation, should follow a clear definition for the term unused, which needs to be verified following clear and robust criteria which are applied in a site-specific assessment at the claimed plot.

## DEFINITION OF UNUSED LAND AND UNUSED LAND CATEGORIES

For the assessment of biomass cultivation on unused land in the context of low iLUC risk certification, it is crucial to define the term unused land robustly. Several specifications of the term unused land exist and can be differentiated. The definition of each unused land category needs to be clear to avoid any misinterpretation or abuse. This section gives an overview of existing definitions of unused land and its several types.

### *Options and requirements for the definition of unused land suitable for low iLUC risk certification*

The respective Delegated Act of the Commission on low iLUC risk biomass sets characteristics for the identification of unused land for the provision of additional biomass. This general definition is highly relevant for the EU bioeconomy, since it sets the framework for the certification of low iLUC risk biofuels. According the Delegated Act, the area under discussion can be defined as unused in case it was not used for the cultivation of food and feed crops as well as energy crops or any amount of fodder for grazing animals for a complete period of at least 5 years (European Commission 2019).

The emphasis of this definition is on a demarcation to cultivated land for agricultural purposes. This comprises the food, feed or energy crop production. Any other land use type, e.g. forestry, cotton or rubber is not explicitly mentioned in the definition (T&E 2019). However, it has to be noted, that this definition for low iLUC certification is embedded in a broader framework of the other sustainability criteria of the RED/RED 2. Amongst others, these criteria define different land use types which can not be converted into agricultural land. This includes areas with high carbon stock or high values for biodiversity (European Commission 2018).

Therefore, unused land in general can be defined as “a plot of land, which is not under cultivation because of biophysical or socioeconomic limitations and not used for other provisioning services currently and during the past 5 years, with low carbon stocks and limited biodiversity value” (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016). Provisioning services are one part of the concept of ecosystem services and include materials and energy, an ecosystem can generate. These are for example food, water, wood and fibre as well as fuel (Millennium Ecosystem Assessment 2005). To determine what the term “not under cultivation” exactly means is very important for the definition of unused land. Therefore, in the following sections different categories of unused land are introduced, with the aim to specify better, what “not under cultivation” in this definition can be.



Furthermore, for some specific areas and regions, careful adaptations and additions to the above mentioned definition of unused land can be meaningful. One might be land that was used for shifting cultivation and is currently set-aside. This is mostly important in regions in Central and South America, Africa and Southeast Asia (Heinimann, Mertz, Frolking, Egelund Christensen, Hurni, Sedano, Parsons Chini, Sahajpal, Hansen, Hurtt 2017). Some fields in these areas can be set aside as fallow land. Traditionally, the fallow period can last for 10 to 15 years (Upadhaya, Barik, Kharbhih, Nongbri, Debnath, Gupta, Ojha 2020) or even 20 to 30 years (Borah, Evans, Edwards 2018) in tropical regions. However, in the last decades a reduced fallow period of 1 to 3 years got more common (Grogan, Lalnunmawia, Tripathi 2012; Upadhaya, Barik, Kharbhih, Nongbri, Debnath, Gupta, Ojha 2020). (RSB 2015) takes into account very long crop rotation systems and assumes a fallow period for up to ten years. An option to deal with this issue and to identify respective areas are interviews with local people (RSB 2015).

Another important aspect regards the time horizon of provisioning services on the unused land plot. Thus, the (RSB 2015) suggests to demonstrate that the land was not in use for its provisioning services during the three years prior to a reference date. Therefore, available data needs to be obtained. In the EU, data can be gathered from the plot growing cadastre for farmers' cross-compliance application. Especially, when less data is available, interviews with landowners and local people or authorities can be performed. Satellite images from the three years growing season can support the data collection (RSB 2015).

### **Options for definitions of unused land categories**

Unused land can be grouped into different categories depending on the reason why the land is unused. The broad definition can comprise e.g. areas of undisturbed wildlife, rainforest and deserts (Wiegmann, Hennenberg, Fritsche 2008). However, most of these categories are out of the scope of the unused land categories suitable for low iLUC risk certification, and are thus not included in the definition of unused land determined above.

Contrarily, in order to avoid negative trade-offs and impacts from the use of unused land, existing approaches for low iLUC risk certification put special emphasis on abandoned land, where the former land use activities were given up, mostly due to economic reasons. Thus, unused land appropriate for the cultivation of low iLUC risk biomass can be assigned to one of the following definitions, with the exemption of waste land. In the Annex, section 6.3.1, several options to define each unused land category are described.

#### **Abandoned agricultural land**

Abandoned land comprise areas, where land use is given up in the past. This can be for example abandoned industrial sites, plantations or farmland. This land was used in the past for agriculture or pasture purposes and was not converted to forest or urban areas. Economic, political or environmental reasons exist for the abandonment of the agricultural land (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012; Wiegmann, Hennenberg, Fritsche 2008).

#### **Degraded land**

Degraded land can be defined as an area, which lost its ecosystem functions and services in the long term. The reasons for this lost are disturbances from which the ecosystem can not recover for its own. Therefore, a recovery is dependent on external aid (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012).

#### **Marginal land**

Marginal land is not in use, because currently the cultivation is too expensive under the given technological and site-specific conditions. Therefore, production of food and feed are actually not cost-effective at this land. Once, the conditions are changing possibly the area will be used for the cultivation of food and feed in the future (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012; Wiegmann, Hennenberg, Fritsche 2008).





### **Set-aside land**

Set-aside land is land that is not used due to political reasons (Wiegmann, Hennenberg, Fritsche 2008). It is not allowed to be used for any agricultural purpose for the period a set-aside policy is implemented. However, the land can be cultivated with non-food crops, including energy crops (Lefebvre, Espinosa, y Paloma 2012).

### **Idle land**

Idle land and unused land can be seen as the same. Therefore, it comprises all categories of unused land, like abandoned agricultural land, degraded land, etc. (Wiegmann, Hennenberg, Fritsche 2008).

### **Under-utilized land**

Under-utilized land can be set-aside land, abandoned land, marginal land and degraded land. It is characterised by the share of land, which does not provide other services, like agriculture, biodiversity, high carbon stocks or other ecosystem services (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015).

On the other hand, low-intensity smallholder agriculture can be seen as under-utilized land (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016).

### **Waste land**

Waste land cannot be used for cultivation under any condition. It is characterised by natural conditions, which can prohibit agricultural land use activities in general (Wiegmann, Hennenberg, Fritsche 2008).

## **APPROACHES FOR THE CERTIFICATION OF LOW ILUC RISK BIOMASS FROM UNUSED LAND**

As stated above, the implementation of biomass from unused land as an additionality measure needs a clear, transparent and robust framework. Thus, the term unused land needs to be defined in a robust manner. Furthermore, an investigation of the proposed area, using remote sensing data or an on-site inspection is necessary. Both methods can be combined to increase the validity of the investigation. In the following sections, potential steps to determine unused land appropriate for low iLUC risk biomass production are described in detail.

### **Options to demonstrate additionality for biomass from previously unused land**

In the context of low iLUC certification, the demonstration of additionality is the precondition for certification. This demonstration shall show that taking the claimed unused land into production is additional to business-as-usual activities. This is important, since due to a growing demand for food worldwide the expansion of agricultural land takes place anyhow. Thus, the operator has to demonstrate, that the low iLUC risk biomass resulted from the cultivation of unused land, which has or would not have been taken in use under business-as-usual conditions. If the operator cannot demonstrate, that the claimed biomass is additional, the biomass cannot be certified as low iLUC risk biomass (Malins 2019; Searle, Giuntoli 2018).

A respective demonstration of additionality could follow the approaches described in the following paragraphs.





## **General steps to demonstrate additionality of biomass from former unused land based on the UN CDM Additionality Tool (Searle, Giuntoli 2018)**

Generally, an additionality demonstration for unused land projects, could follow the analysis proposed by the CDM Additionality Tool. This analysis includes:

### **Investment analysis:**

This analysis should show that the cultivation of the unused land would not be profitable without the expected higher revenues due to certification.

### **Barrier analysis:**

This analysis shall answer the question, whether the unused land would be unused or remain unused in a business-as-usual scenario (e.g. in an area with a general trend for an expansion of agricultural areas).

### **Common practice analysis:**

Based on an analysis of patterns for agricultural expansion in the area, this analysis shall protect types of land, which are expected to be converted to agricultural land in the future (e.g. in case of palm oil, the prevention of a conversion of shrubland, grassland and bare land).

If the share of similar crop producers expanding to cultivate biomass on former unused land in a certain region is less than 20%, the expansion is not a commonly used practice. Alternatively, if less than three similar producers take former unused land in production, it is not a common used practice in the region. Therefore, the expansion of the biomass cultivation to former unused land is additional and the resulting biomass low iLUC risk.

The ideal application of the CDM Additionality concept for the demonstration of additionality from unused land needs to be tested and further developed in case studies and pilot certification projects.



## **Demonstration of additionality according to the Responsible Cultivation Area approach**

In addition, to the general logic of the CDM Additionality Tool, (Dehue, Meyer, van de Staaij 2010) presented a concept of Responsible Cultivation Areas (RCA), which aims to identify unused land which could provide additional biomass without harming existing provisioning services (such as for example food, wood, fibre). In that sense, the approach defines a couple of preconditions, which need to be fulfilled in order to claim a plot of land as unused. The first requirement sets conditions for the period, the claimed land was unused. Thus, the unused land did not deliver services in the last 5 years. Furthermore, at least one of the following conditions need to be met by unused land projects in order to be considered additional according to:

- The unused land project takes place in a region with no actual or foreseen additional agricultural expansion;
- General barriers exist for the establishment of an agricultural production on the unused land in a business as usual scenario (e.g. without any potential benefits from low iLUC risk certification);
- The unused land project is located in a region with a large potential of land with similar characteristics (e.g. a region in an EU country, where the agricultural land is shrinking).

The first requirement regarding the timeframe of 5 years seems to be suitable for the framework of additionality demonstration. For the other three listed requirements, it is crucial to complement them with further sustainability criteria like for example those mentioned in the RED 2. Otherwise, projects can be realised e.g. in regions with no additional agricultural development, which can comprise land with a high biodiversity value like natural forests, etc. too.

## **Specific additionality demonstration for abandoned agricultural land and degraded or contaminated land in dependence of the land use history (Malins 2019)**

Within the broad term of unused land, especially, abandoned agricultural land can be interesting for the provision of additional biomass for low iLUC certification. Therefore, (Malins 2019) propose specific criteria for land abandoned from previous agricultural use. Additional, for degraded or contaminated land, which is not cultivated for a certain period of time, (Malins 2019) suggest requirements to demonstrate that the use of such land is additional compared to a business-as-usual scenario. It must be noted that the operator planning to use the abandoned as well as the degraded or contaminated land needs to provide at least a documented use history of the land of the last 10 years.

For abandoned agricultural land the following preconditions should be applied (Malins 2019):

- There has been a reduction of cultivated land in the region in each of the previous five years;
- There is a general availability of large amounts of land with more favourable conditions (compared to the plot of land under investigation) in the region;
- The abandoned land in a specific region is the consequence of degradation and the cultivation of land in that degraded state is not common practice in the region.

Furthermore, if land was not cultivated within the last 30 years and is currently in a degraded or contaminated state, one of the following requirements need to be fulfilled (Malins 2019):



- Demonstration that the land is contaminated and that regulatory barriers exist, which prevent the supply of biomass from that land for non-energy or non-material use (e.g. food or feed);
- Demonstration that the cultivation of land in that state is not common practice in the region.

In both cases, the relevant principles of the CDM Tool can be applied (Malins 2019).

### **Additionality demonstration in dependence to regions of agricultural shrinkage and expansion**

In general, the UN CDM Tool for the demonstration of additionality provides again, very useful guidance for the demonstration of this additionality measure. However, in some cases it could be appropriate to decrease the effort for the additionality demonstration, since the application of the CDM Additionality Tool can be associated with big efforts. For this purpose, it can be useful to start a general differentiation of low iLUC projects working with unused land, based on their specific regional context. (Malins 2019) proposes a general distinction between regions with agricultural shrinkage and regions with agricultural expansion.

#### **Agricultural shrinkage regions**

In case of unused land, preferably abandoned land, in regions characterised by agricultural shrinkage, proxy additionality criteria can be applied. These can be a combination of a regulatory surplus analysis and the demonstration of availability of land in the region. The regulatory surplus analysis evaluates that in the region there are no regulatory requirements in place that require the agricultural use of land, exclusively (Malins 2019). Hence, the use of land in such a region would mean that the agricultural use of land is common practice in this region, because a legal requirement determines to use the land explicitly for agricultural purposes. Therefore, the use of the abandoned land would happen in that region in a business-as-usual scenario, anyhow. This proxy additionality criterion is only applicable in combination with the second criterion.

The demonstration of land availability verifies that relatively large areas in the region are available for agricultural production in favourable conditions. With this approach it would be unlikely that the use of the formerly abandoned land happens in a business-as-usual scenario (Malins 2019).

#### **Regions with agricultural expansion**

In regions with a trend for an expansion of agricultural lands, (Malins 2019) recommends that the demonstration of additionality should also provide proof for the existence of “enough” potentially available land in the region, which could supply the demand for a growing agricultural expansion. Thus, an operator needs to document that compared to annual rates of agricultural expansion, enough or a large supply of potentially available land in the region exist. Hence, for such areas conducting a full CDM Additionality Tool assessment instead of an application of proxy additionality criteria seems necessary.

However, to reduce effort for the demonstration of additionality, it might be appropriate to approve unused land projects at both, the regional and the certification scheme level. The benefit would be that a full analysis does not need to be conducted for every project. In this case, the certification scheme operator identifies general barriers but also potentials for low iLUC projects based on unused land in a specific region. In case, a potential for unused land projects has been identified for a region, in a second step, the auditor evaluates, if the proposed project is a good example, suitable for the investigated region. Besides, the effort reduction, another benefit of this approach is that the scheme operator can provide additional guidance for the auditor. Additionally, this approach is more sensitive to local considerations than a generalised guidance (Malins 2019).

## Establishing a reference scenario of previously unused land

### Site-specific investigation approach for establishing the reference scenario (Peters et al. 2016)

With the site-specific investigation approach, unused land can be identified, based on the definitions above. According to (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016), therefore a reference scenario is established to assess if a specific plot is eligible as unused land to produce low iLUC risk biomass. The identification of this plot is conducted in two assessment steps, as illustrated in Figure 23 and described in section 6.3.2 in the Annex.

Thus, the land needs to fulfil the requirements of the definition of unused land and one of the relevant land categories, mentioned above. This is complemented by a site specific regulatory as well as a land cover and utilization assessment. An iLUC mitigation plan includes the relevant information of the reference scenario. The mitigation plan is the basis for the certification of agricultural products generated at the identified unused land.

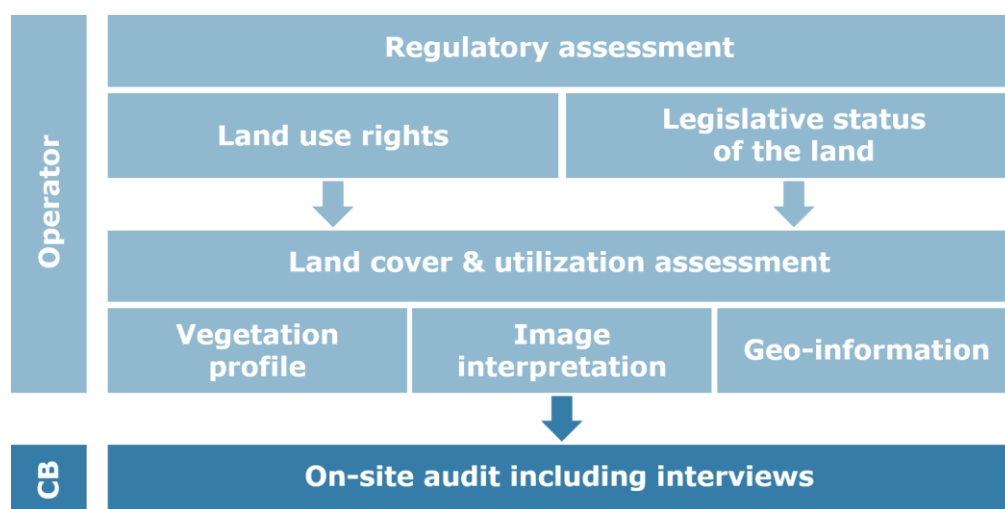


Figure 23 Site-specific investigation approach based on a regulatory and a land cover and utilization assessment combined with on-site auditing by the certification body (CB) to determine the reference scenario according to (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016).

Additionally, an independent on-site audit process needs to be conducted. The aim of this process is to check the results of the regulatory and land cover and utilization assessment approaches. Within the audit process, interviews with local stakeholders and the direct engagement with affected communities can be performed. Besides, the audit can prove the geographical coordinates of the claimed plot of land and the agricultural techniques applied in situ.



### Special case: Land used for a very limited extent

A specific case is land, which is used for a very limited extent. This can be for example an extensively used pastureland for livestock production. This land could be claimed as unused and therefore used for the cultivation of low iLUC risk biomass in case for example the following requirements are met. The user of the specific plot of land with very limited use holds no legal, traditional and/or customary land use rights for this certain land (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016). In this case, a period of three years preceding the reference date can be established.

Additionally, the (RSB 2015) proposes criteria, aiming at the identification of the expected yield on this land and therefore an assessment of its potential value and furthermore, the sustainment of existing uses, which should not be displaced. In that sense, (RSB 2015) proposes that the attainable yield of the area needs to be 25% or less of the yield, which can be expected from the cultivation of the same crop under normal conditions. To demonstrate compliance with this requirement, the economic value of the limited land use can be calculated with regional market prices of the target crop. Alternatively, the protein or energy content of the crop can be used for the comparison. Secondly, the limited provisioning services need to be preserved and not affected by the low iLUC risk biomass cultivation (RSB 2015).

### Calculating the amount of additional low iLUC risk biomass from unused land

The calculation of the amount of low iLUC risk biomass from the cultivation of unused land can be conducted with the actual yield in a certain year or by modelling expected yields to be derived in the future. By the application of the second approach, a marginal yield factor (MYF) of different scenarios can be applied. This factor takes into account a potentially reduced productivity of the plot claimed as unused land.

### Example I: Calculation with the actual amount of harvested feedstock (RSB 2015)

For the calculation of the amount of low iLUC risk biomass produced on unused land, the actual amount of harvested feedstock at this site needs to be known and documented. Thus, the yields need to be tracked and the operator has to provide evidence that these yields were realised. This can be done e.g. by records of the overall amounts of biomass sold or stored. Therefore, the feedstock amount produced on the land that was unused prior to a reference date needs to be determined. The Equation 10 can be used for the calculation of the amount of low iLUC risk biomass. An exception can be made, if limited provisioning services exist at the site. In that case, only the biomass produced in addition to the biomass obtained from existing provisioning services can be certified as low iLUC risk biomass. For the calculation of the amount of the biomass obtained from existing provisioning services, the average harvested biomass amount of the previous three years before the reference date can be considered.

### EQUATION 10:

$$V_{\text{lowiLUC}} = Y_{t=x} \times A$$

$V_{\text{lowiLUC}}$ : Volume of low iLUC risk biomass in year x (t or m<sup>3</sup>);

$Y_{t=x}$ : Actual yield in year x (t ha<sup>-1</sup> or m<sup>3</sup> ha<sup>-1</sup>);

A: System boundary area (ha), i.e. surface land that was previously unused.



An example illustrates this approach, following the Equation 10. If the actual yields of a previously unused land plot are  $4.2 \text{ t ha}^{-1}$  and the area of the claimed unused land is 100 ha, the amount of 420 t harvested from this area can be certified as low iLUC risk biomass.

Potential advantages and disadvantages of this approach can be summarised as listed in Table 6.

*Table 6 Advantages and disadvantages of the Example I: Calculation with the actual amount of harvested feedstock on the identified unused land.*

Advantages:	Disadvantages:
Low calculation effort for the operator and the audit process	Regards only ex-post harvested amounts of feedstock rather than future projections
Usually, the actual yields and the area of the former unused land plot of a farm are known	The yield of the previously unused land plot can only be calculated after the unused land is converted to agricultural land
Transparent and comprehensible calculation methodology	It is not possible to estimate the amount of yields of the plot in the future before the unused land changed to agricultural land

#### **Example II: Calculation with a projected yield and a marginal yield factor for regional low iLUC projects (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)**

In comparison to the approach above, a projected yield of the future of the unused plot can be modelled. To increase accuracy and to minimize uncertainties due to the projected yield, scenarios with different levels of productivity of the plot can be established. Thus, besides the identification of unused land for low iLUC risk biomass production, the productivity of this area can be assessed. This approach assumes, that in the most cases for unused land, the productivity is lower than for the average of land. Therefore, a marginal yield factor (MYF) can be applied to consider this. The MYF expresses the productivity as the share of the average yield (%) (Brinkman, van der Hilst, Faaij, Wicke 2018; Brinkman, Wicke, Faaij 2017). The potential amount of low iLUC risk biomass of a specific plot of unused land can be calculated with the Equation 11.

The marginal yield factor can be applied to adjust the yield due to the lower productivity expected on unused land. However, in some cases the yield of unused land actually is not lower than on agricultural land in use. It depends on soil and climate conditions. Especially, abandoned agricultural land as mentioned above can be similar productive as used agricultural land. Examples are abandoned agricultural land in Eastern Europe and the Imperata grassland in Indonesia. The latter land type is often considered as degraded land due to the grass alang-alang, which dominates the land and is hard to remove. However, the soil fertility and land productivity is similar to land elsewhere. The MYF can be determined specific for each case study region and crop from literature. Similar to the methodology proposed by (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015), different MYFs can be applied in the scenarios low, medium and high due to the uncertainties in land productivity. For example, (Brinkman, van der Hilst, Faaij, Wicke 2018; Brinkman, Wicke, Faaij 2017) assume for the three different scenarios a marginal yield factor of low: 50%; medium: 75%; and high: 99%.



## EQUATION 11:

$$\text{Pot}_{\text{low iLUC, UL}} = A_{\text{UL}} \times Y_{\text{bio-based product feedstock}} \times \text{MYF}$$

Pot <sub>low iLUC, UL</sub> :	Low iLUC risk biomass production potential on unused land (t a <sup>-1</sup> );
A <sub>UL</sub> :	Area of unused land for the production of bio-based products feedstock (ha);
Y <sub>bio-based product feedstock</sub> :	Projected bio-based product feedstock yield (t ha <sup>-1</sup> );
MYF:	Marginal yield factor (%).

Potential advantages and disadvantages of this approach might be summarised as follows in Table 7:

*Table 7 Advantages and disadvantages of the Example II: Calculation with a projected yield and a marginal yield factor for the identified unused land.*

Advantages:	Disadvantages:
Marginal yield factor (MYF) takes into account potentially lower yields on unused land plots	Uses only rough estimations for the MYF
Takes different levels of low, medium and high potential yields of the plot into account	High uncertainties of the MYF due to differences in local climatic and soil conditions
Considers projected yields of the future rather than actual yields of an unused land plot	High uncertainties to estimate projected yields of the future at the unused land plot
Option to use of publicly available input data	Approach is developed and approved only for regional assessments
	Much effort to model projected yields and to consider different share of MYFs
	Modelled input data scale is not necessarily precise enough as farm specific data for unused land plot productivity





#### POTENTIAL NEGATIVE TRADE-OFFS OF THIS ADDITIONALITY MEASURE

Risks for potential negative trade-offs associated with the production of biomass on unused lands can be related to losses of biodiversity (in case there is a conversion of abandoned, degraded or marginal lands as well as extensive pastures, buffer zones, ecological corridors and wildlife habitats). Often, these unused land types have been already set-aside for a long period of time or have been traditionally excluded from agriculture so that rare species and rare habitats are frequently found. Large-scale cultivation of crops is a threat to many areas that have already been fragmented and degraded, are rich in biodiversity and provide habitat for many endangered and endemic species (Beringer, Lucht, Schaphoff 2011; Cherubin, Karlen, Cerri, Franco, Tormena, Davies, Cerri 2016; Delzeit, Zabel, Meyer, Václavík 2017; Gerssen-Gondelach, Wicke, Faaij 2017; Gerwin, Repmann, Galatsidas, Vlachaki, Gounaris, Baumgarten, Volkmann, Keramitzis, Kiourtsis, Freese 2018; Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Meyfroidt, Schierhorn, Prishchepov, Muller, Kuemmerle 2016; Miyake, Smith, Peterson, McAlpine, Renouf, Waters 2015; Pedroli, Elbersen, Frederiksen, Grandin, Heikkilä, Krogh, Izakovičová, Johansen, Meiresonne, Spijker 2013; Verdade, Piña, Rosalino 2015). Furthermore, especially, tropical savannahs are used extensively by smallholders and pastoralists, who can be bereaved by the cultivation of unused and marginal land, because they usually do not produce profit but rather products for subsistence (marginal land) and because they are mobile, and thus rather autonomous and not easily to be captured as state subjects (unused land). Shifting cultivation, can easily be classified as abandoned or unused land (Exner, Bartels, Windhaber, Fritz, See, Politti, Hochleithner 2015; Kitchell 2014; Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Paz, Jara, Wald 2019). Conversion of abandoned, degraded or marginal land to agricultural cropland can threaten the quality of water resources, because crops can require greater fertilization, which can emit higher levels of nitrogen into surface waters causing eutrophication (Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Miyake, Smith, Peterson, McAlpine, Renouf, Waters 2015; Qiu, Huang, Keyzer, van Veen, Rozelle, Fisher, Ermolieva 2011). Thus, a robust approach for the certification of low iLUC biomass from this additionality measure should include appropriate measures to reflect and appropriately address these risks. Further potential negative trade-offs are listed in Table 16 (section 6.2.2 in the Annex).

##### 2.2.4.3 *Increase in livestock production efficiencies*

Another measure to produce additional biomass as a consequence of increasing efficiencies in agricultural systems are improvements in livestock production efficiencies which can reduce the demand for land. This measure, which seems highly controversial follows the general concept that increasing the animal density per area or the animal product yields, might increase availability of unused land. Also, efficiency increases in the production of fodder can result in the provision of additional biomass. So, in case for example an increase in individuals of cattle (heads) at the same meadow and pasture land or an increasing productivity of meat or milk per animal and year could result in less land needed to produce the same amount of animal products. Thus, the land could become available for feedstock production for bio-based products (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015).



Generally, different improvement measures can be applied to increase the livestock production efficiency. An increase in the grazing density per animal concentrates more individuals at a defined area size. Whereas, an increase in pasture productivity can be achieved through the improved use of fertilisers or the use of grasses, which have a high production potential. Improvements in the feeding regime of the animals, for example in regard to the protein content of the fodder, can increase the livestock product yield. Furthermore, keeping the animals in stables or without using land can reduce the demand for land (even though that measure might be associated with several ethical issues). Other measures can be the shortening of grazing periods and changes to less fibrous livestock diets (Brinkman, van der Hilst, Faaij, Wicke 2018; Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012). The increase in livestock production efficiencies can be achieved by an increase in productivity per hectare similar to the additionality practice increased agricultural crop yield, described in chapter 2.2.4.1.

However, this practice is only applicable by farms with further land use activities besides livestock production. Primarily, these comprise farms cultivating agricultural crops. If a farm conducts both, crop cultivation and livestock production, the application of improved livestock production efficiencies might result in less land demand for livestock production. The same farm can use this land for the production of low iLUC biomass. Otherwise, if a farm specialised only on livestock production without using land for crop production applying improvements in livestock production efficiencies, the reduction in land demanded for livestock production can not be used for biomass cultivation by the same farm. In the later, there is no biomass produced, which can be claimed as low iLUC risk.

In the context of low iLUC risk certification, an operator would need to demonstrate, that the improvements in livestock production can result in availability of agricultural land to produce additional biomass. This can be part of an iLUC risk mitigation plan, which the operator establish before the implementation of the efficiency improvements.

#### **APPROACHES FOR THE CERTIFICATION OF LOW iLUC RISK BIOMASS FROM IMPROVEMENTS IN LIVESTOCK PRODUCTION EFFICIENCIES**

The reduction in land demand, resulting from the implementation of improvements in livestock production efficiencies bases in principle on two main variables. This is on the one hand the density of animals per area and on the other hand the amount of livestock products per animal. By increasing one or both variables at a site, an operator can produce livestock products above a baseline. The baseline expresses the case without improvements. In the following section, the methodology for the calculation of the above-baseline scenarios for the example of cattle production is illustrated. Next to the cattle density, this comprises the production of milk and meat. Subsequently, the number of slaughtered or milk producing animals are calculated in a baseline and an above-baseline production scenario (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015). However, the methodology can be applied for other livestock production systems, like sheep (Brinkman, Wicke, Faaij 2017). Cattle and sheep are suitable for productivity improvements due to their land based husbandry system. In contrast, pigs and poultry mostly held landless inside a stable. However, land is needed for the production of feed crops for this animals (Gerssen-Gondelach, Wicke, Faaij 2015).



## Options to demonstrate additionality for the biomass production from improvements in livestock production efficiencies

### General steps to demonstrate additionality of biomass from improvements in livestock production efficiencies based on the UN CDM Additionality Tool

In order to verify that an operator can provide additional biomass compared to a business-as-usual scenario, an additionality demonstration needs to be conducted. Again, it is to discuss, if this verification can be based on the application of the CDM Tool (Clean Development Mechanism Executive Board 2012). In the case of increase in livestock production efficiencies, the additionality assessment can include the following steps:

#### Investment analysis

If the provision of additional agricultural land, which is not used anymore for livestock production due to the implementation of a specific improvement measure is less financially attractive compared to other projects implementing similar efficiency improvement measures in the region (business-as-usual scenario), the project can be additional.

#### Barrier analysis

Are other non-financial barriers exist for the increase in livestock production efficiencies in the region. This can be the case that the efficiency improvement measures would only be implemented with the support of grants from the state and these grants are not on place. Another issue a farmer can face is that no private capital from domestic or international markets is available. Thus, the project can be additional.

#### Common practice analysis

The project can demonstrate that the increase in livestock production efficiencies is additional, if the improvement measure is usually not applied by similar producers within the specific region, where the project is implemented. If the share of similar producers using the same improvement measure to increase livestock production efficiencies in the certain region is less than 20%, the improvement measure is not a commonly used practice. Alternatively, if less than three similar projects use the improvement measure to increase livestock production efficiencies, it is not a common used practice. Therefore, the improvement activity is additional and the resulting biomass low iLUC risk.

The CDM Tool can be an appropriate measure to assess if a project is additional. Therefore, the increase in livestock production efficiencies in a specific region, suitable for low iLUC risk certification needs to be additional compared to a business-as-usual scenario. In a business-as-usual scenario, improvements in livestock production efficiencies can be established, which increase the productivity of the livestock due to technical improvements or knowledge transfer to local stakeholders.

The ideal application of the CDM Additionality concept for the demonstration of additionality from unused land needs to be tested and further developed in case studies and pilot certification projects.



## Calculation of the additional biomass produced from increasing efficiencies in livestock production

### Model-derived yield reference for regional low iLUC projects (*Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015*)

In order to calculate the specific biomass to be certified as additional in the context of low iLUC risk certification, (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015) propose a three step approach, which follows the same rationale as the methodology under example III presented in the chapter of increasing agricultural yields (chapter 2.2.4.1).

#### Determination of the reference scenario:

In a first step, two scenarios will be developed for the respective region. The first, reference scenario focusses on the development of the biomass production (and yield development) of this region. The second scenario is used to estimate the potential demand for biomass resulting from the introduction of a regional biomass target (e.g. a quota or mandate). The difference between both scenarios is the gap between the theoretical supply and the demand side. Thus, this concept gives an idea regarding the potential iLUC risk of a region, associated with a specific biomass policy.

According to the methodology for the additionality practice of the increased agricultural crop yield (chapter 2.2.4.1), the baseline scenario can be determined by considering the average total annual beef or milk production and the annual amount of beef or milk produced per animal of similar producers within a certain region. Data of similar producers in the specific region can be applied for the determination. With the average total annual beef or milk production and the annual amount of beef or milk produced per animal, the total number of slaughtered cows or the number of dairy cows can be calculated for the baseline scenario. In the first step, the total number of animals for meat production or the number of dairy cows producing milk in the above-baseline scenario is calculated with data provided by the operator. This can be done in accordance to the Equation 12. However, the above-baseline scenario (ABS) input variables need to be changed by the implementation of the baseline scenario (BS) input variables.

#### EQUATION 12:

$$C_{\text{producing,ABS}} = \frac{P}{Y_{\text{ABS}}}$$

- $C_{\text{producing,ABS}}$ : Total number of cows (heads), which is slaughtered for meat production or the number of cows producing milk in the above-baseline production scenario (ABS);
- $P$ : Total projected annual meat or milk production in the region (t meat a<sup>-1</sup> or l milk a<sup>-1</sup>);
- $Y_{\text{ABS}}$ : Amount of meat or milk produced per animal per year in the above-baseline scenario (t meat per animal a<sup>-1</sup> or l milk per animal a<sup>-1</sup>).



Because not all non-dairy animals are slaughtered each year for meat production, the total number of land related animals is higher than the amount of animals calculated in Equation 12. Thus, with the data compiled by the operator the total number of cattle in the above-baseline scenario is calculated. To calculate the total number of cattle (heads) required for the projected production in the baseline scenario (BS) according to Equation 13, further variables need to be known. These comprise the number of dairy cows (heads) producing milk ( $C_{\text{milk,BS}}$ ), the total number of meat cows (heads) slaughtered ( $C_{\text{meat,BS}}$ ) and the ratio of slaughtered animals for meat production to the total amount of non-dairy animals ( $R_{\text{slaughtered total non-dairy}}$ ). For the latter variable, information about the total number of non-dairy cows (heads) ( $C_{\text{total non-dairy,BS}}$ ) are needed. Thus, to determine the baseline scenario, an operator needs to consider for each of these variables the average value of similar livestock producers within a certain region, where the project is implemented.

### EQUATION 13:

$$C_{\text{total,ABS}} = C_{\text{milk,ABS}} + C_{\text{total non-dairy,ABS}} = C_{\text{milk,ABS}} + \frac{C_{\text{meat,ABS}}}{R_{\text{slaughtered total non-dairy}}}$$

$C_{\text{total,ABS}}$ :	Total number of cattle (heads) required for the projected production in above-baseline scenario (ABS);
$C_{\text{milk,ABS}}$ :	Number of dairy cows (heads) producing milk in scenario S;
$C_{\text{total non-dairy,ABS}}$ :	Total number of non-dairy cows (heads) in scenario S;
$C_{\text{meat,ABS}}$ :	Total number of meat cows (heads) slaughtered in scenario S;
$R_{\text{slaughtered total non-dairy}}$ :	Ratio of slaughtered animals for meat production to the total amount of non-dairy animals.

With the results of the Equation 13, the potential land demand reduction (ha) by application of an above-baseline scenario is calculated. In Equation 14, the total meadow and pasture land ( $A_{\text{baseline}}$ ) and the cattle density ( $D_{\text{baseline}}$ ) is determined for the baseline scenario. With the results of Equation 14, in Equation 9 the low iLUC risk biomass potential is calculated

### Assessment of low iLUC risk potential:

Secondly, the potential for the supply of low iLUC risk biomass from this specific measure is investigated. Thereby, the potential impact from the implementation of improvements in livestock production efficiencies (low, medium and high scenario because of potential variability and uncertainty in data sets) is being calculated. To calculate the potential agricultural land demand reduction – LDR (ha) the Equation 14 is used. With the results of Equation 14, in Equation 9 the low iLUC risk biomass potential is calculated.



#### EQUATION 14:

$$\text{LDR}_{\text{ABS,livestock}} = A_{\text{baseline}} - A_{\text{ABS}} = \frac{C_{\text{total,baseline}}}{D_{\text{baseline}}} - \frac{C_{\text{total,ABS}}}{D_{\text{ABS}}}$$

$\text{LDR}_{\text{ABS,livestock}}$ :	Land demand reduction (ha) from increased cattle density / productivity in the above-baseline scenario;
$A_{\text{baseline}}$ :	Total meadow and pasture land (ha) needed for the production of the projected amount of meat and milk in the baseline scenario;
$A_{\text{ABS}}$ :	Total meadow and pasture land (ha) needed for the production of the same amount of meat and milk like in the baseline scenario by application of an above-baseline scenario for improved livestock production efficiencies;
$C_{\text{total,baseline}}$ :	Total number of cattle (heads) needed for the projected production of meat and milk without an improved productivity (similar to Equation 13);
$C_{\text{total,ABS}}$ :	Total number of cattle (heads) required for the projected production in above-baseline scenario (ABS) (Equation 13);
$D_{\text{baseline}}$ :	Cattle density (heads per ha of meadow and pasture land) for baseline scenario;
$D_{\text{ABS}}$ :	Cattle density (heads per ha of meadow and pasture land) for above-baseline scenario (ABS).

However, if no regional data exists to determine the baseline scenario, countrywide data can be used. According to (Brinkman, van der Hilst, Faaij, Wicke 2018) this can be for example data provided by national statistics offices.

#### Comparison of the reference scenario and the low iLUC risk potential assessment:

Thirdly, the general potential for biomass production, including the effects of additionality measures from step two is being compared to the difference between the target and baseline scenario of step 1. This general comparison allows to discuss the general potential of a region to produce low iLUC risk biomass. This potential is described in Equation 9 in chapter 2.2.4.1 dealing with yield increase of this document.



## POTENTIAL NEGATIVE TRADE-OFFS

A rapid intensification in the dairy sector can have considerable impacts on animals' physical and mental well-being, particularly in high-income countries, where measures to improve productivity deliver only moderate gains, often at the expense of animal welfare. For example, in intensive production systems, cows often lack freedom to perform natural behaviours of grazing, reproducing, and socializing in pasture but instead live in housing regimes that constrain movement and that require animals to stand on concrete floors for extended periods of time. Particularly breeding cows for higher productivity exacerbates physical and emotional stress, decreasing their welfare. Management strategies that aim to optimize milk productivity can negatively impact animals' life cycles. For example, in intensive operations, cows are artificially inseminated again shortly after they have given birth to a calf and then slaughtered after only a few pregnancy-lactation periods. Additionally, the lower levels of interaction between cows and stockmen that are common on intensive farms can increase the risk that animal welfare issues go unnoticed (Burton, Peoples, Cooper 2012; Haskell, Rennie, Bowell V.A., Bell, Lawrence 2006; Keyserlingk, Rushen, Passillé, Weary 2009; Keyserlingk, Weary 2017; LeBlanc, Lissemore, Kelton, Duffield, Leslie 2006; Oltenacu, Broom 2010).

Intensification of livestock production can pollute river systems, shallow aquifers and decrease the quality of freshwater, cause eutrophication and acidification by emissions of  $\text{NH}_3$ ,  $\text{NO}_x$  and by leaching or run-off of Nitrate ( $\text{NO}_3^-$ ) and  $\text{PO}_4^{3-}$  mainly from the use of fertilizers (organic and inorganic). (Battini, Agostini, Tabaglio, Amaducci 2016; Chobtang, Ledgard, McLaren, Donaghy 2017; FAO 2006; McAuliffe, Takahashi, Mogensen, Hermansen, Sage, Chapman, Lee 2017; Scarsbrook, Melland 2015; Vries, Boer 2010; Zhang, Bai, Luo, Ledgard, Wu, Ma 2017).

Intensification of grazing, due to an intensified livestock production can affect soil qualities and foster aspects such as soil erosion. Thus, an appropriate certification approach needs to include criteria and indicators to counterbalance these potential trade-offs.

Furthermore, intensification in livestock production can cause loss of smallholder farm structures due to price competition, the replacement of traditional skills and ways of life with a corporate mind set. Additional, trading regimes can undermine small-scale production. The maximization of livestock revenue incurs high supplemental feed costs, marginalizes net household income, and promotes larger flock sizes. Furthermore, cost savings that are achieved in more intensive operations can in part be attributed to lower human labour input, which generally results in losses of employment for family and non-family dairy workers (Briske, Zhao, Han, Xiu, Kemp, Willms, Havstad, Le Kang, Wang, Wu, Han, Bai 2015; Clay, Garnett, Lorimer 2019; Davidson 2002). Further potential negative trade-offs are listed in Table 17 (section 0 in the Annex).





#### 2.2.4.4 *Improved by-products integration*

The third additionality measure to be discussed in this report covers aspects related to efficiency increases due to improvements in the by-products integration in the value chain of a bio-based product. The general concept behind this measure is to increase the use of by-products, generated within the supply chain of a bio-based product in order to influence and improve the ratio of biomass use to product output. By-products can arise at different parts of the supply chain. By-products from the crop or feedstock production can include examples such as wheat straw, corn stover or sugarcane leaves. Furthermore, by-products can occur during biomass conversion and production of the bio-based products. Examples of by-products generated during these steps are dried distiller grains with solubles, glycerine or oilseed meal. The increased use of the by-products can reduce the demand for land, because the by-products can be used for e.g. the production of animal feed. Thus, less land is needed to produce the same amount of feed (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015). Besides the increased use of crop residues, multifunctional land use practices such as agroforestry are potential improvements at the feedstock production stage of the supply chain. These systems can potentially generate different production outputs like food, animal feed and feedstock for bio-based products in a combined manner. At the biomass processing stage, the integration of different products can for example be realized with biorefinery systems or the cascading use of biomass, (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012).

As for the other additionality measures under discussion, in the context of low iLUC certification, an operator would need to demonstrate, that the improvements in the by-products integration mitigate the risk of iLUC. This can be part of an iLUC risk mitigation plan, which the operator establishes before the implementation of this additionality practice.

### **APPROACHES FOR THE CERTIFICATION OF LOW iLUC RISK BIOMASS FROM THE IMPROVED BY-PRODUCTS INTEGRATION**

The main objective for the demonstration of additionality with this measure is to show the reduction in land demand (ha) through the improved integration of by-products in the supply chain of a bio-based product. Thus, an assessment of the low iLUC risk potential of by-products need to be conducted.

In the following paragraphs, two approaches for the calculation of additional biomass from improved by-product integration measures will be summarised.

### **Options to demonstrate additional biomass from the improved by-products integration**

#### **General steps to demonstrate additionality of biomass from by-products integration based on the UN CDM Additionality Tool**

In order to verify, that a project is additional compared to a business-as-usual scenario, an additionality demonstration needs to be conducted. Again, this can be potentially based on the application of the UN CDM Additionality Tool (Clean Development Mechanism Executive Board 2012). In the case of by-products integration, the additionality assessment can include the following steps:

#### **Investment analysis**

If the integration of a by-product in the production chain is less financially attractive compared to the use of similar feedstock in a region and is only feasible due to the low iLUC certification, the project can be additional.



### Barrier analysis

Are other non-financial barriers existent for the by-products integration in the region, like difficulties in accessing the by-products due to lack in infrastructure or steep slopes, the project can be additional.

### Common practice analysis

The project operator shall demonstrate that the integration of by-products is not usual and not a common practice within the specific region. If the share of similar producers integrating the same by-products into their production process in a certain region is less than 20%, the integration is not a commonly used practice. Alternatively, if less than three similar producer integrate the same by-products in the production process, it is not a common used practice in the region. Therefore, the integration of these by-products is additional and the resulting biomass low iLUC risk.

The CDM Tool can be an appropriate instrument to assess if a project is additional in the context of low iLUC risk certification.

The ideal application of the CDM Additionality concept for the demonstration of additionality from unused land needs to be tested and further developed in case studies and pilot certification projects.

### Calculating the amount of additional low iLUC risk biomass from improved by-product integration

#### **Example 1: Model-based approach to determine improvements in by-product integration for regional low iLUC projects (Brinkman et al. 2015)**

Again, following the basic rationale of the examples given on for the additionality measures of increased yields and increased livestock production efficiencies the model based approach for an assessment of the additionality potential from (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015) might be applied.

#### Determination of the reference scenario:

Firstly, two scenarios will be developed for the respective region. The first, reference scenario focusses on the development of the biomass production (and yield development) of this region. The second scenario is used to estimate the potential demand for biomass resulting from the introduction of a regional biomass target (e.g. a quota or mandate). The difference between both scenarios is the gap between the theoretical supply and the demand side. Thus, this concept gives an idea regarding the potential iLUC risk of a region, associated with a specific biomass policy.

#### Assessment of low iLUC risk potential:

Secondly, the potential for the supply of low iLUC risk biomass from this specific measure is investigated. Thereby, the potential impact from the implementation of improvements in by-product integration (low, medium and high scenario because of potential variability and uncertainty in data sets) is being calculated. To calculate the potential agricultural land demand reduction – LDR (ha) the Equation 18 is used. With the results of Equation 18, in Equation 9 the low iLUC risk biomass potential is calculated.

The assessment of improved by-products integration can be realised in two main steps:

1. Inventory analysis of the by-products;
2. Assessment of the potential by-products use and replacement rate of other products.



### *Inventory analysis of the by-products*

In the first step, an inventory analysis of the by-products arise within the supply chain of the bio-based product is realised. This includes the currently produced amount and the actual use of the by-products.

As described above, by-products can be generated at the crop cultivation and at the biomass conversion process. Therefore, for both by-products pathways the methodology for the inventory analysis is described as follows.

#### *By-products from crop production (crop residues)*

The amount of crop residues usable for low iLUC risk biomass production depends on the share of the residues, which potentially can be removed from the sites without causing negative impacts, e.g. decrease in soil fertility. Therefore, an analysis due to this share needs to be conducted specific for each crop. Two variables need to be considered to realise this analysis. The one is the residue-to-product ratio (RPR), which describes the relationship between crop and residue yield. It is defined as the ratio of above ground crop production to the total grain production (Daioglou, Stehfest, Wicke, Faaij, van Vuuren 2016; Lal 2005). It varies with the crop type and the crop yield (Scarlat, Martinov, Dallemand 2010).

Whereas, the sustainable removal fraction (SRF) expresses the share of the residue, which can be removed from the field without causing negative impacts on the site, i.e. in regard to soil fertility (Kluts, Wicke, Leemans, Faaij 2017). Parameters for the RPR and SRF for different agricultural crop residues in Europe are provided by (Scarlat, Martinov, Dallemand 2010). Whereas, (Lal 2005) evaluates values for the RPR for residues of different crops in the US.

Both variables, the RPR and SRF are crop residue and region specific. Thus, an operator needs to consider the RPR and the SRF specifically for the region, where the residue integration project is located.

The calculation of the amount of crop residues available in a specific region can be calculated with the Equation 15. The equation combines the assessment of the theoretical and the sustainable potential as described in the section of the alternative approach for residue assessment, below.

#### **EQUATION 15:**

$$P_{\text{crop-residues}} = Y \times \text{RPR} \times \text{SRF} \times A_{\text{bio-based product crop}}$$

- $P_{\text{crop-residue}}$ : Amount of crop residues for the bio-based product crop (t);
- $Y$ : Crop yields ( $\text{t ha}^{-1}$ );
- $\text{RPR}$ : Residue-to-product ratio ( $\text{t residue t product}^{-1}$ );
- $\text{SRF}$ : Sustainable removal fraction (%);
- $A$ : Area under crop cultivation for bio-based product production (ha).



### *By-products from crop processing and conversion*

The assessment of the amount of by-products from the biomass processing needs to regard besides the production volume of the bio-based product, two other variables. Firstly, it is the conversion efficiency of the feedstock to the bio-based product (CE). This means how much of the bio-based product can be produced from the feedstock. This is a simple input-output analysis. Therefore, this variable is usually known by a biomass conversion facility. Secondly, the by-product factor (CPF) needs to be known. This is the amount of by-products, which can be produced per feedstock. This variable can be calculated similar to the feedstock to bio-based product conversion efficiency, because it is an input-output analysis, too. However, it regards the amount of by-products that can be produced from a certain amount of feedstock.

With the Equation 16, the amount of by-products from the biomass conversion can be calculated.

#### **EQUATION 16:**

$$P_{\text{by-product}} = \frac{P_{\text{bio-based product}}}{\text{CE}} \times \text{CPF}$$

$P_{\text{by-product}}$ :	Amount of by-products generated from the production of the bio-based product (t)
$P_{\text{bio-based product}}$ :	Production volume of the bio-based product (t)
CE:	Feedstock to bio-based product conversion efficiency (t bio-based product per t feedstock)
BPF:	By-product factor (t by-product per t feedstock)

### *Assessment of the potential by-products use and replacement rate of other products*

In the second step, an assessment of the potential by-products use and replacement rate of other products by the by-products is conducted. The assessment of the potential use of a by-product identifies the potential use pathways of the by-product. The potential use of residues can be the production of advanced biofuels (see Annex IX of RED 2, (European Commission 2018) or electricity, for example. In case, a crop residue is suitable for the production of advanced biofuels, an estimation of the low iLUC risk potential of bio-based products made from crop residues is conducted. This is done by converting the amount of crop residues to the bio-based product by applying the residue-to-product conversion efficiency as applied in Equation 15.

Following the identification and assessment of the potential use of by-products, an analysis of the potential replacement of other products needs to be conducted. For example in case of by-products used for livestock feed, the potential replacement of other feed types needs to be examined. Therefore, an analysis of the nutritional and energetic value of the by-product and the replacement of other feed types needs to be conducted per by-product and livestock type. This can be expressed with a substitution ratio (Equation 17). The substitution ratio describes the amount of feed crops substituted by a certain amount of the by-product.

Because the reduction in land demand resulting from the application of the improved by-products integration can be in the same region or outside of it, the geographical origin of the feed crop that is substituted needs to be considered.



The aim of this section is to calculate the amount of agricultural crops used for feed purposes, which can be substituted by by-products from the production of bio-based products. Thus, the amount of by-products and the substitution ratio, specifically for the feed crop substituted by the by-product, needs to be known by the operator. The amount of substituted feed crops can be calculated with the Equation 17.

#### EQUATION 17:

$$FS = P_{\text{by-products}} \times SR$$

- FS: Amount of feed crops saved by substituting them with by-products from bio-based product production (t);
- $P_{\text{by-products}}$ : Amount of by-products generated by the production of bio-based products (t) (similar to  $P_{\text{crop-residue}}$  from Equation 16);
- SR: Substitution ratio (t feed crop substituted per t by-product)

#### *Land demand reduction (ha) from improved by-products integration*

With the results of the equation above, the potential agricultural land demand reduction (LDR) (ha) is calculated. It takes into account the amount of substituted feed crops by by-products from the production of bio-based products and is calculated in Equation 18. With the results of Equation 18, in Equation 9 (chapter 2.2.4.1) the low iLUC risk biomass production potential (t a<sup>-1</sup>) of the by-products integration practice is calculated.

#### EQUATION 18:

$$LDR_{\text{chain integration}} = \frac{FS}{Y_{\text{feed crops}}}$$

- $LDR_{\text{chain integration}}$ : Land demand reduction (ha) by using by-products from the production of bio-based products,
- FS: Amount of feed crops saved by substituting them with by-products from bio-based product production (t);
- $Y_{\text{feed crops}}$ : Yield of feed crops displaced by by-products (depends on the area where the replaced feed would have come from)

#### Comparison of the reference scenario and the low iLUC risk potential assessment:

Thirdly, the general potential for biomass production, including the effects of additional measures from step two is being compared to the difference between the target and baseline scenario of step 1. This general comparison allows to discuss the general potential of a region to produce low iLUC risk biomass. This potential is described in Equation 9 in the chapter 2.2.4.1 of this document.

Potential advantages and disadvantages of this approach might be summarised as listed in Table 8:



*Table 8 Advantages and disadvantages of the Example I: Model-based approach to determine improvements in by-product integration*

Advantages	Disadvantages
Combination of the analysis of the theoretical and sustainable potential in one term	Much effort to calculate the amount of by-products eligible as low iLUC risk biomass
Comprehensive methodology to calculate the low iLUC risk biomass production potential	Many input variables needs to be known by the operator
Universally applicable calculation methodology	The methodology is originally conceptualized for regional low iLUC risk assessment and not for certification
Methodology can be applied for the assessment of residues and by-products of the biomass conversion at different stages of the supply chain	Information about the yield of substituted feed crops and projected bio-based products feedstock yield probably outside of the scope of the operator

**Example II: Alternative approaches for residue integration (RSB 2015; Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012)**

In addition, two the model-based assessment approach described above, two alternative calculation approaches for the quantification of additional biomass from improved by-product integration. One of the approaches is part of the Low iLUC Risk Biomass Criteria & Indicators of the RSB (RSB 2015). The other is developed within the Low Indirect Impact Biofuel (LIIB) Methodology (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012). In a few aspects, both approaches differ from each other. However, the approach of the RSB bases on the LIIB Methodology.

Chapter 2.2.4.6 is dealing with the assessment of waste as a resource for low iLUC risk biomass production. In the context of additionality certification, waste as a feedstock can be comparable to residues as a feedstock. In both cases, unused or inefficiently used materials will be made available as feedstock in a specific region, increasing the overall efficiency of a supply chain. Thus, the methodology described in the chapter about waste use, can be applied for the assessment of potential additionalities from residues, too. According to the methodology, a feedstock-region assessment, resulting in a positive list, comprising residues suitable as low iLUC risk feedstock are identified for the region under assessment. For the quantification of the amount of residues eligible for low iLUC risk biomass, the calculation methodology of the approaches of (RSB 2015) and (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012) can be applied.



Following this approach, based on the information about the amount of the feedstock in the respective region, potentials of residues are estimated. For the calculation of the different potentials, based on (Scarlat, Martinov, Dallemand 2010) a calculation methodology is proposed by (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013). Firstly, the available theoretical potential of a material is identified (Equation 19). This is the available quantity of the material harvested or collected in theory. Based on this, the sustainable potential is estimated (Equation 20). This is the harvestable or collectable quantity, in a sustainable way. This means, for example, to take into account the protection of soil quality. Finally, the low iLUC potential is estimated. It focuses at the current non-biomaterial and non-bioenergy uses of the residues. The difference between the sustainable potential and the existing non-biomaterial and non-bioenergy uses is the low iLUC potential (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013). Therefore, the existing non-biomaterial and non-bioenergy uses in a region needs to be known. Residues can be potentially used in livestock farming, e.g. livestock bedding among others (Scarlat, Martinov, Dallemand 2010).

#### Theoretical potential, **EQUATION 19:**

$$P_{\text{crop-residue}} = RPR \times P_{\text{bio-based product}}$$

- $P_{\text{crop-residue}}$ : Amount of total crop residue production ( $\text{t a}^{-1}$ )
- $RPR$ : Residue to product ratio ( $\text{t residue t}^{-1} \text{ bio-based product}$ )
- $P_{\text{product}}$ : Production volume of the bio-based product ( $\text{t a}^{-1}$ )

#### Sustainable potential, **EQUATION 20:**

$$SA_{\text{crop-residue}} = P_{\text{crop-residue}} \times SRF$$

- $SA_{\text{crop-residue}}$ : Sustainable residue availability ( $\text{t a}^{-1}$ )
- $P_{\text{crop-residue}}$ : Amount of total crop residue production ( $\text{t a}^{-1}$ )
- $SRF$ : Sustainable removal fraction (%)

#### Low iLUC risk potential

The low iLUC risk potential can be calculated by deducting the existing alternative uses resp. non-biomaterial and non-bioenergy uses of the residue from the sustainable potential of the residue, calculated by Equation 20 (Scarlat, Martinov, Dallemand 2010). Potential advantages and disadvantages of this approach might be summarised as follows in Table 9:





*Table 9 Advantages and disadvantages of the Example II: Alternative approaches to determine improvements in residue integration*

Advantages	Disadvantages
Straightforward determination of the feedstock-region combination and the positive list	The step to calculate low iLUC risk potential differs for each crop residue
Simple calculation methodology	No universally applicable calculation methodology for the determination of the low iLUC risk potential
Less input variables need to be known by the operator and the auditor	Input variables like the residue-to-product ratio (RPR) and the sustainable removal factor (SRF) can be found in literature for specific cases and specific region, however they can differ from real cases
Approach originally developed for low iLUC risk certification	The step to calculate low iLUC risk potential differs for each crop residue

#### POTENTIAL NEGATIVE TRADE-OFFS OF THIS ADDITIONALITY MEASURE

Removal and use of residues can decrease the amount of material used by smallholder households for cooking and energy generation, especially in developing regions (Vitali, Parmigiani, Vaccari, Collivignarelli 2013). Where residues are an integral part of livestock feeding, farmers need to buy external feed. Thus, the removal of crop residues can cause limited availability of domestically produced fodder on a farm, especially for smallholders (Beuchelt, Camacho Villa, Göhring, Hernández Rodríguez, Hellin, Sonder, Erenstein 2015; Hellin, Erenstein, Beuchelt, Camacho, Flores 2013; Klapwijk, van Wijk, Rosenstock, van Asten, Thornton, Giller 2014; Sapkota, Aryal, Khatri-Chhetri, Shirsath, Arumugam, Stirling 2018). Furthermore, residue removal can cause a decreasing in soil organic carbon over time, which can lead to a loss in carbon stocks and soil fertility (Hansen, Budde, Prochnow 2016; Khatiwada, Leduc, Silveira, McCallum 2016; Meul, Ginneberge, van Middelbaar, Boer, Fremaut, Haesaert 2012; Monteleone, Garofalo, Cammerino, Libutti 2015; Sampaio, Cardoso, Souza, Watanabe, Carvalho, Bonomi, Junqueira 2019; Zijlstra, Beltranena 2013). Further potential negative trade-offs can be found in Table 18 (section 0 in the Annex).

#### 2.2.4.5 Reduction in biomass losses

Another measure to increase the efficiency of a products value chain and thus, to provide additional, low iLUC risk biomass are reductions in biomass losses throughout the value chain. Reductions of biomass losses can be realised in transport and storage, as well as in the biomass conversion and processing. By the reduction of biomass losses in the production chain and the improved biomass conversion, more biomass can be used for the production of bio-based products. Therefore, less land is needed to produce the same amount of bio-based products (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012). The efficiency improvements can be applied in agriculture, forestry and the bio-based products manufacturing process. Applied in agriculture and forestry it increases the productivity per hectare. The increases in conversion and processing can be achieved for example with the establishment of biorefinery concepts (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012).



Particularly, food losses can play a considerable role in these steps of the production chain. For clarification, it must be strictly distinguished between food losses and food waste. Food losses deal with losses of food at the pre-consumer stages of the supply chain. This refers to the decrease in edible food within the food processing supply chain. Contrarily, food waste occurs at the end of the food supply chain, characterised by post-consumption losses (FAO 2011b). The pre-consumer food losses occur mostly in developing and emerging economies. A big issue are post-harvest losses, e.g. grain losses due to physical losses, like spillage, pests as well as loss in quality (Parfitt, Barthel, Macnaughton 2010). Because the certification of products can only take the pre-consumer stages of the supply chain into account, the scope of this additionality practice is on the pre-consumer losses, as described in the following.

In the context of low iLUC risk certification, an operator needs to demonstrate, that the reduction in biomass losses are a direct consequence of the application of a specific additionality practice. Thus, an operator needs to establish an iLUC risk mitigation plan before the implementation of the additionality practice.

#### **APPROACHES FOR THE CERTIFICATION OF LOW iLUC RISK BIOMASS FROM THE REDUCTION OF BIOMASS LOSSES**

In principle, the estimation of low iLUC risk biomass bases on the calculation of the amount of biomass prevented from being lost as a result of the implementation of efficiency improvements in the production chain of bio-based products. In particular, the following methodology bases at the reduction of food losses, as defined by (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015). However, the calculations for food loss reduction can be generalised for the assessment of biomass loss reduction due to improvements in the production chain efficiency.

#### **Options to demonstrate additionality for biomass provided from the reduction of biomass losses**

##### **General steps to demonstrate additionality of biomass from reduction of biomass losses based on the UN CDM Additionality Tool**

To verify that a project is additional compared to a business-as-usual scenario, an additionality demonstration needs to be conducted. Again, this can be conducted according to the guidelines of the UN CDM Additionality Tool (Clean Development Mechanism Executive Board 2012). In the case of reduction of biomass losses, the additionality assessment can include the following steps:

##### **Investment analysis**

If the reduction of biomass losses by application of a certain efficiency improvement measure is less financially attractive compared to projects that apply this measure for efficiency improvements within the production chain in a certain region, the project can be additional. In other words, the operator would need to demonstrate, that the benefits of low iLUC certification are the main economic driver for the implementation of the additionality measure.

##### **Barrier analysis**

Are other non-financial barriers existent for the reduction of biomass losses in the region, like a lack on skilled and well trained workers, which can operate machines to reduce e.g. post-harvest losses, the project can be additional.



## Common practice analysis

The project operator can demonstrate that the reduction of biomass losses in the production chain is additional, if the reduction of biomass losses and the use of the biomass preserved from being lost is not a usually applied practice within the specific region, where the project is implemented. If the share of similar producers increasing their production efficiency to reduce biomass losses with the same measure in a certain region is less than 20%, the efficiency increase with this measure is not a commonly used practice. Alternatively, if less than three similar producer reduce their biomass losses by implementing the same efficiency improvements, it is not a common used practice in the region. Therefore, the reduction of biomass losses in the production chain is additional and the resulting biomass low iLUC risk.

The CDM Tool can be an appropriate instrument to assess if a project is additional. Therefore, the reduction of biomass losses in a specific region, suitable for low iLUC risk certification needs to be additional compared to a business-as-usual scenario. In a business-as-usual scenario, improvements in the pre-consumer supply chain can be established, which reduce biomass losses due to technical improvements or knowledge transfer to local stakeholders.

The ideal application of the CDM Additionality concept for the demonstration of additionality from unused land needs to be tested and further developed in case studies and pilot certification projects.

## Calculating the amount of additional low iLUC risk biomass from reductions in biomass losses

### **Example: Model based approach for biomass loss reduction for regional low iLUC projects (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)**

Following the general concept of (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015), a low iLUC risk potential from the implementation of this additionality measure can be calculated using a three step approach.

#### Determination of the reference scenario:

Firstly, two scenarios will be developed for the respective region. The first, reference scenario focusses on the development of the biomass production (and yield development) of this region. The second scenario is used to estimate the potential demand for biomass resulting from the introduction of a regional biomass target (e.g. a quota or mandate). The difference between both scenarios is the gap between the theoretical supply and the demand side. Thus, this concept gives an idea regarding the potential iLUC risk of a region, associated with a specific biomass policy.

If no data at regional level exist to determine the baseline scenario, countrywide data can be used. According to (Brinkman, van der Hilst, Faaij, Wicke 2018), this can be for example FAOSTAT data. This database provides data of crop-specific food losses at country level. The crop-specific food losses are used to calculate the share of the crop lost, expressed in percentage of the total supply of the crop. This total supply is the sum of the production, imports and stock withdrawals. Because the losses can occur at all stages of the supply chain, (Brinkman, Wicke, Faaij 2017) considers the total supply rather than only the production.



### Assessment of low iLUC risk potential:

Secondly, the potential for the supply of low iLUC risk biomass from this specific measure is investigated. Thereby, the potential impact from the implementation of improvements in reductions of food losses (low, medium and high scenario because of potential variability and uncertainty in data sets) is being calculated. The reduction of biomass losses is expressed by the amount of a specific crop prevented from being lost resulting from the application of the efficiency improvements, calculated in the Equation 21. To calculate the potential agricultural land demand reduction – LDR (ha) the Equation 22 is used. The LDR expresses the reduction in demand for land due to the application of the efficiency improvements. Furthermore, it is the area generated from the improvements. With the results of Equation 22, in Equation 9 the low iLUC risk biomass potential can be calculated.

#### EQUATION 21:

$$P_{saved,i} = \sum_{i=1}^n P_i \times (L_{i,baseline} - L_{i,reduced})$$

- $P_{saved,i}$ : Amount of crop i prevented from being lost due to efficiency improvements in the biomass supply chain (t);
- $P_i$ : Production of crop i in baseline (t);
- $L_{i,baseline}$ : Share of biomass lost in the biomass chain in the baseline (without efficiency improvements) (%);
- $L_{i,reduced}$ : Share of biomass lost in the biomass chain after efficiency improvements (%).

#### EQUATION 22:

$$LDR_{loss\ reduction} = \sum_{i=1}^n \frac{P_{saved,i}}{Y_i}$$

- $LDR_{loss\ reduction}$ : Land demand reduction (ha) from chain efficiency improvements;
- $P_{saved,i}$ : Amount of crop i prevented from being lost due to efficiency improvements in the biomass supply chain (t);
- $Y_i$ : Projected yield of crop i ( $t\ ha^{-1}$ ).

### Comparison of the reference scenario and the low iLUC risk potential assessment:

Thirdly, the general potential for biomass production, including the effects of additional measures from step two is being compared to the difference between the target and baseline scenario of step 1. This general comparison allows to discuss the general potential of a region to produce low iLUC risk biomass.



#### POTENTIAL NEGATIVE TRADE-OFFS OF THIS ADDITIONALITY MEASURE

Measures to reduce biomass losses, can for example result in increasing energy demands and related GHG emissions due to technics enhancing food durability, e.g. temperature controlled cold chains and refrigeration. Postharvest emissions added from cold chain operations can be larger than food loss emissions avoided. Additionally, dietary shifts facilitated by refrigeration may increase GHG emissions. Post-harvest and transport stages are hot-spot stages for energy demand and climate impact, especially packaging activities at post-harvest stage as well as grain drying before and during storage can contribute to environmental burden. Better infrastructure and increase in transportation to connect smallholders to markets can increase the fuel consumption at the transport stage (Bosona, Gebresenbet 2018; Heard, Miller 2019; HLPE June 2014; Hodges, Buzby, Bennet 2011; Mahajan, Caleb, Singh, Watkins, Geyer 2014; Pagani, Menna, Johnson, Vittuari 2019; Salemdeeb, Font Vivanco, Al-Tabbaa, Ermgassen 2017; Wu, Beretta, Cronje, Hellweg, Defraeye 2019). Furthermore, activities aiming to reduce biomass losses can increase the amount of used packaging and resources for better protection and shelf life (FAO 2011a; Gutierrez, Meleddu, Piga 2017; Vergheze, Lewis, Lockrey, Williams 2015). Additionally, an increased use of synthetic insecticides for pest control, for example in grain storage or the application of chemicals on the surroundings, walls, floor and roof to kill or keep away storage pests such as insects and rodents, can contaminate the environment and threaten human health. Thus, these activities can potentially increase the presence of toxic residues in food products, inducing further impacts such as, a high persistence and its associated environmental pollution, the direct toxicity to users as well as the increased risk to workers safety (Chegere 2018; Harish, Nataraja, Ajay, Holajjer, Savaliya, Gedia 2014; Hiruy, Getu 2018; Kostyukovsky, Trostanetsky, Quinn 2016; Kumar, Kalita 2017; Mahajan, Caleb, Singh, Watkins, Geyer 2014). In the Table 19 (section 6.2.5 in the Annex) further potential negative trade-offs are described.



#### 2.2.4.6 *Increasing use of waste*

The final additionality measure to be discussed in this report is the increasing use of waste as a feedstock for the production of bio-based products. This can reduce the demand for land caused by the increased production of bio-based products. However, some requirements need to be fulfilled regarding a correct determination of the term waste, which is of crucial importance. In comparison to the land based additionality practices, two important aspects need to be considered in regard to use waste as a feedstock for low iLUC risk biomass production. On the one hand, the alternative uses of the waste stream needs to be observed. On the other hand, the potential impacts of displacing the waste stream from its original use or application by using it for the production of bio-based products need to be regarded. Therefore, a detailed assessment process needs to be conducted for the identification of sustainable waste streams (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012).

#### **Approaches for the certification of low iLUC risk biomass from the INCREASED use of waste**

The potential use of waste as a feedstock for the production of bio-based products with a low iLUC risk depends on the fulfilment of different preconditions. Following the approach presented by (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012), the identification of appropriate waste streams can be realized in three steps.

1. Identification and definition of waste in demarcation to a product or by-product;
2. Determination of the available quantity of the waste (feedstock) in a specific region (feedstock-region combination);
3. Determination of identified region specific waste streams suitable for a positive list of low iLUC risk waste streams provided and updated by the certification scheme operator.

The steps mentioned above are explained in more detail in the following sections. In addition, two different approaches for the quantification of the low iLUC risk biomass obtained from waste are introduced, subsequently.

#### **Options to demonstrate additional biomass from the increasing use of waste**

##### **General steps to demonstrate additionality of biomass from increasing use of waste based on the UN CDM Additionality Tool**

To verify that a project is additional compared to a business-as-usual scenario, in case of the other low iLUC risk practices, an additionality demonstration needs to be conducted. This can potentially be based on the application of the UN CDM Additionality Tool (Clean Development Mechanism Executive Board 2012). In the case of waste, the additionality assessment can include the following steps:

##### *Investment analysis*

If the use of a waste stream, e.g. municipal organic waste to produce a bio-based product is less financially attractive than using other feedstock in a region, the project can be additional.

##### *Barrier analysis*

Do other non-financial barriers exist in the region, like an underdeveloped waste collecting infrastructure or lack in knowledge to separate the organic waste fraction, the project can be additional.



## Common practice analysis

The project operator can demonstrate that the waste use project is additional, if the use of this waste stream for bio-based products is not usual within the specific region. If the share of similar producers using the same waste stream in a certain region is less than 20%, increasing use of the waste is not a commonly used practice. Alternatively, if less than three similar producer using the same waste stream for bio-based products, it is not a common used practice in the region.

In general, the CDM Tool can be an appropriate instrument to assess if a project is additional. Furthermore, the three steps to identify waste streams suitable for low iLUC risk certification, listed in the general concept above, imply that the waste identified in the feedstock-region combination is additional to a business-as-usual scenario. In a business-as-usual scenario, the waste stream would not be used as a feedstock for the production of bio-based products. According to the definition of waste, it would be discarded, as described in the next section. Thus, the additionality demonstration can be seen as already included within the general concept of waste use.

The ideal application of the CDM Additionality concept for the demonstration of additionality from unused land needs to be tested and further developed in case studies and pilot certification projects.

## Approach to determine a feedstock-region-combination and a positive list of waste streams

### Identification and definition of waste in contrast to a product or by-product

A precondition for the identification of a potential waste stream is an appropriate definition of the term waste for the purpose of iLUC risk mitigation. An obvious approach would be a definition in accordance with the EU waste framework directive 2008/98/EC, which defines waste as "...any substance or object which the holder discard or intends or is required to discard" (European Commission 2008). Besides, the directive defines the term bio-waste as: "biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants" (European Commission 2008). The directive determines the term by-product, too. Thus, a by-product is a result of a production process. However, it is not the aim of the production process to produce the by-product. For a differentiation between waste and by-product, the by-product needs to meet the following conditions:

The use of the by-product is certain. No further processing steps are needed for its use. The by-product is an integral part of the production process. The use of the by-product is legal and lawful (European Commission 2008).

Further determinations of potential waste streams can be found in the Annex IX of the RED 2, which lists several feedstock for the production of advanced biofuels. Amongst others, this annex comprises the biomass fraction of mixed municipal waste, of industrial waste and of wastes and residues from forestry, etc. (European Commission 2018).

Waste eligible for the provision of additional biomass for the low iLUC risk certification can be defined as "waste stream originating in the region, which is not used for alternative uses, other than waste disposal including waste incineration and landfill disposal" (van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012). Additionally, waste can fulfil the following criteria: Its use causes no indirect greenhouse gas (GHG) emissions and no land use displacement. Used cooking oil, municipal solid waste, wastewater and animal fats are mentioned as examples for potential low iLUC risk waste (RSB 2015).





Associated with the use of waste for the manufacturing of a product is a change in the general status of the waste. Thus, the waste is per definition no longer a waste, when it is used for the production of bio-based products (STAR4BBI 2019). This issue is specified within the EU waste framework directive 2008/98/EC. According to the directive, waste can lose its status. This can happen, if for example a material, which was defined as waste is used for a specific purpose. In case there is a market or demand for this material and the material fulfils specific technical requirements as well as all necessary legislation and standards applied for products. Furthermore, the use of that material does not negatively impacts the environment and the human health (European Commission 2008). A waste stream used as a low iLUC risk feedstock for bio-based products can probably fulfil all requirements to change the waste status. By using material, previously defined as waste, the economic value of this material might increase. This means that a market and a demand is developing. Thus, if a waste stream is used as a low iLUC risk feedstock for bio-based products, it automatically changes its status from waste to a product.

### **Assessment of available quantities of waste (feedstock) in a specific region (feedstock-region combination)**

In the first step, an assessment of the available quantity of materials is conducted, which coincides with the definition of potential waste streams appropriate for the production low iLUC risk biomass. This excludes materials, which are currently used for other purposes, e.g. food, animal feed or oleochemicals.

The current uses of a material can obviously differ significantly between regions, meaning that a material in region A can be a waste, because its use causes no displacement of this material from other uses in the region. Therefore, the waste from region A is eligible for low iLUC risk certification. In contrast, in region B the use of the same material might lead to the displacement from the current uses of the material. Therefore, the same material in region B is not suitable for low iLUC risk certification.

Thus, a general understanding of the situation in a specific region is an important precondition for the assessment of this additionality measure. A region can cover a country, a part of a country or several countries together, e.g. the European Union. The relation between the general availability of a waste resp. the feedstock and the specific situation in a region can be expressed in a feedstock-region combination. This combination is very important for the assessment of the waste stream as a low iLUC risk feedstock. It describes the combination of a material (feedstock) in a certain region, where a surplus of the feedstock exists, which is not used for other purposes. This surplus of the feedstock is the waste able to be certified as low iLUC risk (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013). More general in regard to waste "A region is a geographical area where conclusions (on use, disposal, regulation, etc.) may be drawn for a particular end-of-life product stream" (van de Staaij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012).

The determination of the available quantity of the feedstock-region combination is characterised by two main steps (Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013):

1. Selection of the most promising feedstock-region combination
2. Analysis of the potential surplus amount for the selected feedstock-region combination



## Positive list of low iLUC risk waste

The results of the analysis described above are included in a positive list, which could be prepared by local authorities or the operators of a certification scheme. The positive list comprises the determined feedstock-region combinations. Additionally, for each feedstock-region the potential additional amount of waste eligible for low iLUC risk certification is part of the positive list.

The development of the positive list can be conducted in several steps. The first steps are described in the sections above. These comprise the definition of waste and the assessment of the available quantity of waste based on the identified feedstock-region combination.

(van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012) suggests to standardise the assessment and evaluate the positive list periodically. This can be conducted in a timeframe of every three to five years for each feedstock-region combination. The evaluation can be used for updating the positive list, if the status of a waste stream changes over time to the status of a by-product, for example. This can be the case when a material in a feedstock-region is utilized in the future for purposes like food, feed or chemical production. In these cases, its use for the production of bio-based products causes displacement effects in the production chains.

In some cases it is possible, that only a part of the waste stream in the feedstock-region can be used for the production of low iLUC risk biomass and the other part needs to be disposed of, e.g. in incineration or land filled. If only a share in percent of a feedstock-region combination can be certified as low iLUC risk biomass, the scheme owner can include this share in the positive list, expressed by the term  $S_{\text{positive list}}$  in the Equation 23. It is suggested to exclude any waste stream from the positive list, for which this share is less than 25% (van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012).

## Approaches for the quantification of the amount of low iLUC risk biomass from waste

This section describes options for the quantification of the additional amount of waste suitable for low iLUC risk biomass certification. The methodology to quantify the volume of low iLUC risk biomaterials or bio-based products bases on the Low Indirect Impact Biofuels (LIIB) methodology according to (van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012). Two approaches do exist for the operationalisation of the methodology. One originates from the LIIB methodology. The other is part of the RSB Low iLUC Risk Biomass Criteria and Compliance Indicators Methodology (RSB 2015). Both approaches will be discussed and compared in regard to their differences.

### Low Indirect Impact Biofuels (LIIB) Methodology (van de Staij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012)

For the calculation of the volume of LIIB compliant bio-based products, the amount of produced bio-based products in a specific feedstock-region needs to be documented. This can be realized for example using the unit of annual production in mass (e.g. kg) or volume (e.g. m<sup>3</sup>). Only the share ( $S_{\text{positive list}}$ ) in percent of the total production of the feedstock-region combination included in the positive list can be claimed as LIIB-compliance.

The volume of LIIB compliant bio-based products is calculated in accordance to the approach suggested in the LIIB methodology. The equation is corrected in regard to the variable  $S_{\text{positive list}}$ . The volume of low iLUC risk bio-based product is quantified with the corrected Equation 23.



The LIIB methodology can be used, if the scheme owner publishes a positive list including the share ( $S_{\text{positive list}}$ ) of the eligible waste stream meeting the requirements of the feedstock-region combination. Therefore, this approach is in compliance with the methodological concept suggested to assess waste streams as a source for low iLUC risk biomass, illustrated above.

#### EQUATION 23:

$$V_{\text{LIIB},t=x} = P_{t=x} \times \frac{S_{\text{positive list}}}{100}$$

$V_{\text{LIIB},t=x}$ : Volume of LIIB compliant bio-based product in year x ( $\text{m}^3$  or kg)

$P_{t=x}$ : Total production in year x from waste feedstock ( $\text{m}^3$  or kg)

$S_{\text{positive list}}$ : Share of the waste stream in the region eligible (%)

### RSB Low iLUC Risk Biomass Criteria and Compliance Indicators Methodology (RSB 2015)

Following the methodology of the RSB, the actual amount of the low iLUC risk bio-based product can be determined by multiplying the identified volume of the low iLUC risk waste with an average conversion rate, as it is shown in Equation 24. The conversion rate is based on the ratio of waste to bio-based product and is expressed by a decimal digit. A precondition for this quantification approach is a documented input-output analysis. This analysis considers the amount of low iLUC risk waste entering the production process (input) and the amount of low iLUC risk bio-based products manufactured out of it (output). Based on the input-output analysis, the average conversion rate is determined.

#### EQUATION 24:

$$V_{\text{LowiLUC},t=x} = V_{W,t=x} \times C$$

$V_{\text{LowiLUC},t=x}$ : Volume of low iLUC risk bio-based product produced in year x ( $\text{m}^3$  or t)

$V_{W,t=x}$ : Volume of entering low iLUC risk waste in year x ( $\text{m}^3$  or t)

$C$ : Conversion rate (waste to bio-based product)

In comparison to the LIIB methodology, the RSB methodology uses a conversion rate to calculate the amount of a low iLUC risk bio-based product. This approach seems useful in case, the amount of waste (input) and the amount of the bio-based product (output) is known. In most cases, both variables are known to the operator, because the producer of a bio-based product is usually aware of the amount of the input and output of the production process.



Therefore, the RSB methodology is appropriate in cases, when no positive list with the share of a feedstock-region exist. However, the approach requires evidence that a waste stream is available for the use as a feedstock, for a bio-based product in a certain region. This includes also that no other uses of the waste resp. feedstock exist in this region. Thus, the RSB methodology can be seen as a shortened version of the LIIB methodology. It only requires the definition of waste in a specific region, which is followed by the calculation of the amount of a low iLUC risk bio-based product. It does not require the establishment of a periodically evaluated positive list, like the LIIB methodology originally does.

#### **POTENTIAL NEGATIVE TRADE-OFFS OF THIS ADDITIONALITY MEASURE**

An increasing use of waste materials in the supply or production chain of bio-based products can be associated with increasing in GHG emissions due to higher energy consumption from pre-treatment as well as from the collection and transport of the waste. Additionally, the higher energy demand might increase the costs for the treatment of the waste to produce bio-based products (Mansir, Teo, Rashid, Saiman, Tan, Alsultan, Taufiq-Yap 2018; Offenhuber, Lee, Wolf, Phithakkitnukoon, Biderman, Ratti 2012; Zhang, Ning, Khalid, Zhang, Liu, Chen 2018). Furthermore, used waste streams can contain toxic metals, which can contaminate the product from waste as well as be discharged with waste-water occurred within the waste-to-product conversion process. (Yang, Bao, Xie 2019; Yasmin Regina, Saraswathy, Balu, Karthik, Muthukumaran 2015). Further potential negative trade-offs are listed in Table 20 (section 6.2.6 in the Annex).

### 3 Exemplary iLUC risk assessment for case studies of bio-based products

The following chapter deals with potential implementation pathways of the iLUC additionality measures within the supply chain of bio-based products, i.e. bioplastics. For this purpose, case studies relevant for the STAR-ProBio project will be analysed with the iLUC risk tool in order to demonstrate its applicability.

#### 3.1 Maize

##### 3.1.1 SydILUC model

###### 3.1.1.1 Baseline simulations:

The results of the baseline simulations are shown in Figure 24. The differences between the two plastics is minimal, even though they have different production yields, different co-product production and different initial production rates. The most important factor influencing the future need for maize agricultural land expansion is the projection of future yields. Note that, for a target production of 173 Mt of plastics in 2050, both maize yields scenarios give “negative maize land expansion” after 100 years; this means that, in the model simulations, future yields are enough to offset the increase in demand for maize feedstock for the set policy bio-based production target. However, remember that these projections are for substitution of all plastics in EU, but on a global maize production. A more interesting simulation should account for global plastic substitution (1000 Mt); this, however, goes beyond the scope of the present study.

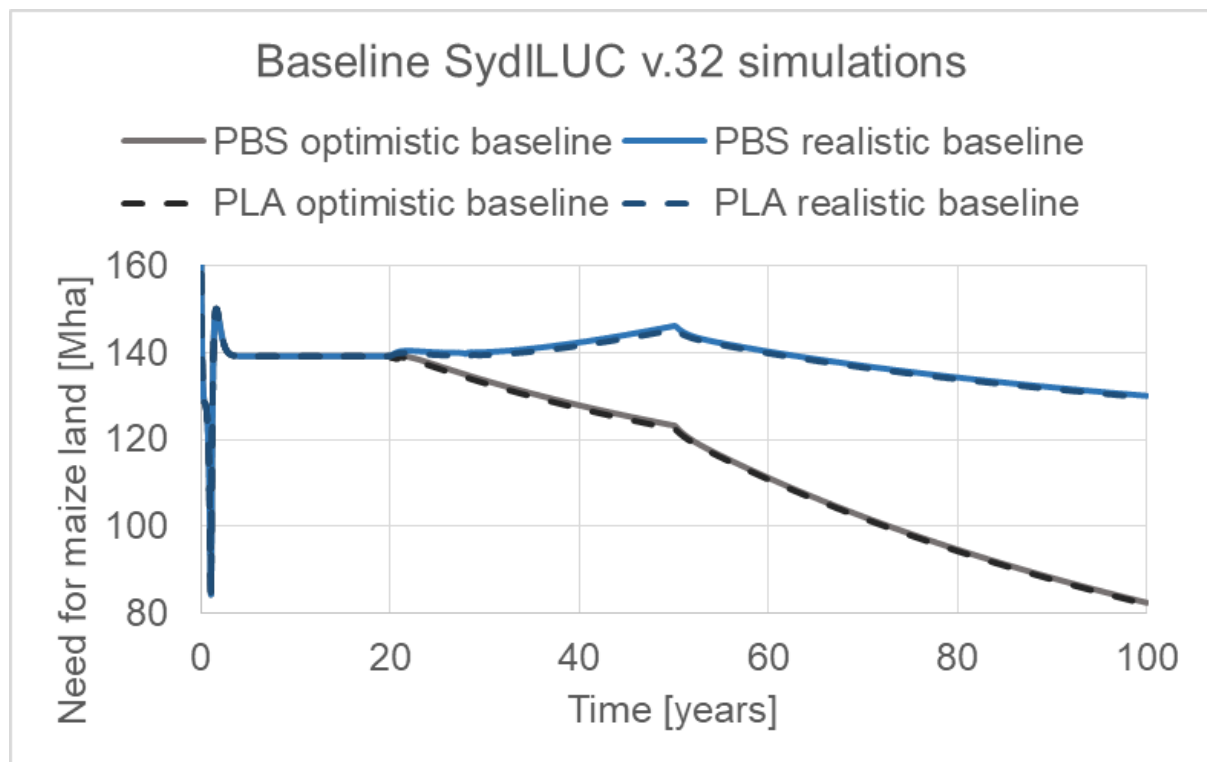


Figure 24 SydILUC output time series of changes in need for land cultivated to maize in order to reach the target production of substituting all E.U. fossil plastics with bio-based plastics, for PLA and PBS, for the optimistic and realistic scenario. The policy for the increase in bio-based material stops in simulation year 2050, so this is where the iLUC risk is calculated. Since the demand for land projected for the optimistic baseline is lower than the initial crop land, it is assigned to the lowest iLUC risk class.

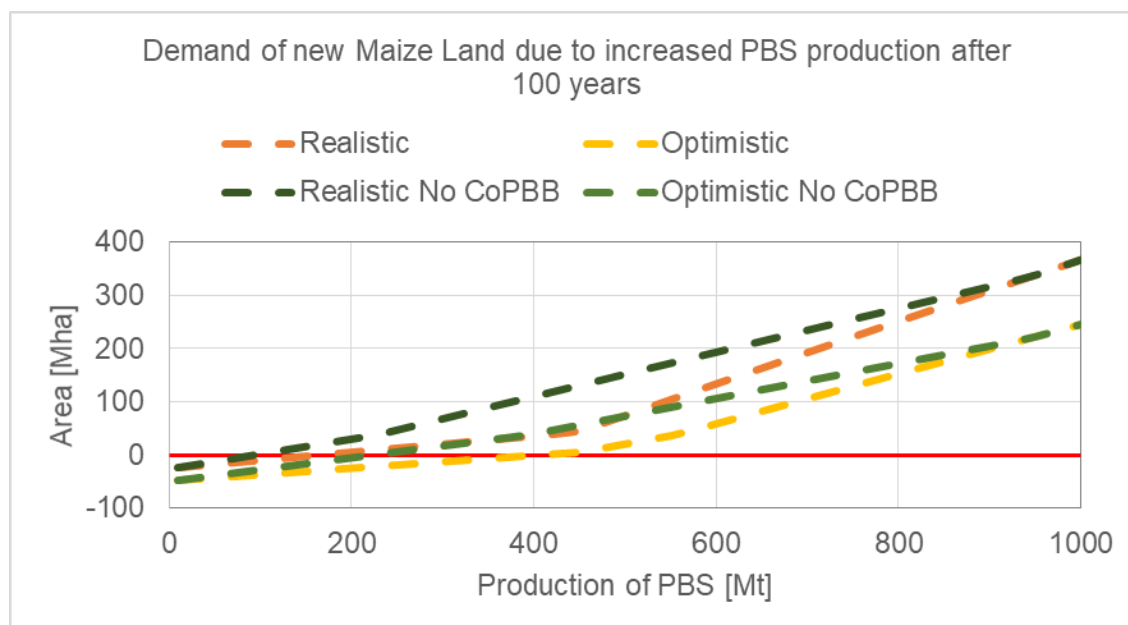
### 3.1.1.2 Bio-based plastic production target effect on need for crop land

The change in need for maize land due to increase in bio-based plastics production after 100 years is shown in Figure 25 for PBS and in Figure 26 for PLA. The production of relatively (with respect to world future needs) small amounts of plastics is not related to an expansion in maize land, meaning that the iLUC risk is low at those target production levels. This is due, essentially, to the increase in global maize yields, which balances the increased consumption of maize feedstock: notice that the optimistic projections reach the zero line (above which iLUC risk is not zero) for larger target bio-based plastic production. The exact value of bio-based material policy target that triggers an increase in maize land global area is reported in Table 10 for both PBS and PLA. It is possible to appreciate both the small differences between the two plastics at small policy target values (110, 170 Mt) and the big effect of the co-products on the need for new maize land.

*Table 10 Bio-based material policy target at which maize land area increases with respect to 2016 value, for both PBS and PLA, after 100 years of simulation.*

Bio-based material	Optimistic	Optimistic no CoP	Realistic	Realistic no CoP
PBS	410.1	230.1	170.1	110
PLA	430.21	270.21	170.21	110.21

The effect of co-product utilization is that it decreases the risk of iLUC, since it substitutes the need of maize feedstock for animal feed. The effect of the co-products starts to increase with increasing production of bio-based plastics, reaches a maximum effect in lowering iLUC risk around a policy production target of ~400 Mt, then decreases, and finally has no effect whatsoever at ~900 Mt. Figure 27 shows the reason behind this decrease in iLUC lowering effect of co-products for policy productions > 400 Mt: since the demand of animal feed is kept fixed in time (following the *ceteris paribus* concept), large productions of bio-based plastics result in an amount of co-product large enough to completely substitute conventional animal feed. This is unrealistic, since: (a) maize feedstock is not only used for animal feed, but also food, seed and other uses; (b) demand for animal feed will probably increase in the future, since there is an increasing global demand for meat consumption.



*Figure 25 Need for maize agricultural land with respect to target production of PBS in 2050. The results are shown for the realistic and optimistic scenario, and for the co-product utilization and no co-product utilization scenario.*

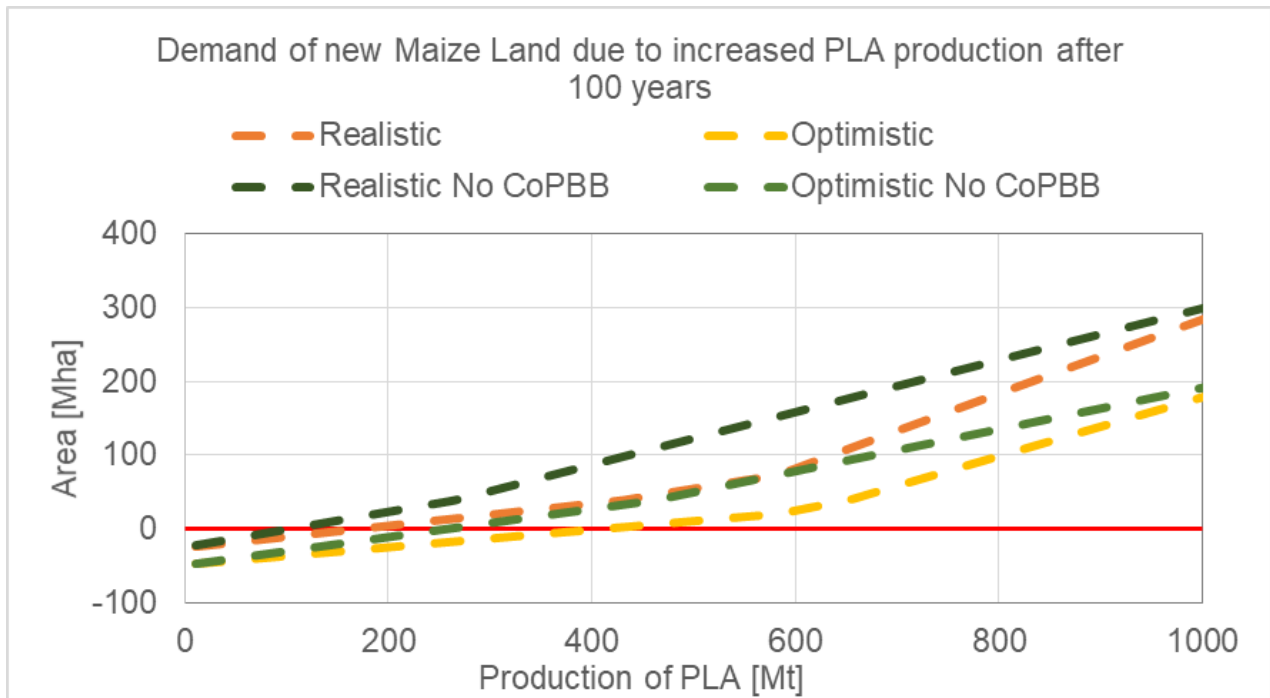


Figure 26 Need for maize agricultural land with respect to target production of PLA in 2050. The results are shown for the realistic and optimistic scenario, and for the co-product utilization and no co-product utilization scenario.

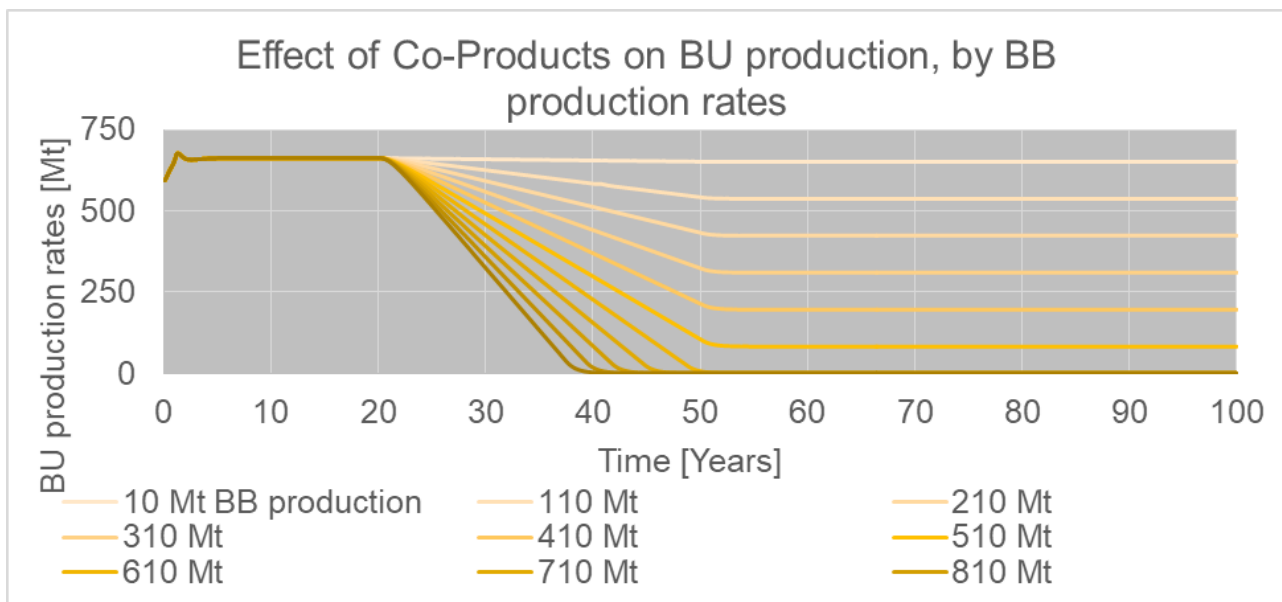


Figure 27 SydILUC predicted time-series of BU (feed) production rates as affected by different levels of bio-based plastic production, based on the assumption that all relevant co-products will be used to offset need for feed. Another assumption is that actual need for feed will not increase in the future (likely unrealistic, since meat consumption is increasing worldwide).

A comparison of the effect on maize land expansion due to increased bio-based plastic production between PBS and PLA is shown in Figure 28. The levels of plastic production in 2016 and future projection for 2050 for both the E.U. and the world are shown as reference values. The main difference between the two plastics can be appreciated only for large production rates ( $\sim 450$  Mt, well over actual global plastic production).



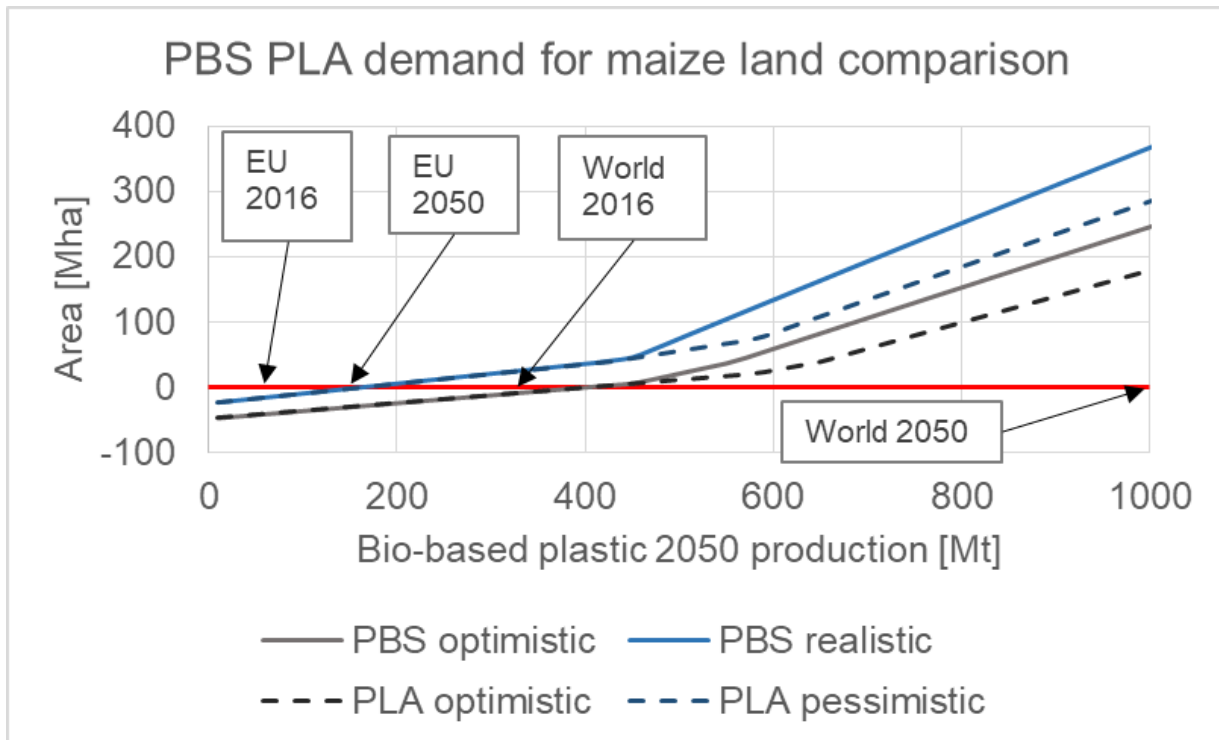
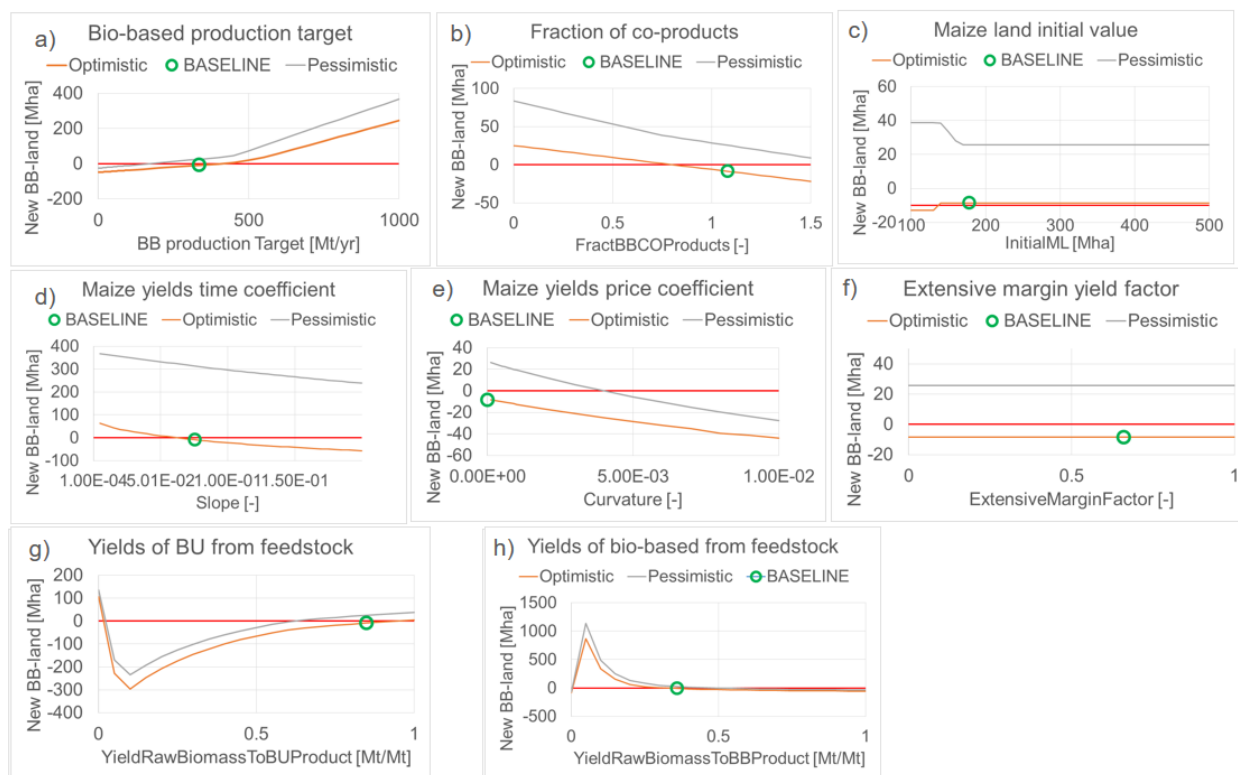


Figure 28 Comparison of change in needed maize land for the two yields scenarios, for different target 2050 production for PBS and PLA.

### 3.1.1.3 Local OAT sensitivity analysis to assess the effect of changing the parameters' values

Since the sensitivity analysis showed similar results for both bio-based plastics, we present here only the results for the PBS plastic (PLA results show similar behaviour). In Figure 29, the effect of different policy targets for bio-based PBS production is shown, with a behaviour similar to what is seen also in Figure 25, Figure 26 Figure 28. In b), it is possible to see the effect of the co-product on increase in need of maize land: not only the model is sensitive to this factor, but it can be the difference between having or not an iLUC risk. In c) it is shown that the model is not very sensitive to initial conditions of maize land extension; the only effect is visible for initial maize land of 160, corresponding to the increase in maize land that triggers the extensive margin effect. The latter is shown in f): the model is insensitive to it, since the increase in maize land needed in the baseline simulation remains below the value that triggers it (i.e. remains below the initial maize land value). d) and e) show the effects of changing the coefficients of yields projections in time and maize price: as discussed before, the future projections of maize yields have a great impact on the model predictions. The price coefficient, however, has a relatively small effect, and, above all, there is no direct observation of any effect of price on maize yields (see the calibration document). The effects of the yields of feed product and bio-based material production from one unit of maize feedstock on the need for maize land after 100 years are shown in g) and h). The effects are not negligible, but only for very small, unrealistic values, that are not relevant in the reality (they are not economically viable). Thus, the most important factors having an effect on the model results are the co-products and the yields future projections; special care, thus, should be taken to properly estimate these model inputs.

## Sensitivity analysis results for PBS 100% bio-based



*Figure 29 Results of the local OAT sensitivity analysis for the PBS SydILUC v32 simulations. Changes of required maize land with respect to: a) bio-based plastic (PBS) policy 2050 production target; b) fraction of co-products obtained for every unit of PBS; c) initial global agricultural area dedicated to maize cultivation; d) slope coefficient of the maize yield increase in time; e) slope coefficient of the maize yield increase with changes in maize price; f) maize yields of the new land cultivated with maize (extensive margin); g) yields of BU product obtained from a unit of maize feedstock; h) yields of bio-based plastic (PBS) obtained from a unit of maize feedstock.*

As a conclusion, it is possible to say that, for small values of policy target for increase in bio-based plastic production, the model predicts either no or very small iLUC risk. Large iLUC risks are predicted from the global model, however, whenever the scale of production target is increased as much as to have an effect on the global projected plastic production in 2050: if we want really to substitute fossil plastics with bio-based plastics, the iLUC risk is non negligible. The most important factors determining the model predictions are the future projections of maize yields and the use of co-products to decrease iLUC risk. The model gives similar results for different plastics based on starch feedstock; the results could be potentially different for organic oil based plastics.

### 3.1.2 iLUC risk tool (USA and China)

The iLUC risk associated with default production of PLA and PBS from USA and China, calculated using the SydILUC risk tool, is shown in Table 11. The default values are obtained simply selecting the country of production and the type of bio-based material produced in the "Input" page of the tool. The application of different low iLUC risk practices, and their effect, is also shown. Note that the larger iLUC risk reductions, for China, are obtained from agricultural yield increases, since it is a very influential parameter in the model and there is good range for improvement. In the USA, instead, where yield rates are already close to maximum potentials, the use of co-products is the most promising strategy to reduce iLUC risk.



Table 11 iLUC risk levels obtained using the iLUC risk tool with default values and applying simple low iLUC risk practices. \* = Land use practice changed from "Up and down slope tilling" to "strip cropping, contour".

Country	BB material	Default iLUC risk level	Land demand change [Mha]	Yield increase +0.1 [t ha <sup>-1</sup> yr <sup>-1</sup> ]	Conservative Land Practice *	Production on reclaimed land +1 [Mt yr <sup>-1</sup> ]	Use of co-products = 1	Increase of yield efficiency +0.2
USA	PLA	A+	5	A++	A++	A+	A+++	A+
China	PLA	B	29	A+++	A	A+	A+	B
USA	PBS	C	42	B	C	A+	A++	C
China	PBS	D	50	A+++	C	A+	B	C

## 3.2 Soybean

### 3.2.1 SydILUC model

#### 3.2.1.1 Baseline simulations

Figure 30 shows the results for the baseline simulations for 100% bio PUR production from soybean. Notice that, with respect to the production from maize, the increase in land demand (and, hence, the iLUC risk) is much higher here, with values being ~5 times higher. This is due to the much lower yields of soybean to PUR production. With soybean, the difference between the pessimistic and the optimistic agricultural yield projections makes little difference, since both are very low in absolute value (0.0277 t ha<sup>-1</sup> year<sup>-1</sup> is the actual trend of agricultural yield increase).

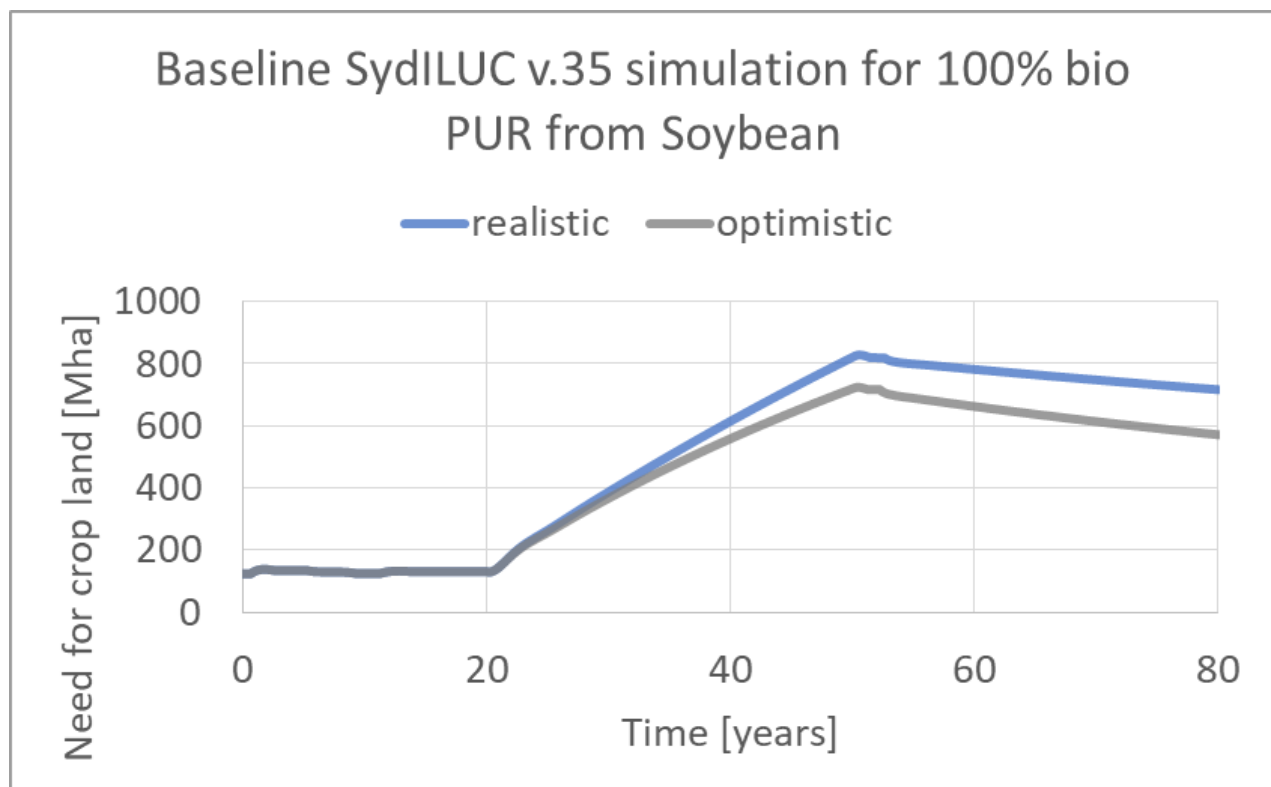


Figure 30 SydILUC time series output of change in land demand for the substitution of all EU plastic with 100% bio PUR by 2050. The policy of bio-based material increase stops at Time = 50 years; after that the production is kept constant, but the increase in agricultural yields results in a decrease in land demand.

### 3.2.1.2 Bio-based plastic production target effect on need for crop land

The most interesting feature visible in the analysis of the predicted change in land demand depending on the production of 100% bio PUR from soybean (Figure 31) is that: 1) the land demand projections are ~10 times larger than for maize, 2) there is no initial “negative” land demand. The last points means that the yields of transformation are so low that the increase in agricultural yields (also very low) are not enough to balance the increased demand of soybean. In general, the difference between the *optimistic* and the *realistic* scenario is very low through the target increase in bio-based material produced. Figure 32 shows the same results, but with more focus on the range of bio-based material production for EU; remember that 2016 total bio-plastic (including bio-PUR) production was ~4 Mt; plastic production by the EU projected to 2050 is ~173 Mt. At this scale, the difference between the use of the co-products to reduce land demand is clearly visible, with the maximum effect reached for a bio-based material production of 60 Mt. If the actual production of bio-plastic is maintained, the predicted effect on land demand is negligible.

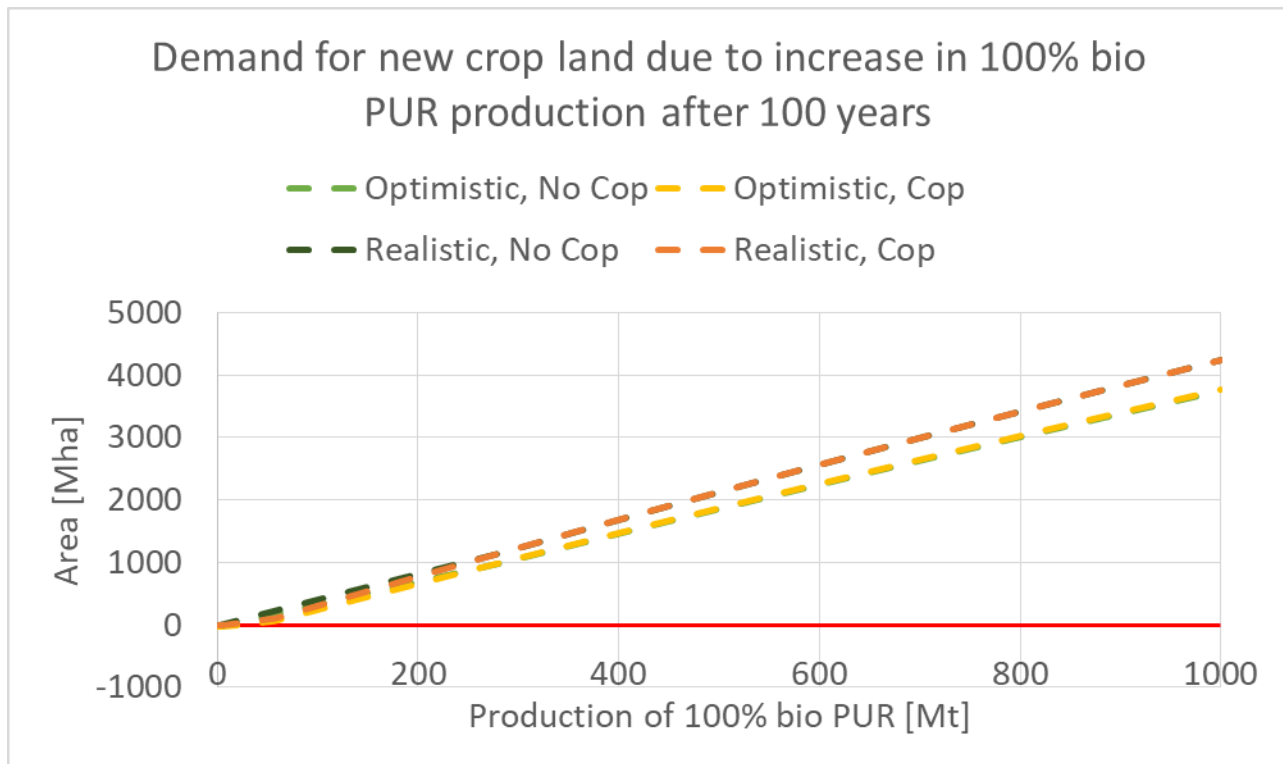


Figure 31 Increase in land demand due to increased production of 100% bio PUR from soybean, with different agricultural yield increase scenarios and with/without use of co-products.

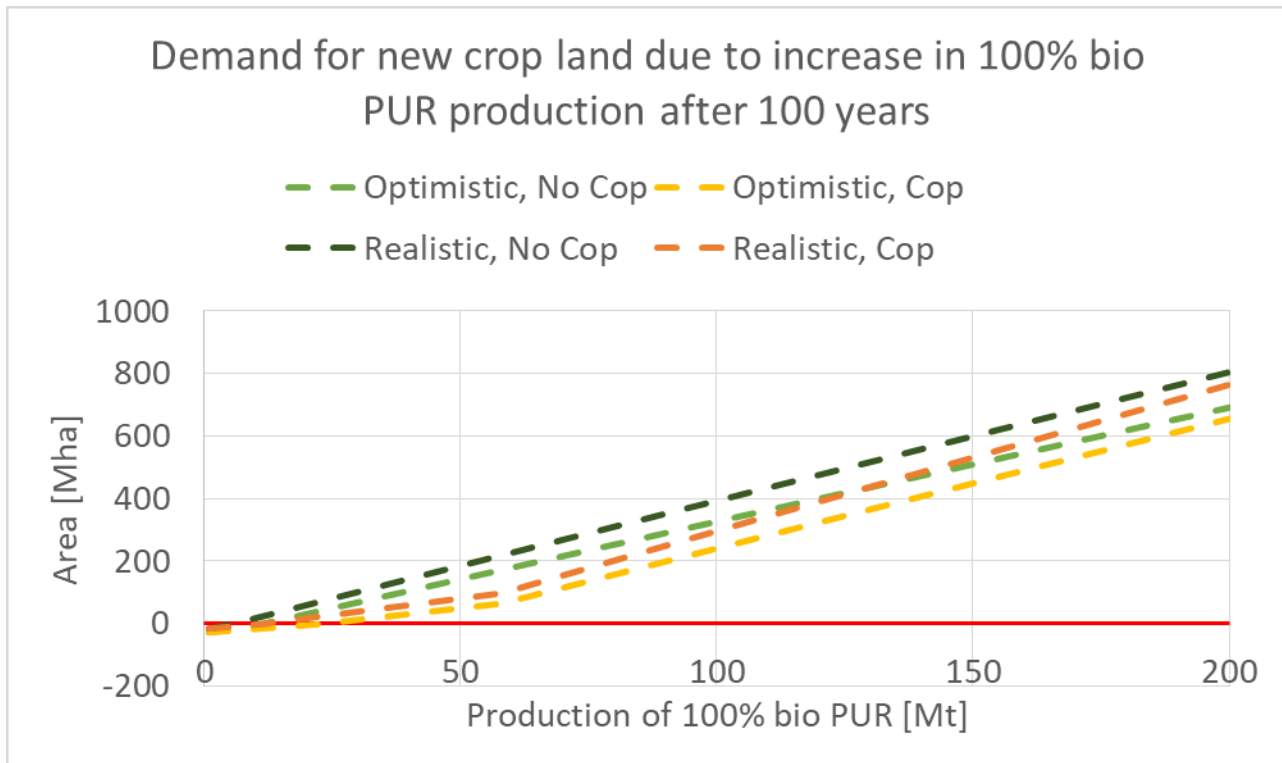


Figure 32 Increase in land demand due to increased production of 100% bio PUR from soybean, with different agricultural yield increase scenarios and with/without use of co-products. Focus on the production level of interest for the substitution of the plastics used in the EU (complete substitution being 173 Mt, projection for 2050).

### 3.2.1.3 Local OAT sensitivity analysis to assess the effect of changing the parameters' values

The results of the local one at a time (OAT, Figure 33) sensitivity analysis show that: a) the co-product use is not effective in reducing the demand for crop land; b) the initial crop land is influential on the output of the model, so should be carefully considered for every run; c) yield trends have a very large influence on the land demand projections, but in line with other variables; d) the yield gap is not influential, at least in the proximity of the baseline simulation; e) the extensive margin parameter is influential, and should be determined with higher accuracy to reduce the uncertainty of the model results; f) the yields of the BU and BB products from the soybean are very influential. In conclusion, the best way to reduce iLUC risk related to 100% bio PUR production from soybean is to improve the efficiency of the agricultural sector on one side, and of the bio-plastic production on the other. However, the most influential factor is the yield of production of food from the soybean; it is possible to assume, however, that the process is already very efficient; the food product, however, could be substituted in processed food with a surrogate. With respect to the maize simulations, we see that initial crop land and extensive margin are, now, having a non-negligible effect on the model output, and that the optimistic and pessimistic scenarios are always very similar.

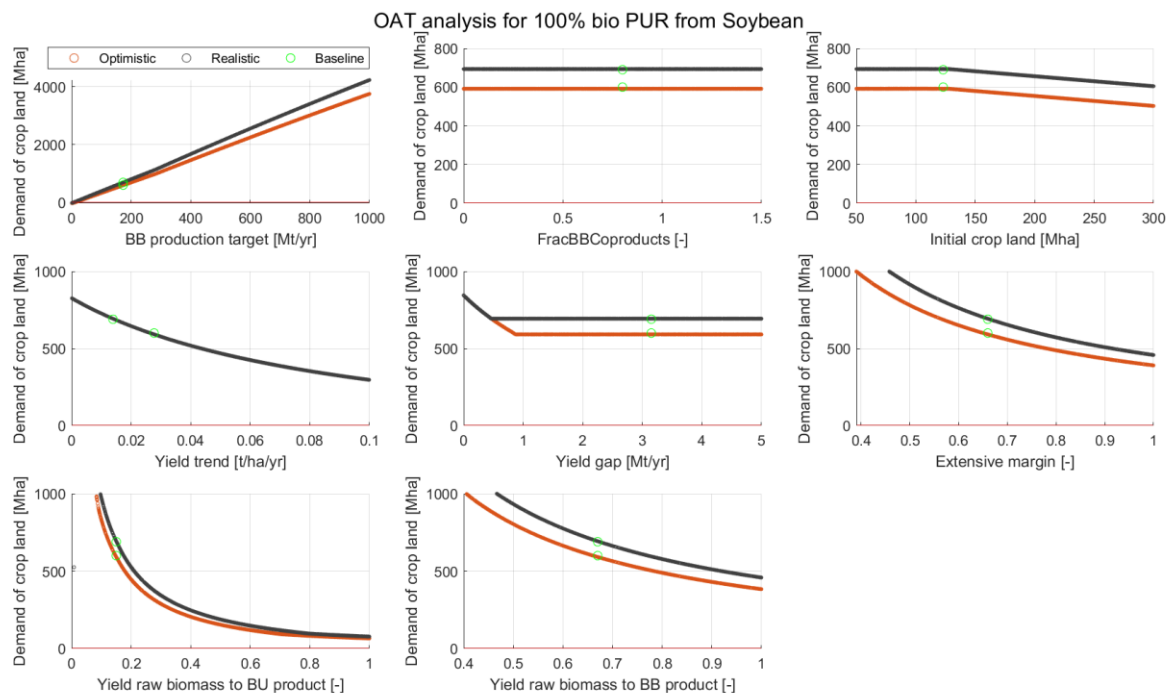


Figure 33 Results of the local OAT for the production of 100% bio-PUR from soybean using SydILUC v35. From top left moving right first, then down a row, the graphics represent the predicted change in land demand with respect to changes in the parameter: a) bio-PUR policy 2050 production target; b) fraction of co-products obtained for every unit of bio-PUR; c) initial global agricultural area dedicated to soybean cultivation; d) slope coefficient of the soybean yield increase in time; e) yield gap of the soybean, representing how far global soybean yield are from reaching their maximum potential values; f) soybean yields when expanding over the actual crop land extension (extensive margin); g) yields of BU product obtained from a unit of soybean feedstock; h) yields of bio-based plastic (bio-PUR) obtained from a unit of soybean feedstock.

### 3.2.2 iLUC risk tool (Brazil and Argentina)

The iLUC risk associated with default production of 100% bio PUR from Argentina and Brazil is shown in Table 12. Note that, in this case, the possibility for the use of co-products is not enabled (all feed-usable co-products are already used while obtaining soy oil). Since the characteristics and the production of the two countries analysed are very similar, the results are similar as well. In this case, the most influential low iLUC risk strategy is the production on abandoned/degraded land. However, such land should be carefully certified, since there is a high risk of expanding on otherwise natural land. Increased chain efficiency and increase in agricultural yields are also valuable risk strategies. Due to the large erosion patterns in these two countries, and the low land protection given by soybean cultivation, better land practices seem to have little impact on iLUC risk.

Table 12 iLUC risk levels obtained using the iLUC risk tool with default values and applying simple low iLUC risk practices. \* = Land use practice changed from "Up and down slope tilling" to "strip cropping, contour".

Country	BB material	Default iLUC risk level	Land demand change [Mha]	Yield increase +0.1 [t ha <sup>-1</sup> yr <sup>-1</sup> ]	Conservative Land Practice *	Production on reclaimed land +1 [Mt yr <sup>-1</sup> ]	Use of co-products = 1	Increase of yield efficiency +0.2
Brazil	PUR	D	1465	A	C	A+++		A+
Argentina	PUR	D	1495	A	D	A+++		A+

### 3.3 Sugar beet pulp

#### 3.3.1 SydILUC model

##### 3.3.1.1 Baseline simulations

The baseline simulations for the PLA and PBS production from sugar beet pulp (Figure 34) show that the difference in land demand change prediction is negligible when comparing the two agricultural yield scenarios, and minimal for the two different bio-plastics. However, the overall change in and demand is similar to that calculated for the same bio-plastics, but produced from maize in the realistic scenario, and much less than that of 100% bio-PUR from soybean. However, the predictions of change in land demand are higher for PLA and PBS from maize with respect to the same bio-plastics obtained from maize in the optimistic scenario, meaning that an improvement in agricultural yields is going to be more beneficial for the maize biomass than for the sugar beet pulp.

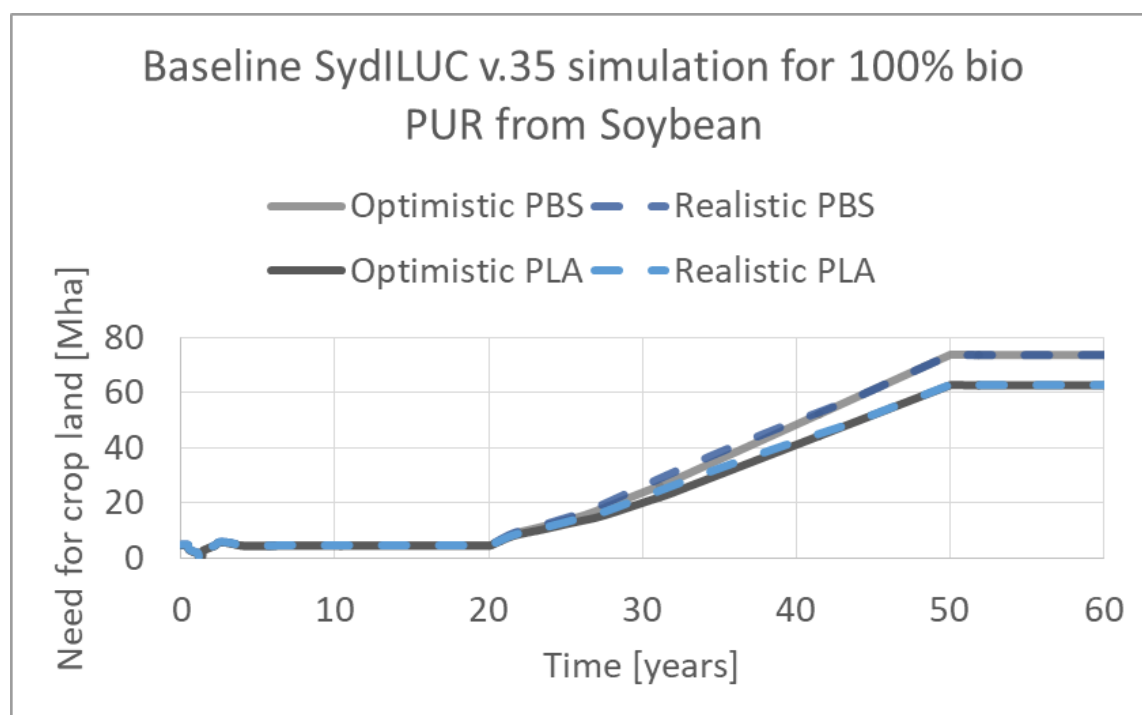


Figure 34 SydILUC time series output of change in land demand for the substitution of all EU plastic with either PLA or PBS produced by sugar beet pulp by 2050. The policy of bio-based material increase stops at Time = 50 years; after that the production is kept constant.

##### 3.3.1.2 Bio-based plastic production target effect on need for maize land PBS

The dependence of change in land demand on the target production of PBS obtained from sugar beet pulp is shown in Figure 35, for the optimistic and for the realistic agricultural yield increases, with and without the use of co-products as substitutes for feed. In this case, there is no difference between the various options, even when focusing on the production target more realistic for the EU (Figure 36). This is due to the kind of direct competition with the feed sector and its high demand, balancing all changes in the other parameters. The overall change in land demand is much higher than that predicted for the maize biomass, and comparable with that of soybeans (for the production, in the latter case, of 100% bio PUR).



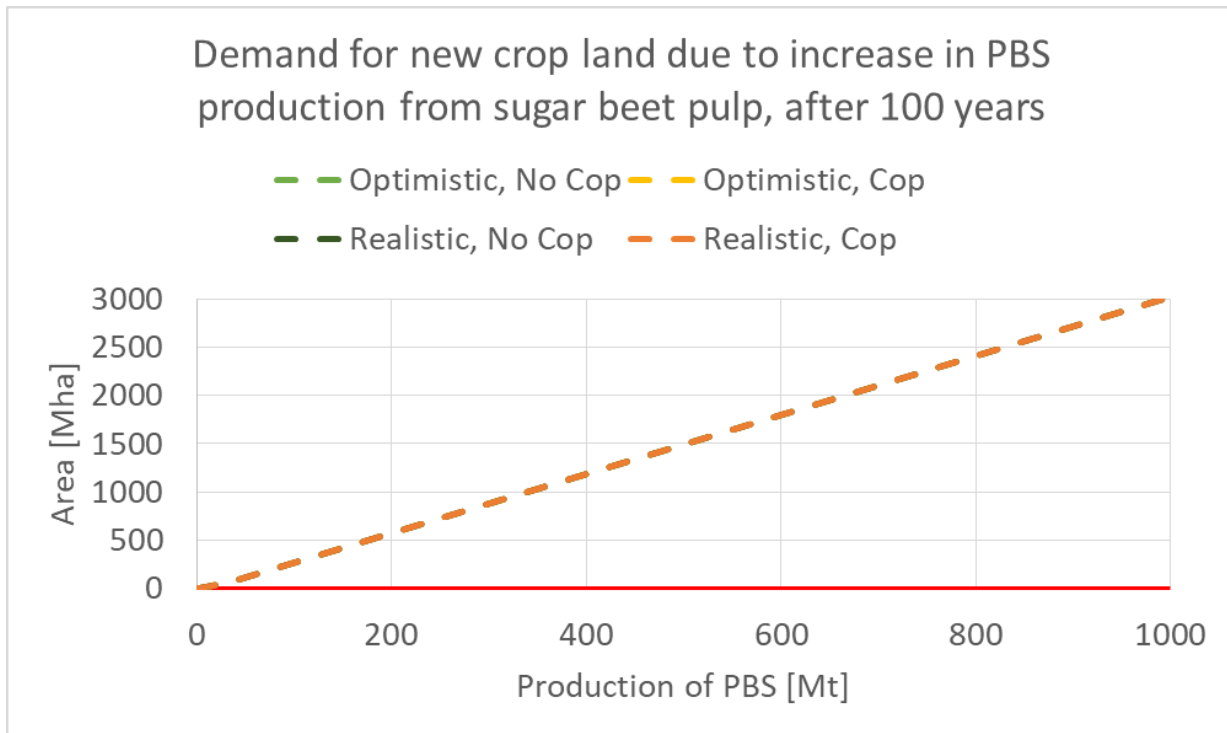


Figure 35 Increase in land demand due to increased production of PBS from sugar beet pulp, with different agricultural yield increase scenarios and with/without use of co-products.

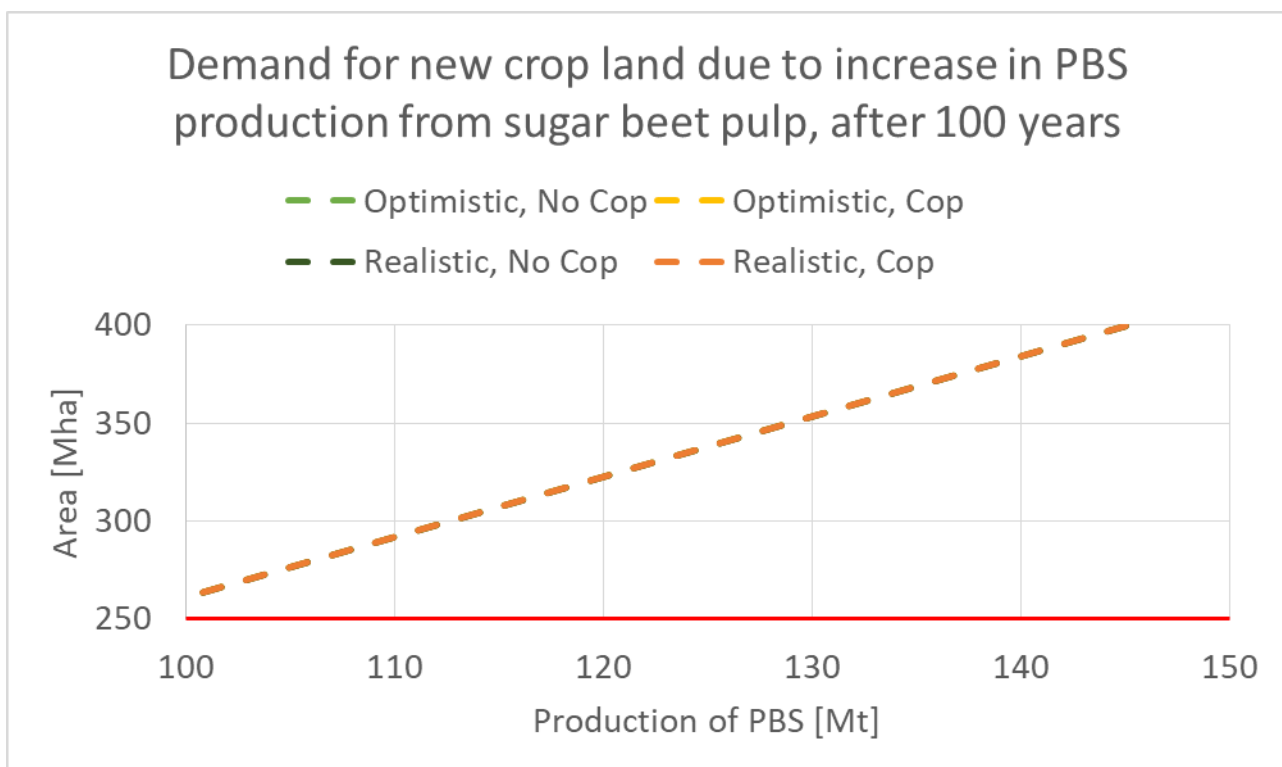


Figure 36 Increase in land demand due to increased production of PBS from sugar beet pulp, with different agricultural yield increase scenarios and with/without use of co-products. Focus on the production level of interest for the substitution of the plastics used in the EU (complete substitution being 173 Mt, projection for 2050).

### 3.3.1.2.1 PLA comparison

Figure 37 shows the comparison between the model predictions for the PLA and the PBS bio-plastic production from sugar beet pulp. Since the dependence on predicted change in land demand on bio-based material target production is insensitive to different agricultural yield scenarios and use of co-products, Figure 37 shows only the realistic scenario with no co-product use for both PLA and PBS. The difference between the two bio-plastics is minimal.

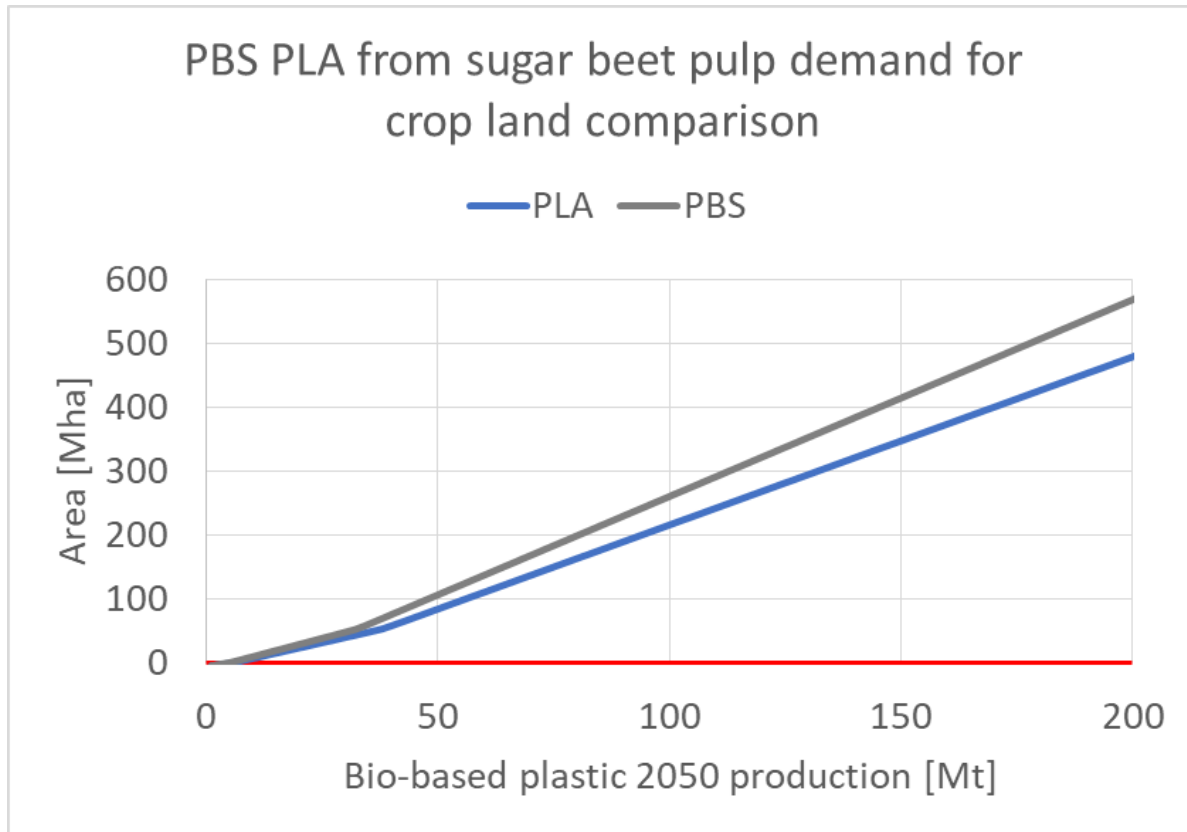
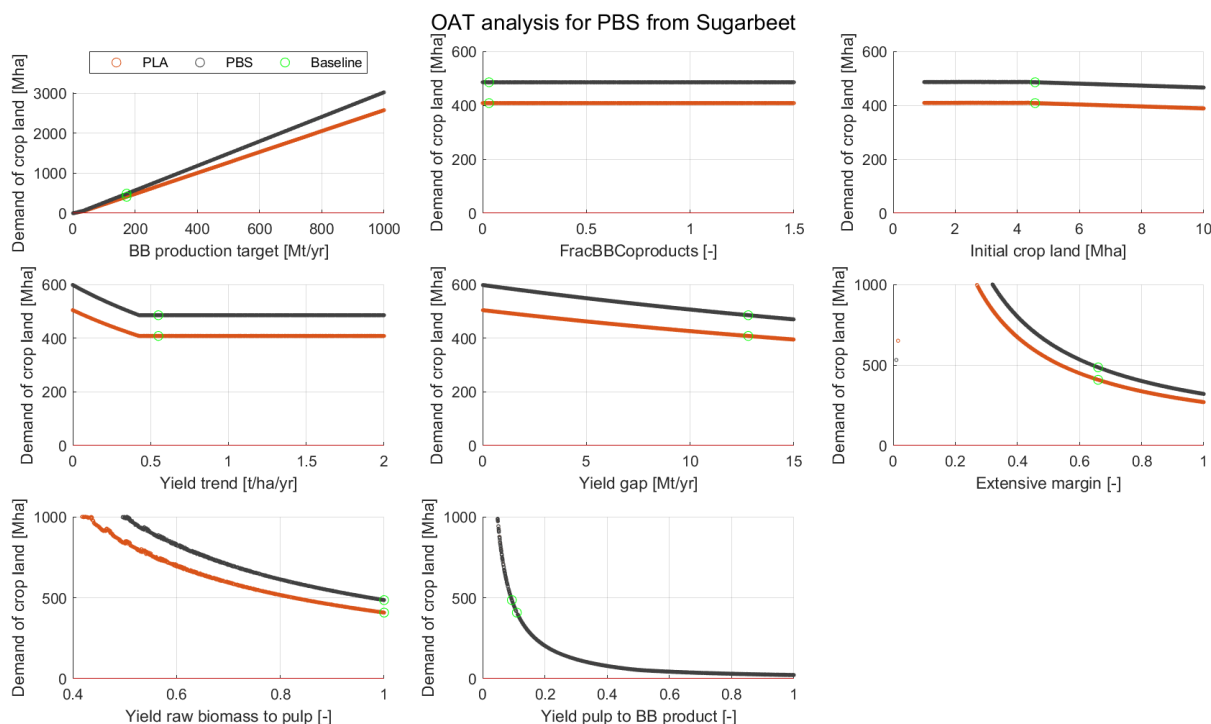


Figure 37 Comparison of the increase in land demand due to increased production of PLA or PBS from sugar beet pulp, with different agricultural yield increase scenarios and with/without use of co-products. Focus on the production level of interest for the substitution of the plastics used in the EU (complete substitution being 173 Mt, projection for 2050).

### 3.3.1.3 Local OAT sensitivity analysis to assess the effect of changing the parameters' values

The OAT analysis (Figure 38) shows why we see no difference between the lines plotted in Figure 35 and Figure 36: the effect of yield trend and fraction of co-products used in the BU sector on the model output is negligible. The initial crop land definition is also not influencing the model output. The yield gap, in the case of sugar beet pulp, instead, shows some influence on the output; looking its behaviour in conjunction with the yield trend shows that the yield trend reaches a maximum effect on the model output around a value of 0.4, then reaches the maximum yield potential for sugar beet, which is defined by the yield gap. The most influential parameter is the yield of bio-plastic obtained from the pulp: an improvement there would have a large effect on the iLUC risk. Since the extensive margin value influences the model output in a non-negligible way, an improvement in the determination of that parameter could decrease the uncertainty in the model output.



*Figure 38 Results of the local OAT for the production of PLA and PBS from sugar beet pulp using SydILUC v35. From top left moving right first, then down a row, the graphics represent the predicted change in land demand with respect to changes in the parameter: a) PLA and PBS policy 2050 production target; b) fraction of co-products obtained for every unit of PLA and PBS; c) initial global agricultural area dedicated to sugar beet cultivation; d) slope coefficient of the sugar beet yield increase in time; e) yield gap of the sugar beet, representing how far global sugar beet yield are from reaching their maximum potential values; f) sugar beet yields when expanding over the actual crop land extension (extensive margin); g) yield of pulp obtained from the sugar beet raw biomass; h) yields of bio-based plastic (PLA and PBS) obtained from sugar beet pulp.*

### 3.3.2 iLUC risk tool (Germany and Russia)

The iLUC risk associated with default production of PLA and PBS from sugar beet produced in Germany and Russia is shown in Table 13. The first thing to note is the difference with iLUC risk levels and predicted demand for land from increased production of PLA and PBS when compared with results for maize (Table 11). The iLUC risk level is much lower for sugar beet pulp than for maize; however, when looking at the demand for land, this is 2-3 orders of magnitude larger. This shows that the iLUC risk calculated is a relative measure of low iLUC risk practices effects, with respect to a certain bio-based material and crop. To compare between different crops and bio-based materials, however, the estimated land demand should be used. In this case, the most promising low iLUC risk strategies are the production on reclaimed land and the increase in yield efficiency. This is due to the relatively small effects of agricultural yields on overall production, as shown in Figure 38.



Table 13 iLUC risk levels obtained using the iLUC risk tool with default values and applying simple low iLUC risk practices. \* = Land use practice changed from "Up and down slope tilling" to "strip cropping, contour".

Country	BB material	Default iLUC risk level	Land demand change [Mha]	Yield increase +0.1 [t ha <sup>-1</sup> yr <sup>-1</sup> ]	Conservative Land Practice *	Production on reclaimed land +1 [Mt yr <sup>-1</sup> ]	Use of co-products = 1	Increase of yield efficiency +0.2
Germany	PLA	B	1791	B	B	A+++		A+++
Russia	PLA	A+++	1433	A+++	A+++	A+++		A+++
Germany	PBS	D	1954	D	D	A+++		A+
Russia	PBS	A	1635	A	A	A+++		A+++



## 4 Conclusions regarding the development of low iLUC risk certification

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Recent adaptations in EU biofuel policies have shown a diversification of strategies regarding iLUC mitigation and the general reduction of potentially negative impacts from EU biofuel policy targets. Consequently, recent approaches aim for a differentiation of the iLUC risks for different feedstocks and pathways. In that sense, EU Directive 2015/1513 has established a cap for biofuels from “conventional” agricultural crops. Furthermore, the recently passed recast of the EU renewable energy directive (RED 2) introduces a differentiation between high and low iLUC risk biomass as well as biomass and biofuels from “additionality” measures, which are also considered as low iLUC risk. The respective classification of a biomass or the corresponding biofuel has an impact on the possibilities for its promotion and supportive framework. While there are specific elements in place for the promotion of low iLUC risk biofuels (e.g. sub-targets), the promotion and options for the use of high iLUC risk biomass have been significantly limited in the RED 2.

A meaningful implementation of this concept into the policy framework for biofuels or even the EU bioeconomy requires appropriate and robust tools, which can be used to make the necessary differentiations regarding iLUC risks and can verify potential claims for low iLUC or additional biomass. Furthermore, it seems important to constantly monitor the effects of the RED 2 framework including, different elements for the differentiation and promotion of biomass and biofuels according to their iLUC risk.

The implementation of this low iLUC risk framework, in close connection with the general sustainability requirements of the RED 2 (including the new criteria for agricultural residues) provides interesting opportunities to foster a general development towards improved land use and gains in productivity in agriculture more generally. This is especially the case, if the logic of this framework would be expanded to the whole EU bioeconomy in the future.

However, robust tools and verification approaches are needed, to support the implementation of this framework and to avoid free riders (i.e. projects certified as low iLUC without introducing effective additionality practices). Otherwise, a low iLUC framework would lose integrity and acceptance and fail to create the necessary incentives for good projects.

STAR-ProBio WP 7 is contributing to this general development, by providing a risk assessment tool, which can be used to support low iLUC risk certification, as well as the development of iLUC mitigation strategies on a producer level. This tool could be integrated in certification schemes and modules for low iLUC risk certification. Furthermore, producers of biomass or bio-based products can use it to understand the potential impact of possible additionality measures on their specific iLUC risk. Based on the outcome of this assessment, a producer might develop strategies regarding the selection and implementation of additionality measures into their operation.

In order to verify potential claims for low iLUC risk biomass or products, appropriate and robust certification approaches are necessary. In general, the concept of low iLUC risk certification has been discussed already for years and first approaches have already been implemented in existing certification schemes (e.g. the RSB). This report summarised existing work and methodologies for the verification of additionality measures aiming at the increase of efficiency in the utilisation of the resources land or biomass as well as the utilisation of currently unused potentials (again land and biomass).



The review of existing approaches shows shortcomings in all available methodologies. Furthermore, existing approaches differ significantly regarding the level of complexity and the potential effort needed for a robust verification. Thus, it seems highly relevant, that the Commission provides more guidance and minimum requirements for low iLUC risk certification than currently included in the existing, respective Delegated Act of the RED 2. Since it seems especially important to avoid the certification of free riders and a potential “race-to-the-bottom”, where existing certification schemes compete on the market with respect to their individual low iLUC risk certification approach, it seems necessary that policy makers define a robust set of “baseline” certification rules. In that sense, it seems important, that out of the existing approaches, a robust set of rules is being selected and defined. This framework of rules needs to be constantly monitored and updated. Comparable to the criteria of GHG mitigation for biofuels, whose methodology and background data is also frequently updated, this approach seems more promising than to wait for a “final” methodology that overcomes all existing shortcomings for low iLUC certification (e.g. the issue of a baseline yield).

The definition of such a framework of certification rules should be able to account for the most relevant additionality measures to be expected. In that sense, especially measures to increase agricultural yields and to use currently unused resources such as residues and wastes as well as unused land seem highly relevant. Especially for the latter, clear definitions are necessary in order to avoid a potential shift of negative impacts into areas of social sustainability or biodiversity. As pointed out already by other authors (e.g. (Malins 2019)), the already existing UM CDM Additionality Tools provide an excellent framework of orientation for the verification of additionality in the certification of projects. The CDM Additionality Tool follows a different objective than additionality demonstration under the EU RED framework. In that sense, the different steps for additionality demonstration need to be adapted (as it seems, also not all of them are relevant (e.g. step 1) to low iLUC risk certification).

In that sense, as a next step, it seems necessary to test the real life implementation of the existing certification approaches, including the iLUC risk tool, in a series of pilot certification projects. Based on these projects, a starting set of rules and guidelines for low iLUC risk certification can be developed.



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## 6 Technical Annex

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### 6.1 Table of additionality practices considered in this report

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Table 14 summarise the iLUC additionality measures addressed in this report with their potential application, guidance for execution, geographical relevance and possible trade-offs by unsustainable implementation. It is designed to get a comprehensive overview of the identified and developed iLUC additionality measures within the WP 7 of STAR-ProBio. In the column Application are possibilities for the implementation and use of the different measures shown. Under Guidance is explained how the measures can be assessed.





Table 14 List of relevant additionality practices with their potential application, guidance for execution, geographical relevance and potential negative trade-offs by unsustainable implementation.

iLUC additionality measures	Supply chain <sup>5</sup>	Application	Guidance	Geographical scope	Potential negative trade-offs <sup>6</sup>	Reference
Increased agricultural crop yield	FP	<b>Examples</b> for yield improvement strategies <ul style="list-style-type: none"> <li>Choice of crop varieties (i.e. higher yielding variety, better adaption to eco-physiological or climatic conditions)</li> <li>Sowing (e.g. improved drilling machine)</li> <li>Soil management (e.g. mulching instead of ploughing, low tillage)</li> <li>Fertilisation (e.g. optimisation of fertilisation, use of better fertiliser)</li> <li>Crop rotation (e.g. change in crop rotation, cultivation of catch crops)</li> <li>Crop protection (i.e. change in weed,</li> </ul>	<b>Historical yield reference:</b> Establishing a reference scenario for specific crop(s) to calculate reference yield calculating a linear trendline based on the historical yields of the last 10 years  After introduction of a yield improvement measure, the actual yields per crop are compared to a reference yield  Above-baseline-yield = low iLUC risk biomass (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016)  <b>Dynamic baseline:</b> Dynamic baseline yield takes average yield of similar producers in a region into account (Malins 2019; RSB 2015)	Regions with low yields caused by a less developed agricultural sector, i.e. developing countries, eastern Europe	Air contamination Biodiversity loss Decrease in native pollinators Decrease in soil quality Decrease in water quality Hazardous impacts of fertilizers and pesticides use to human health and other organisms Increase in GHG emissions Increase in water consumption due to increased irrigation	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; Malins 2019; Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016; RSB 2015)

<sup>5</sup> Feedstock Production (FP); Biomass Conversion (BC) comprises Pre-treatment/ Pre-processing, Conversion, Formulation; Packaging (P) (In accordance to Lokesh, K., Ladu, L., Summerton, L. (2018), 'Bridging the Gaps for a 'Circular' Bioeconomy: Selection Criteria, Bio-Based Value Chain and Stakeholder Mapping', *Sustainability*, Vol. 10, No. 6, p. 1695).

<sup>6</sup> Detailed descriptions and references for the identified potential negative trade-offs are listed in chapter 6.2.



		pest and disease control) • Pollination (e.g. by using bees) • Harvest (e.g. new harvest machine, harvest at optimal time) • Precision farming	<b>Regional assessment approach:</b> Calculation of the land demand reduction (ha) that results from applying an above-baseline yield increase for crops, applying an improved yield growth rate (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)			
<b>Specific yield increase measure: multicropping</b>	FP	Two <b>main types</b> of multi-cropping • Intercropping • Sequential cropping	Calculating a reference scenario for a mono-crop (according to increased crop yield)  Calculating above-reference biomass • Crop component approach • Forage Unit (FU) approach	EU and regions with low yields caused by a less developed agricultural sector, i.e. developing countries, eastern Europe	Same as increased agricultural crop yield	(Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016)
<b>Biomass cultivation on unused land</b>	FP	<b>Definition according to Delegated Act complementing EU RED 2:</b> Areas, which were not used for cultivation of food and feed crops, other energy crops or fodder for grazing animals for a period of at least 5 years before the start of cultivation of the feedstock used for the production of biofuels, bioliquids	Establishing the reference scenario or situation for unused land  Requirements to <b>demonstrate unused land reference</b> (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016): • Regulatory assessment • Legal right to use the land	Various regions globally	Biodiversity loss  Decrease in rural development and participation of local people  Decrease in soil quality  Decrease in water availability  Decrease in water quality	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; European Commission 2019; Peters, Spöttle, Hähl, Kühner, Cuijpers,



		and biomass fuels, e.g. degraded land, marginal land, abandoned agricultural land	<ul style="list-style-type: none"> <li>No traditional and /or customary land use rights</li> <li>Remote sensing analysis determines the land cover and land use during the past five years</li> </ul> <p><b>Quantification approaches:</b></p> <p>Calculation with the <b>actual amount</b> of harvested feedstock (RSB 2015)</p> <p>Calculation with a <b>projected yield</b> and a marginal yield factor for regional low iLUC projects (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)</p>		<p>High costs to rehabilitate degraded land</p> <p>Increase in GHG emissions</p> <p>Land grabbing</p>	Stomph, van der Werf, Grass 28. November 2016)
Increased livestock production efficiencies	FP	<ul style="list-style-type: none"> <li>Increase in <b>livestock efficiency</b> on meadow and pasture land</li> <li>Growth in <b>cattle product yield</b> (higher meat or milk production per animal per year)</li> <li>Increase <b>pasture productivity</b> ( e.g. fertilization or introduction of higher productivity grasses)</li> </ul>	<p>Calculation of a land demand reduction (ha) that results from applying an above-baseline scenario for cattle density and/or productivity</p> <p>Based on land demand reduction (ha), amount of low iLUC risk biomass can be determined</p>	Regions with a large amount of land-based animal husbandry under the conditions of low animal density per area and productivity per animal	<p>Biodiversity loss</p> <p>Decreased food security for livestock producing households</p> <p>Decrease in human health</p> <p>Increased threats to animal welfare</p> <p>Increase in air pollution</p>	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012, 2012)



		<ul style="list-style-type: none"> <li>• Improved <b>feeding practices</b> (e.g. partially replacing forage with more concentrated fodder and higher protein diets)</li> <li>• <b>Landless</b> livestock production</li> </ul>			<p>Increase in animal diseases and antibiotic resistance</p> <p>Increase in gender inequality due to increased livestock productivity</p> <p>Increase in GHG emissions due to intensive livestock production</p> <p>Increase in soil degradation and erosion</p> <p>Increase in water consumption due to crop-based feed production</p> <p>Increase in water pollution</p> <p>Loss of smallholder farm structures and employment opportunities for local people</p>	
Improved by-products integration	FP BC	<u>Feedstock production:</u> Use of <b>by-products</b> from crop production, like crop residues, e.g.: <ul style="list-style-type: none"> <li>• Wheat straw</li> <li>• Corn stover, cobs</li> </ul>	<b>Regional assessment approach</b> (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015): Assessment of the amount of residues generated with the crop yield and area under	Various regions globally	Biodiversity loss due to removal of crop residues  Decrease in material (residues) useable by	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015; RSB



	<ul style="list-style-type: none"> <li>• Sugarcane leaves</li> <li>• Thrash</li> <li>• Bark branches and leaves</li> </ul> <p><u>Biomass conversion:</u> Use of <b>by-products</b> from crop processing and biofuel production, e.g.:</p> <ul style="list-style-type: none"> <li>• DGS (distiller grain solubles)</li> <li>• Glycerine</li> <li>Oilseed meal</li> </ul>	<p>crop cultivation as well as the share available for removal</p> <ul style="list-style-type: none"> <li>• Residue-to-product ratio (RPR)</li> <li>• Sustainable removal fraction (SRF)</li> </ul> <p>or</p> <p>Assessment of the amount of co-products from biofuel production</p> <p>Assessment of the potential use of by-products and the rate at which they can replace other products:</p> <ul style="list-style-type: none"> <li>• e.g. amount of second generation biofuels</li> <li>• e.g. amount of feed crops saved by substituting them with biofuel co-product</li> </ul> <p>Calculation of land demand reduction (ha) results from using by-products</p> <p>Alternative approaches for <b>residue integration</b> similar to increasing use of waste (RSB 2015; Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staaij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012)</p>		<p>smallholder households for cooking, energy generation, etc.</p> <p>Decrease in on-farm produced fodder from residues</p> <p>Decrease in soil fertility</p> <p>Decrease in water quality</p> <p>Increased energy use and GHG emissions</p> <p>Increase in soil degradation and erosion</p> <p>Increase in water consumption due to water intense biomass conversion</p> <p>Increase of hazardous components in products</p> <p>Increase of synthetic fertilizer use can increase costs and</p>	<p>2015; Spöttle, Alberici, Toop, Peters, Gamba, Ping, van Steen, Bellefleur 4. September 2013; van de Staaij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012)</p>
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					environmental implications	
					Pollution of the environment by chemicals used for pre-treatment of residues	
<b>Reduction in biomass losses</b>	FP BC P	<u>Feedstock production:</u> Reduction of <b>food losses</b> in transport, storage, (un)loading, etc., especially avoidance or reduction of <b>post-harvest losses</b>  <u>Biomass conversion:</u> Increasing <b>conversion and processing</b> efficiencies (e.g. through biorefinery concepts)	Assessment of the land demand reduction (ha) generated from efficiency improvements by calculating the amount of crop prevented from being lost due to efficiency improvements in the food chain, e.g. post-harvest losses	High potential for improvement in developing countries  Still potential for improvement in industrialized countries	Chemical postharvest treatments can contaminate the environment and threat human health  Increase in materials used for storage options  Increase in energy demand and GHG emissions  Increase in labour hours per worker or farmer  Increase in packaging and related resource use  Rebound effect	(Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015)
<b>Increasing use of waste</b>	FP BC	<b>Usable surplus</b> of a waste (or residues), e.g.: • Cereal straw	Assessment of the iLUC-free potential of wastes (and residues)	Various regions globally	Increased energy use and related GHG emissions	(Spöttle, Alberici, Toop, Peters,



		<ul style="list-style-type: none"> <li>• Corn cobs</li> <li>• Bark, branches and leaves</li> <li>• Animal fats</li> <li>• Used cooking oils (UCO)</li> <li>• Sawdust and cutter shavings</li> </ul>	<ul style="list-style-type: none"> <li>• Is the material a waste (or residue) (and not a by-product or a product)?</li> <li>• Available quantity of the material which is not already used for other purposes (food, animal feed, oleochemicals etc.) in a certain region (feedstock-region-combination)</li> <li>• Establishment of a waste (and residue) positive list</li> </ul> <p>Introduction of a maximum removal rate for primary land-using agricultural and forestry wastes and residues with specification at regional or national scale</p>		<p>Increase in expenditures for the separation of organic waste fraction</p> <p>Transmission of hazardous substances</p>	<p>Gamba, Ping, van Steen, Bellefleur 4. September 2013) (van de Staaij, Peters, Dehue, Meyer, Schueler, Toop, Junquery, Máthé 2012)</p>
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## 6.2 Potential negative trade-offs of the additionality practices

### 6.2.1 Increased agricultural crop yield

*Table 15 Negative trade-offs potentially resulting from the unsustainable application of the additionality practice increased agricultural crop yield*

Trade-off	Description	References
<b>Air contamination</b>	Air contamination by increased pesticides use as well as NO emissions, tropospheric smog and ozone caused by increased fertilizer application.	(Gerssen-Gondelach, Wicke, Faaij 2017; Hickman, Huang, Wu, Diru, Groffman, Tully, Palm 2017; Huang, Hickman, Wu 2018; Liu, Pan, Li 2015)
<b>Biodiversity loss</b>	Loss in biodiversity caused by increased fertilizer uses, the expansion of monocultures, and conventional intensification can effect species not only in croplands but also in surrounding habitats.	(Beckmann, Gerstner, Akin-Fajiyé, Ceaşu, Kambach, Kinlock, Phillips, Verhagen, Gurevitch, Klotz, Newbold, Verburg, Winter, Seppelt 2019; Gerssen-Gondelach, Wicke, Faaij 2017; Liu, Pan, Li 2015; Wingeyer, Amado, Pérez-Bidegain, Studdert, Varela, Garcia, Karlen 2015; Zabel, Delzeit, Schneider, Seppelt, Mauser, Václavík 2019)
<b>Decrease in native pollinators</b>	Decrease in native pollinator diversity and pollination services due to high fertilizer application.	(Deguines, Jono, Baude, Henry, Julliard, Fontaine 2014; Ramos, Bustamante, Silva, Carvalheiro 2018)
<b>Decrease in soil quality</b>	Decreased soil functionality caused by increased fertilizer use, inefficient fertilizer and pesticides use, over-fertilized soils, impact of monocultures on soil degradation through wind and water erosion, SOM depletion and nutrient loss, and intensive irrigation increases soil acidification as well as land degradation and erosion.	(Gerssen-Gondelach, Wicke, Faaij 2017; Gregory, Ingram, Andersson, Betts, Brovkin, Chase, Grace, Gray, Hamilton, Hardy, Howden, Jenkins, Meybeck, Olsson, Ortiz-Monasterio, Palm, Payn, Rummukainen, Schulze, Thiem, Valentin, Wilkinson 2002; Ju, Xing, Chen,



		Zhang, Zhang, Liu, Cui, Yin, Christie, Zhub, Zhan 2009; Lambin, Meyfroidt 2011; Liu, Pan, Li 2015; Smith, House, Bustamante, Sobocká, Harper, Pan, West, Clark, Adhya, Rumpel, Paustian, Kuikman, Cotrufo, Elliott, McDowell, Griffiths, Asakawa, Bondeau, Jain, Meersmans, Pugh 2016; Tian, Lu, Melillo, Ren, Huang, Xu, Liu, Zhang, Chen, Pan, Liu, Reilly 2012; Wingeyer, Amado, Pérez-Bidegain, Studdert, Varela, Garcia, Karlen 2015)
<b>Decrease in water quality</b>	Increased fertilizer and pesticides use cause eutrophication of surface waters (particularly fresh water streams and coastal seas) and the degradation of downstream water quality.	(Gerssen-Gondelach, Wicke, Faaij 2017; Liu, Pan, Li 2015; Westarp, Schreier, Brown, Shah 2004; Withers, Edwards, Foy 2001)
<b>Hazardous impacts of fertilizers and pesticides use to human health and other organisms</b>	Elevated levels and increased leaching of pesticides pose risk on environment, humans and other organisms. Application of organic waste and by-products as agricultural soil amendments can bear risks for environmental and human health	(Gerssen-Gondelach, Wicke, Faaij 2017; Liu, Liu, Pan, Li 2012; Liu, Pan, Li 2015; Urrea, Alkorta, Garbisu 2019)
<b>Increase in GHG emissions</b>	Increase in GHG emissions, e.g. nitrous oxide (N <sub>2</sub> O) due to increased fertilizer use, mechanization and cultivation of groundwater-irrigated crops.	((Brinkman, Wicke, Faaij 2017); (Hickman, Tully, Groffman, Diru, Palm 2015); (McGill, Hamilton, Millar, Robertson 2018); (Smith, Haberl, Popp, Erb, Lauk, Harper, Tubiello, Siqueira Pinto, Jafari, Sohi, Masera, Böttcher, Berndes, Bustamante, Ahammad, Clark, Dong, Elsiddig, Mbow, Ravindranath, Rice, Robledo Abad, Romanovskaya, Sperling, Herrero, House, Rose 2013))



<b>Increase in water consumption due to increased irrigation</b>	Intensification in irrigation causes over-use of groundwater and increases the risk of groundwater deficiencies and droughts. Heavy irrigation in arid areas will produce salinization and water scarcity that can appear in regions, which depend on stored water reserves (aquifers).	(Darré, Cadenazzi, Mazzilli, Rosas, Picasso 2019; Gerssen-Gondelach, Wicke, Faaij 2017; Gregory, Ingram, Andersson, Betts, Brovkin, Chase, Grace, Gray, Hamilton, Hardy, Howden, Jenkins, Meybeck, Olsson, Ortiz-Monasterio, Palm, Payn, Rummukainen, Schulze, Thiem, Valentin, Wilkinson 2002; Pei, Scanlon, Shen, Reedy, Di Long, Liu 2015; Spiertz 2013)
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## 6.2.2 Biomass cultivation of unused land

*Table 16 Negative trade-offs potentially resulting from the unsustainable application of the additional practice biomass cultivation on unused land*

Trade-off	Description	References
<b>Biodiversity loss</b>	Biodiversity loss due to the conversion of abandoned, degraded or marginal lands as well as extensive pastures, buffer zones, ecological corridors and wildlife habitats with a high biodiversity value. Often, these unused land types have been already set-aside for a long period or have been traditionally excluded from agriculture so that rare species and rare habitats are frequently found. Large-scale cultivation of crops is a threat to many areas that have already been fragmented and degraded, are rich in biodiversity and provide habitat for many endangered and endemic species	(Beringer, Lucht, Schaphoff 2011; Cherubin, Karlen, Cerri, Franco, Tormena, Davies, Cerri 2016; Delzeit, Zabel, Meyer, Václavík 2017; Gerssen-Gondelach, Wicke, Faaij 2017; Gerwin, Repmann, Galatsidas, Vlachaki, Gounaris, Baumgarten, Volkmann, Keramitzis, Kiourtsis, Freese 2018; Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Meyfroidt, Schierhorn, Prishchepov, Muller, Kuemmerle 2016; Miyake, Smith, Peterson, McAlpine,



		Renouf, Waters 2015; Pedroli, Elbersen, Frederiksen, Grandin, Heikkilä, Krogh, Izakovičová, Johansen, Meiresonne, Spijker 2013; Verdade, Piña, Rosalino 2015)
<b>Decrease in rural development and participation of local people</b>	Large farms (agroholdings) investing in labour-saving technologies and contributing little to overall employment and livelihood opportunities in rural areas.	(Meyfroidt, Schierhorn, Prishchepov, Muller, Kuemmerle 2016)
<b>Decrease in soil quality</b>	The conversion of abandoned, marginal and degraded land into agricultural used cropland, can threat soil quality, like a higher soil compaction and structural degradation as well as lower soil organic carbon (SOC) and soil organic matter (SOM) content leading to soil erosion; The cultivation can increase the nitrogen load due to the higher levels of fertilizer use. Intensive high-yielding biomass plantations on lands with sparse vegetation (e.g. degraded pastures) can salinize or acidify soils.	(Cherubin, Karlen, Cerri, Franco, Tormena, Davies, Cerri 2016; Lal 2005; Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Love, Nejadhashemi 2011; Manuel-Navarrete, Gallopín, Blanco, Díaz-Zorita, Ferraro, Herzer, Laterra, Murmis, Podestá, Rabinovich, Satorre, Torres, Viglizzo 2009; Qiu, Huang, Keyzer, van Veen, Rozelle, Fisher, Ermolieva 2011; Smith, Haberl, Popp, Erb, Lauk, Harper, Tubiello, Siqueira Pinto, Jafari, Sohi, Maser, Böttcher, Berndes, Bustamante, Ahammad, Clark, Dong, Elsiddig, Mbow, Ravindranath, Rice, Robledo Abad, Romanovskaya, Sperling, Herrero, House, Rose 2013; Turner, Wuellner, Malo, Herrick, Dunn, Gates 2018; Verdade, Piña, Rosalino 2015; Wingeyer, Amado, Pérez-Bidegain, Studdert, Varela, Garcia, Karlen 2015)



<b>Decrease in water availability</b>	High-yielding biomass plantations on lands with sparse vegetation (e.g. degraded pastures) can reduce downstream water availability. Water scarcity can occur in regions that depend on stored water reserves (aquifers)	(Smith, Haberl, Popp, Erb, Lauk, Harper, Tubiello, Siqueira Pinto, Jafari, Sohi, Masera, Böttcher, Berndes, Bustamante, Ahammad, Clark, Dong, Elsiddig, Mbow, Ravindranath, Rice, Robledo Abad, Romanovskaya, Sperling, Herrero, House, Rose 2013; Spiertz 2013)
<b>Decrease in water quality</b>	Conversion of abandoned, degraded or marginal land to agricultural cropland can threaten the quality of water resources, because crops can require greater fertilization, which can emit higher levels of nitrogen into surface waters causing eutrophication	(Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Miyake, Smith, Peterson, McAlpine, Renouf, Waters 2015; Qiu, Huang, Keyzer, van Veen, Rozelle, Fisher, Ermolieva 2011)
<b>High costs to rehabilitate degraded land</b>	High expenditures to rehabilitate unused land, such as soils affected by salinization or chemical contamination, or lands whose use is impeded by invasive species.	(Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013)
<b>Increase in GHG emissions</b>	Increase in GHG emissions from the conversion of land with larger carbon stocks to cropland, like abandoned land or extensively managed (grass) land. Fertilization of crops emit higher levels of nitrous oxide.	(Brinkman, van der Hilst, Faaij, Wicke 2018; Gerssen-Gondelach, Wicke, Faaij 2017; Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Meyfroidt, Schierhorn, Prishchepov, Muller, Kuemmerle 2016; Qiu, Huang, Keyzer, van Veen, Rozelle, Fisher, Ermolieva 2011)



<b>Land grabbing</b>	<p>Displacement of impoverished and foodinsecure people can be caused, if large-scale agribusinesses take land into production. Especially, tropical savannahs are used extensively by smallholders and pastoralists, who can be bereaved by the cultivation of unused and marginal land, because they usually do not produce profit but rather products for subsistence (marginal land) and because they are mobile, and thus rather autonomous and not easily to be captured as state subjects (unused land). Shifting cultivation can easily be classified as abandoned or unused land.</p>	<p>(Exner, Bartels, Windhaber, Fritz, See, Politti, Hochleithner 2015; Kitchell 2014; Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri, Munger 2013; Paz, Jara, Wald 2019)</p>
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### 6.2.3 Increase in livestock production efficiencies

*Table 17 Negative trade-offs potentially resulting from the unsustainable application of the additionality practice increase in livestock production efficiencies*

Trade-off	Description	References
<b>Biodiversity loss</b>	Intensification in livestock production can cause biodiversity loss by planting of crops for animal feed, conversion of natural land to pastures (including deforestation), introduction of exotic fodder plants, use of fire for pasture management, overgrazing, persecution of livestock predators and wild animal types of livestock, whereas ecosystems converted to cropland for livestock feed have the greatest negative impacts on biodiversity. In traditionally biodiverse grasslands, monocultural pasture and high use of fertilizers present risks to biodiversity and ecosystem stability, whereas grassland homogeneity can decrease species diversity and richness. Particularly, grazing-based dairy systems have an opportunity cost in that more land devoted to pasture means less overall land that could be set aside for nature conservation	(Battini, Agostini, Tabaglio, Amaducci 2016; Cederberg, Mattsson 2000; Dross, Princé, Jiguet, Tichit 2018; FAO 2006, 2016; Lucia, Pazienza, Vecchione 2017; Otte, Costales, Dijkman, Pica-Ciamarra, Robinson, Ahuja, Ly, Roland-Holst 2012)
<b>Decreased food security for livestock producing households</b>	Intensified livestock productivity can have negative impacts on the food security of livestock producing households. For example, in developing regions women's workloads can increase, resulting in less time spent with young children. This might cause negative effects on child nutrition during intermediate stages; or a greater reliance on processed feed crops rather than natural pastures to raise livestock; or high supplemental feed costs, marginalizes net household income, and promotes larger flock sizes.	(Briske, Zhao, Han, Xiu, Kemp, Willms, Havstad, Le Kang, Wang, Wu, Han, Bai 2015; Njuki, Wyatt, Baltenweck, Yount, Null, Ramakrishnan, Webb Girard, Sreenath 2016; Salmon, Teufel, Baltenweck, van Wijk, Claessens, Marshall 2018)





<b>Decrease in human health</b>	Intensive livestock production systems can present direct risks to human health through acute and chronic soil, air, and water pollution as well as by increasing exposure to zoonotic diseases, pathogens, and exacerbating risk of antimicrobial resistance.	(Wing, Wolf 2000)
<b>Increased threats to animal welfare</b>	A rapid intensification in the dairy sector can have considerable impacts on animals' physical and mental well-being, particularly in high-income countries, where measures to improve productivity deliver only moderate gains, often at the expense of animal welfare. For example, in intensive production systems, cows often lack freedom to perform natural behaviours of grazing, reproducing, and socializing in pasture but instead live in housing regimes that constrain movement and that require animals to stand on concrete floors for extended periods. Particularly breeding cows for higher productivity exacerbates physical and emotional stress, decreasing their welfare. Management strategies that aim to optimize milk productivity can negatively affect animals' life cycles. For example, in intensive operations, cows are artificially inseminated again shortly after they have given birth to a calf, and then slaughtered after only a few pregnancy-lactation periods. Additionally, the lower levels of interaction between cows and stockmen that are common on intensive farms can increase the risk that animal welfare issues go unnoticed.	(Burton, Peoples, Cooper 2012; Haskell, Rennie, Howell V.A., Bell, Lawrence 2006; Keyserlingk, Rushen, Passillé, Weary 2009; Keyserlingk, Weary 2017; LeBlanc, Lissemore, Kelton, Duffield, Leslie 2006; Oltenacu, Broom 2010)
<b>Increase in air pollution</b>	Intensification in livestock productivity can increase the effluent air pollution. This can be caused by ammonia emissions mainly from deposited and applied manure (e.g. odour), the manufacturing of chemical fertilizers, the use of fossil fuels for transportation, an increase in volatile organic compounds (mainly from animal excreta) and emissions of nitrogen oxides (NO <sub>x</sub> ), which are associated with the production of brought-in feeds and transportation of off-farm inputs.	(Chobtang, Ledgard, McLaren, Donaghy 2017; FAO 2006; Otte, Costales, Dijkman, Pica-Ciamarra, Robinson, Ahuja, Ly, Roland-Holst 2012)



<b>Increase in animal diseases and antibiotic resistance</b>	Animals of intensive livestock systems (i.e. dairy production) show a higher prevalence of lameness and other (infectious) diseases as well as an increasing risk of antibiotic resistance.	(Koeck, Loker, Miglior, Kelton, Jamrozik, Schenkel 2014; Thornton 2010)
<b>Increase in gender inequality due to increased livestock productivity</b>	Increased livestock productivity bear the risk of increasing rather than reduced gender inequalities, because as livestock systems become more productive and increase in income generation, they can be more economically attractive to men and women lose control of assets and associated incomes.	(Alston, Clarke, Whittenbury 2017; Salmon, Teufel, Baltenweck, van Wijk, Claessens, Marshall 2018)
<b>Increase in GHG emissions due to intensive livestock production</b>	Intensification in livestock production is characterised by a high-energy demand and global warming potential (GWP). Whereas, carbon dioxide (CO <sub>2</sub> , via energy use and land use change), nitrous oxide (N <sub>2</sub> O, from feed production and excreta), methane (CH <sub>4</sub> , enteric and from manure) and NH <sub>3</sub> (production of brought-in feeds, agrichemicals (i.e. chemical fertilizers and pesticides) and transportation of off-farm inputs) are the main contributors to increases in GHG emissions.	(Berton, Cesaro, Gallo, Pirlo, Ramanzin, Tagliapietra, Sturaro 2016; Chobtang, Ledgard, McLaren, Donaghy 2017; Clay, Garnett, Lorimer 2019; FAO 2006; Mogensen, Kristensen, Nielsen, Spleth, Henriksson, Swensson, Hesse, Vestergaard 2015; Otte, Costales, Dijkman, Pica-Ciamarra, Robinson, Ahuja, Ly, Roland-Holst 2012)
<b>Increase in soil degradation and erosion</b>	Intensification in livestock production systems can cause soil erosion and land degradation, especially heavy grazing of structurally unstable soils under wet conditions and with low cover can increase soil strength and bulk density and reduce macro-porosity and infiltration rate.	(Bell, Kirkegaard, Swan, Hunt, Huth, Fettel 2011; FAO 2006; Otte, Costales, Dijkman, Pica-Ciamarra, Robinson, Ahuja, Ly, Roland-Holst 2012)
<b>Increase in water consumption due to crop-based feed production</b>	An intensified livestock production can increase the use of water, mainly used for feed production (e.g. in the beef production).	(FAO 2006; Legesse, Cordeiro, Ominski, Beauchemin, Kroebe, McGeough, Pogue, McAllister 2018; McAuliffe, Takahashi, Mogensen, Hermansen, Sage, Chapman, Lee 2017)



<b>Increase in water pollution</b>	Intensification of livestock production can pollute river system, shallow aquifers and decreasing the quality of freshwater, causing eutrophication and acidification by emission of $\text{NH}_3$ , $\text{NO}_x$ and leaching or run-off of Nitrate ( $\text{NO}_3^-$ ) and $\text{PO}_4^{3-}$ mainly from the use of fertilizers (organic and inorganic), like deposited and applied manure; besides by pesticides, antibiotics and heavy metals.	(Battini, Agostini, Tabaglio, Amaducci 2016; Chobtang, Ledgard, McLaren, Donaghy 2017; FAO 2006; McAuliffe, Takahashi, Mogensen, Hermansen, Sage, Chapman, Lee 2017; Scarsbrook, Melland 2015; Vries, Boer 2010; Zhang, Bai, Luo, Ledgard, Wu, Ma 2017)
<b>Loss of smallholder farm structures and employment opportunities for local people</b>	Intensification in livestock production can cause loss of smallholder farm structures due to price competition, the replacement of traditional skills and ways of life with a corporate mind set. Additional, trading regimes can undermine small-scale production. The maximization of livestock revenue incurs high supplemental feed costs, marginalizes net household income, and promotes larger flock sizes. Furthermore, cost savings that are achieved in more intensive operations can in part be attributed to lower human labour input, which generally results in losses of employment for family and non-family dairy workers.	(Briske, Zhao, Han, Xiu, Kemp, Willms, Havstad, Le Kang, Wang, Wu, Han, Bai 2015; Clay, Garnett, Lorimer 2019; Davidson 2002)



#### 6.2.4 Improved by-products integration

*Table 18 Negative trade-offs potentially resulting from the unsustainable application of the additionality practice improved by-products integration*

Trade-off	Description	References
<b>Biodiversity loss due to removal of crop residues</b>	Risks of additional biodiversity loss for all crops exist, if expansion and intensification of monocultures are undertaken to generate additional residues for energy or material purposes. Especially, harvesting crop residues can have strong adverse impacts on the activity and species diversity of the soil fauna.	(Lal 2009; Terrapon-Pfaff 2012)
<b>Decrease in material (residues) useable by smallholder households for cooking, energy generation, etc.</b>	Removal and use of residues can decrease the amount of material used by smallholder households for cooking and energy generation, especially in developing regions.	(Vitali, Parmigiani, Vaccari, Collivignarelli 2013)
<b>Decrease in on-farm produced fodder from residues</b>	Where residues are an integral part of livestock feeding, farmers need to buy external feed. Thus, the removal of crop residues can cause limited availability of domestically produced fodder on a farm, especially for smallholders.	(Beuchelt, Camacho Villa, Göhring, Hernández Rodríguez, Hellin, Sonder, Erenstein 2015; Hellin, Erenstein, Beuchelt, Camacho, Flores 2013; Klapwijk, van Wijk, Rosenstock, van Asten, Thornton, Giller 2014; Sapkota, Aryal, Khatri-Chhetri, Shirsath, Arumugam, Stirling 2018)



<b>Decrease in soil fertility</b>	Removal of crop residues can lead to a decline in soil fertility and quality as well as a reduction in agronomic productivity, characterised by a decline in SOM content, recycling of plant nutrients and sequestering soil carbon.	(Cardoen, Joshi, Diels, Sarma, Pant 2015; Karlsson, Börjesson, Hansson, Ahlgren 2014; Klapwijk, van Wijk, Rosenstock, van Asten, Thornton, Giller 2014; Lal 2005, 2009; Torma, Vilček, Lošák, Kužel, Martensson 2017; Valbuena, Tui, Erenstein, Teufel, Duncan, Abdoulaye, Swain, Mekonnen, Germaine, Gérard 2015)
<b>Decrease in water quality</b>	Harvesting crop residues as feedstock, e.g. for biofuels can jeopardize water resources, characterised by a declined water retention, water infiltration rate and water in the root zone as well as an increase in water runoff.	(Lal 2009)
<b>Increased energy use and GHG emissions</b>	Increased GHG emissions can be caused by the utilization of by-products or residues like e.g. bagasse and sugarcane residues at the feedstock processing. Higher energy usage (e.g. fossil fuels) due to by-products generation or additional residue collection operations lead to higher GHG emissions. Additionally, residue removal can cause a decreasing SOC, which can lead to a loss in carbon stocks.	(Hansen, Budde, Prochnow 2016; Khatiwada, Leduc, Silveira, McCallum 2016; Meul, Ginneberge, van Middelaar, Boer, Fremaut, Haesaert 2012; Monteleone, Garofalo, Cammerino, Libutti 2015; Sampaio, Cardoso, Souza, Watanabe, Carvalho, Bonomi, Junqueira 2019; Zijlstra, Beltranena 2013)
<b>Increase in soil degradation and erosion</b>	Harvesting crop residues can have strong adverse impacts on soil quality, like an increased risk of erosion by water and wind, organic matter depletion and structural degradation. Especially, already fragile and poor soils can be threatened by the removal of residue.	(Huffman, Coote, Green 2012; Lal 2009; Valbuena, Tui, Erenstein, Teufel, Duncan, Abdoulaye, Swain, Mekonnen, Germaine, Gérard 2015)
<b>Increase in water consumption due to water intense biomass conversion</b>	Conversion pathways of particular residues like biogas recovery or the pre-treatment of empty oil palm fruit bunches using hot water to produce animal feed and ethanol need considerable amounts of water.	(Terrapon-Pfaff 2012; Vaskan, Pachón, Gnansounou 2018)



<b>Increase of hazardous components in products</b>	The improved integration of residues and by-products in the production chain, like in biorefinery concepts can lead to products where specific harmful components are up-concentrated to undesirable levels in relation to safety of the products produced.	(Lange, Meyer 2019)
<b>Increase of synthetic fertilizer use can increase costs and environmental implications</b>	The removal of residues can lead to an increasing use of synthetic fertiliser to be applied to compensate the nutrients removed with the residue, like straw, which can increase the expenditures for the fertilizer by the farmer.	(Gabrielle, Gagnaire 2008; Torma, Vilček, Lošák, Kužel, Martensson 2017)
<b>Pollution of the environment by chemicals used for pre-treatment of residues</b>	Pre-treatment of residues like empty oil palm fruit bunches using chemicals, like dilute acid to produce animal feed and ethanol can cause severe environmental disadvantages due to the large consumption of chemicals.	(Vaskan, Pachón, Gnansounou 2018)

## 6.2.5 Reduction in biomass losses

*Table 19 Negative trade-offs potentially resulting from the unsustainable application of the additionality practice reduction in biomass losses*

Trade-off	Description	References
<b>Chemical postharvest treatments can contaminate the environment and threat human health</b>	Increased use of synthetic insecticides for pest control in grain storage as well as the storage facility disinfection, by application of chemicals on the surroundings, walls, floor and roof to kill or keep away storage pests such as insects and rodents, can contaminate the environment and threat human health. Thus, it can increase the presence of toxic residue in food products, the toxicity against non-target species, the development of genetic resistance by targeted species, a high persistence and its associated environmental pollution, the direct toxicity to users as well as the increased risk to workers safety.	(Chegere 2018; Harish, Nataraja, Ajay, Holajjer, Savaliya, Gedia 2014; Hiruy, Getu 2018; Kostyukovsky, Trostanetsky, Quinn 2016; Kumar, Kalita 2017; Mahajan, Caleb, Singh, Watkins, Geyer 2014)
<b>Increase in materials used for storage options</b>	Increase material use due to advanced storage facilities, e.g. metallic or plastic silos and polythene bags for insect pest control in grain storage, controlled atmosphere storage or ripening chambers.	(HLPE June 2014; Kumar, Kalita 2017; Tefera, Kanampiu, Groote, Hellin, Mugo, Kimenju, Beyene, Boddupalli, Shiferaw, Banziger 2011)



<b>Increase in energy demand and GHG emissions</b>	Increase in energy demand and related GHG emissions due to technics to enhance durability of food, e.g. temperature control in perishable products' cold chains and refrigeration. Postharvest emissions added from cold chain operations can be larger than food loss emissions avoided. Additionally, dietary shifts facilitated by refrigeration may increase GHG emissions. Post-harvest and transport stages are hot-spot stages for energy demand and climate impact, especially packaging activities at post-harvest stage as well as grain drying before and during storage can contribute to environmental burden. Better infrastructure and increase in transportation to connect smallholders to markets can increase the fuel consumption at the transport stage.	(Bosona, Gebresenbet 2018; Heard, Miller 2019; HLPE June 2014; Hodges, Buzby, Bennet 2011; Mahajan, Caleb, Singh, Watkins, Geyer 2014; Pagani, Menna, Johnson, Vittuari 2019; Saleemdeen, Font Vivanco, Al-Tabbaa, Ermgassen 2017; Wu, Beretta, Cronje, Hellweg, Defraeye 2019)
<b>Increase in labour hours per worker or farmer</b>	The application of post-harvest measures to reduce biomass losses at the farm level can increase the labour hours for workers or farmer. For example, for maize practices like harvesting at maturity, spreading maize cobs on a platform or hanging them after harvesting and separating dirty and infected cobs and grains from those, which are clean and uncontaminated, disinfection of storage facility and the application of traditional or chemical protectants to the grain to kill and keep away the pests.	(Chegere 2018)
<b>Increase in packaging and related resource use</b>	Reduction in biomass losses can increase the amount of used packaging and resources for better protection and shelf life of fresh produce with distribution packaging from farm to retailer and finally an increase of waste.	(FAO 2011a; Gutierrez, Meleddu, Piga 2017; Verghese, Lewis, Lockrey, Williams 2015)
<b>Rebound effect</b>	The lower price of foods, economic benefits or resource savings resulting from biomass loss reduction in the supply chain may encourage additional production or purchase of food or other goods, which may lead to additional waste and environmental impacts, known as rebound effect. Additionally, improved production systems can increase direct and indirect incentives for cropland expansion due to increases in the profitability of farming. Improved efficiency in the food supply chain can	(Greening, Greene, Difiglio 2000; Grever, Nash, Gurwick, Bockel, Galford, Richards, Junior, White, Pirolli, Wollenberg 2018; Irawan, Tacconi, Ring 2013; Richards, Walker, Arima 2014; Shafiee-Jood, Cai 2016; Smith, Haberl, Popp, Erb, Lauk, Harper, Tubiello, Siqueira Pinto, Jafari,





	reduce the quantity of waste flows, which negatively affect the mitigation potential of bioenergy from residues and waste.	Sohi, Masera, Böttcher, Berndes, Bustamante, Ahammad, Clark, Dong, Elsiddig, Mbow, Ravindranath, Rice, Robledo Abad, Romanovskaya, Sperling, Herrero, House, Rose 2013)
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### 6.2.6 Increasing use of waste

*Table 20 Negative trade-offs potentially resulting from the unsustainable application of the additionality practice increasing use of waste*

Trade-off	Description	References
<b>Increased energy use and related GHG emissions</b>	Increase in GHG emissions can be caused by higher energy consumption of the pre-treatment as well as by the transport of the waste. Additionally, the high energy demand increases the costs for the treatment of the waste to produce bio-based products.	(Mansir, Teo, Rashid, Saiman, Tan, Alsultan, Taufiq-Yap 2018; Offenhuber, Lee, Wolf, Phithakkitnukoon, Biderman, Ratti 2012; Zhang, Ning, Khalid, Zhang, Liu, Chen 2018)
<b>Increase in expenditures for the separation of organic waste fraction</b>	The separation of the organic fraction from municipal solid waste increases the effort and therefore the expenditures for the management of the waste.	(Ardolino, Parrillo, Arena 2018; Elkhailifa, Al-Ansari, Mackey, McKay 2019)
<b>Transmission of hazardous substances</b>	Used waste streams can contain toxic metals, which can contaminate the product from waste as well as be discharged with waste-water occurred within the waste-to-product conversion process. Additionally, contaminated food waste, e.g. from restaurants can transmit diseases.	(Yang, Bao, Xie 2019; Yasmin Regina, Saraswathy, Balu, Karthik, Muthukumaran 2015)



## 6.3 Biomass cultivation on unused land: Detailed definitions of unused land categories and site-specific assessment

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### 6.3.1 Definitions of unused land categories

#### 6.3.1.1 *Abandoned agricultural land*

The European Commission determines abandoned land was used in the past for food and feed crops production. However, the cultivation of these crops was stopped and the reasons are biophysical or socioeconomic constraints (European Commission 2019).

Abandoned land in general comprise areas, where land use is given up in the past. This can be for example abandoned industrial sites, plantations or farmland. This land was used in the past for agriculture or pasture purposes and was not converted to forest or urban areas. Economic, political or environmental reasons exist for the abandonment of the agricultural land. The land can be called marginal land in case of economic reasons, set-aside-land, if political reasons are the decisive factor and degraded farmland, when environmental reasons cause the abandonment of the land. Abandoned agricultural land or farmland, which is still productive, is in the focus for the production of low iLUC risk biomass. However, abandoned agricultural land differs from fallow, which describes a temporarily suspension of the cultivation of agricultural land for a certain vegetation period with the aim to increase the soil fertility (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012; Wiegmann, Hennenberg, Fritsche 2008).

Within the framework of unused land, a distinction between two categories of abandoned land can be made. Transitional abandoned land is an area, which is abandoned due to policy changes or land reforms (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016), e.g. land in the former Soviet Union or Eastern Europe (Schierhorn, Müller, Beringer, Prishchepov, Kuemmerle, Balmann 2013). However, the conversion of this land category is mostly driven by market prices for certain products. In comparison, actual abandoned land is farmland, which is no longer used. This land can be fallow, too. Reasons for the abandonment of this land category can be a declined soil fertility or working opportunities outside of the agricultural sector. Furthermore, abandoned land ranges between temporarily unused land and entirely abandoned land. The first one have overlaps with fallow and transitional abandoned land (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016). Due to the aim of a fallow mentioned above, this type of actual abandoned land is excluded from the cultivation of low iLUC risk biomass.

The mentioned differences between the categories of abandoned land can be expanded by a third category. Besides transitional and actual abandoned land, semi-abandoned or hidden abandoned land is cultivated with a very low level of management intensity. This comprises very extensive farming practices, likely with low economic revenues (Keenleyside, Tucker 2010).



#### 6.3.1.2 *Degraded land*

The European Commission introduces the term severely degraded lands in the context of low iLUC risk biofuels (European Commission 2019). It is defined in the EU RED 2 as follows. “‘Severely degraded land’ means 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.” (European Commission 2018). On the one hand, this definition is very precise, because it mentions areas, which are characterised by salination, reduced organic matter content and erosion. On the other hand, it focuses only on a few cases of degraded land. Other types of degraded land, which are not covered by this definition, are excluded. According to the definition of the Commission, these areas cannot be counted as degraded land and therefore the land cannot be used for the production of low iLUC risk biomass. Therefore, degraded land is defined more general in this section. Additionally, some examples for this land use category are mentioned.

Degraded land in general can be defined as an area, which lost its ecosystem functions and services in the long term. The reasons for this lost are disturbances from which the ecosystem cannot recover for its own. Therefore, a recovery is dependent on external aid (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012). Degraded land is the cause of the process of land degradation. This process is characterised by “the reduction in the capacity of land to provide ecosystem goods and services over a period of time for its beneficiaries” (Biancalani, Nachtergaele, Petri, Bunning 2013). Whereas, ecosystem goods are produced by the land and has an economic or social value. Among others, these can be availability of land, the production of animals and plants, soil productivity as well as water quantity and quality (Biancalani, Nachtergaele, Petri, Bunning 2013). Ecosystem services are benefits people can get from ecosystems. These are for example, primary biomass production, photosynthesis as well as nutrient and water cycling (Millennium Ecosystem Assessment 2005). The definitions mentioned above have an ecosystem perspective in common. They comprise land, which lost relevant aspects of the ecosystem. Besides, the disturbed ecosystem needs support from an external factor to recover its functionality.

Under the term degradation, several processes can be comprised. These are for example desertification, salinization, erosion, compaction or the distribution of invasive species. The process of degradation can be induced by human activities. Whereas, areas with naturally low productivity can be part of degraded land, too, like heathlands or saline soils. However, the definition of degraded land needs to be conducted region-specific. This approach avoids unwanted impacts and contributes to the conditions of degraded land in different regions (Gibbs, Salmon 2015). Therefore, the definition of degraded land in this section is a first step to identify areas potentially usable for low iLUC risk biomass production. The site-specific assessment of the land, which fulfil the requirements of the definition, is an obligatory step in the identification of degraded land. The reason for this are regional differences in regard to the conditions of land degradation and related types of degraded land.

#### 6.3.1.3 *Marginal land*



Marginal land is often characterised by dry, wet and rocky conditions or it is difficult to reach. Therefore, the commercial production at this land is mostly not profitable (Allen, Kretschmer, Kieve, Smith, Baldock 2013). Thus, the land of this category is not in use, because currently the cultivation is too expensive under the given technological and site-specific conditions. Therefore, production of food and feed are actually not cost-effective at this land. Once, the conditions are changing possibly the area will be used for the cultivation of food and feed in the future. These changes can be related to technological developments, which allow a more cost-effective feedstock production, or in changes of the cost structure, e.g. when the price for a commodity increases and the farmer can gain higher revenues (Wicke, Verweij, van Meijl, van Vuuren, Faaij 2012; Wiegmann, Hennenberg, Fritsche 2008). Some constraints are problematical in regard to use marginal land for the production of low iLUC risk biomass. Firstly, it does not factor in subsistence agriculture. Secondly, marginal land can provide food, feed, medical plants, fertilizer or fuel to local people. However, these products are not traded on a market. Thirdly, marginal land is characterised by tenure issues in regard to land use rights (Wiegmann, Hennenberg, Fritsche 2008). A further issue related to the use of marginal land is its relative region specific meaning. Marginal land in one region do not need to be necessarily marginal land in another region. This is because marginal land is determined by economic factors (Allen, Maréchal, Nanni, Pražan, Baldock, Hart 2015). Thus, the example of marginal land underlines the necessity to identify unused land usable for the low iLUC risk biomass production in combination with a site-specific assessment approach as described below.



#### 6.3.1.4 *Set-aside land*

Set-aside land is land that is not used due to political reasons (Wiegmann, Hennenberg, Fritsche 2008). It is not allowed to be used for any agricultural purpose for the period a set-aside policy is implemented. However, the land can be cultivated with non-food crops, including energy crops (Lefebvre, Espinosa, y Paloma 2012). At EU level, an incentive scheme for set-aside arable land was implemented in 1988 (Regulation (EEC) 1272/88). With the 1992 MacSharry Common Agricultural Policy (CAP) reform, set-aside was made mandatory to get payments from the European Economic Community (EEC) (Matthews 2013). However, these policies are no longer in force (Alons 2017). Furthermore, due to the increasing demand for land to produce biomass for food, feed, biofuel and other purposes, it is unlikely that set-aside land play a considerable role, currently. Therefore, this unused land category is not regarded within the low iLUC risk biomass assessment.

#### 6.3.1.5 *Under-utilized land*

If under-utilized land can be used for the production of low iLUC risk biomass, is discussed controversial. Two opposite positions exist in regard to this questions. Therefore, both positions are outlined in this section.

The one position promotes under-utilized land for the cultivation of low iLUC risk biomass. The one position determines under-utilized land in accordance to set-aside land, abandoned land, marginal land and degraded land. It is characterised by the share of land, which does not provide other services, like agriculture, biodiversity, high carbon stocks or other ecosystem services. However, for the identification of under-utilized land suitable for low iLUC risk biomass production, site specific information like the current uses and functions as well as the suitability for crop cultivation needs to be observed (Brinkman, Wicke, Gerssen-Gondelach, van der Laan, Faaij 2015).

The other position excludes under-utilized land for the production of low iLUC risk biomass, currently. The reason for this is that in some cases low-intensity smallholder agriculture can be seen as under-utilized land. This can increase the risk of land grabbing (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016). Thus, this unused land category play no considerable role for the low iLUC risk assessment. On the one hand, the first position attributes the other relevant land categories mentioned above to under-utilized land. Therefore, this land category is covered by the other land categories. On the other hand, the second position suggests handling this category with care concerning land use rights and landing use intensity. These can be found in some points in the unused land categories described above as well as in the following site-specific investigation approach.

#### 6.3.1.6 *Waste land*

This land category cannot be used for cultivation under any condition. Therefore, the production of the feedstock for bio-based products is not possible. Waste land is characterised by natural conditions, which can prohibit agricultural land use activities in general (Wiegmann, Hennenberg, Fritsche 2008). Wasteland is mentioned here to complement the list of unused land categories. However, for the cultivation of low iLUC risk biomass it is not suitable and needs to be excluded from the further assessment steps.

### **6.3.2 Steps of the site-specific assessment (Peters, Spöttle, Hähl, Kühner, Cuijpers, Stomph, van der Werf, Grass 28. November 2016)**

#### 6.3.2.1 *Regulatory assessment*



The regulatory assessment proves if the plot of land claimed to be unused fulfil relevant legal and regulatory requirements. This means that the land can be used for the cultivation of crops, eligibly and legally. It has the legislative status for agricultural production. Furthermore, the land user needs to have the legal right to use the land, i.e. for the cultivation of crops. This includes the demonstration to respect traditional and/or customary land use rights of local communities. These local communities need to be considered in the assessment by free prior and informed consent. The latter is especially important in countries with lacking traditional and customary land use rights.

#### 6.3.2.2 Land cover and utilization assessment

The land cover and utilization assessment determines the land cover and land use of the last five years with remote sensing and geo-information methods and data. It is realised in three steps. Whereby, the first (vegetation profile) and second (image interpretation) steps have a higher priority as the third step (geo-information).

### STEPS OF THE LAND COVER AND UTILIZATION ASSESSMENT

#### Assessment of the vegetation profile

It is proposed to use the Normalised Difference Vegetation Index (NDVI) to generate annual vegetation profiles, which can be used to assess the healthiness and the vegetation growth over a certain time. It is calculated by means of satellite data. Practically, the NDVI value (y-axis) and the time (x-axis) are plotted in a diagram. With the diagrams for each of the last five years, the smoothness/noise of the temporal vegetation profile is analysed. It must show a smooth and bell-shaped profile with one maximum peak to identify the plot as unused land. Thus, spatial patterns of different land use intensities can be identified with the NDVI, like (Estel, Kuemmerle, Levers, Baumann, Hostert 2016) demonstrated for Europe. The Enhanced Vegetation Index (EVI) is an additional vegetation profile, which can complement the NDVI or substitute it. For example, the GRAS Tool<sup>7</sup> uses EVI values to detect changes in land cover. The EVI can improve the accuracy and robustness of the vegetation profile assessment. However, it is suggested to use only the NDVI due to its simplicity and common use.

#### Image interpretation

In the second step, high resolution imagery from satellites or aerial images can be used to check the land cover and utilisation visually by eye. Images from different times can be compared with each other to illustrate changes in land use. Over a period of five years, the images shall show no sign of agricultural management. In particular, no crop cultivation and/or pasture can be seen on the images of the land.

#### Analysis of land parcel specific geo-information

The last step of the land cover and utilization assessment is characterised by checking relevant information from digital geoportals or cadastre systems from authorities of different administrative levels. Like in the steps before, the analysis is conducted for the period of the past five years. To identify unused land, the data is not classified as managed cropland and/or pasture.

#### Optional EU-specific steps



For the identification of unused land within the EU, two optional steps are suggested, which can support the three steps described above.

- COPERNICUS Land Monitoring Services<sup>8</sup>

This service from the European Environmental Agency provides land cover geo-information for areas within the EU at different years (e.g. CORINE Land Cover database, Pan-European High Resolution Layers on land cover, Urban Atlas).

- EU Land Use/Cover Area Survey (LUCAS)<sup>9</sup>

LUCAS is a service provided by Eurostat, which includes data on land cover sourced from photo-interpretation and field samples.

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<sup>7</sup> <https://www.gras-system.org/>

<sup>8</sup> <https://land.copernicus.eu/pan-european/corine-land-cover>

<sup>9</sup> <https://esdac.jrc.ec.europa.eu/projects/lucas>