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Methodologies for the identification and certification of Low ILUC risk biofuels

Final report

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This report also benefited from the recent assessments of sequential cropping practices for the purpose of low ILUC risk biomass which we conducted with experts from Wageningen University. The assessments took place in Italy with CIB, the Italian Biogas Consortium, and in Uruguay with UPM. This allowed us to test our yield increase methodology based on real data and led to some new insights that we could take into account.

Table of contents

1 Introduction

1.1 Producing low ILUC risk conventional biofuels

Biofuels can be an important instrument to decarbonise the transport sector. However, the greenhouse gas performance of biofuels can be negatively impacted by Indirect land use change (ILUC) effects. In a recent study (the GLOBIOM study, 2015) for the European Commission, Ecofys, IIASA and E4tech found that in particular the increased amount of conventional biodiesel consumed in the EU since 2008 has high associated land use change effects, while advanced biofuels and ethanol pathways have much lower risks to adverse land use change. Debate on the ILUC emission impact of conventional biofuels has reduced public support for biofuels in the European Union to such an extent that continued public support for conventional biofuels post 2020 is uncertain.

Modelling studies such as the GLOBIOM study treat biofuels as the new entrant to the global agricultural system. The study takes as a starting point that all necessary food and feed production to feed a world population growing in both numbers and wealth is included in the baseline. Then, a quantity of biofuels is introduced as a marginal new entrant to the system, and can trigger the conversion of forests, natural grassland and other high carbon stock areas into agricultural land anywhere globally. The GLOBIOM study shows that the resulting greenhouse gas emissions from land use change effects can be very high. The study also shows however that it is possible to develop solutions for low ILUC risk biofuels: both advanced and conventional biofuels can be cultivated with a low risk to cause ILUC. Advanced cellulosic biofuels can have very low ILUC risk if it is ensured that agricultural and forestry residues are not collected to their maximum potential, by leaving part of the biomass at the field or forest floor. Understandably, policy makers focus on increasing the share of advanced biofuels. However, it is also possible to produced conventional biofuels with a low ILUC risk.

One of the most important options to mitigate ILUC risks associated with conventional biofuels is to effectively stop peat land drainage in South-east Asia combined with a considerable decrease of tropical deforestation. This would require a pro-active policy by various international actors and is outside the reach of what the biofuel industry can influence. Low ILUC risk conventional biofuels can also result from <u>additional biomass</u> produced beyond the baseline or reference scenario. In that case, food-crop based biofuels do not displace the existing use of crops for food and feed, but are produced from a *new* feedstock base which is additional to current production levels as well as future productivity increases triggered by food and feed demand.

The ILUC Directive[1] defines low ILUC risk biofuels and bioliquids as follows: 'biofuels and bioliquids the feedstocks of which were produced within schemes which reduce the displacement of production for purposes other than for making biofuels and bioliquids and which were produced in accordance with the sustainability criteria for biofuels and bioliquids set out in Article 17.'

Low ILUC risk biofuels are produced from biomass of which displacement is reduced to such an extent that the displacement risk can be considered as low. A low displacement risk can be achieved if

[1] Directive (EU)2015/1513

biofuels are produced from biomass that is created additionally to current and trend-based future agricultural production levels used for food and feed, meaning that displacement of food production is avoided. Low ILUC risk conventional biofuels could be an acceptable, even desirable part of a low carbon transport system.

So how to achieve additional biomass production? Two important options are: (1) increasing crop yields through improved inputs and management practices, including better fertilisation, irrigation, seeds and equipment or (2) expanding agriculture on previously non-agricultural land with low carbon stocks and low biodiversity value. In this report, Ecofys proposes two methodologies to identify and demonstrate low ILUC risk biofuel feedstock production through the application of yield increase (see Chapter 3) or unused land (see ILUC mitigation methodology for unused land). The yield increase methodology is based on productivity increases of single target crops but also includes the possibility to apply multi-cropping systems, as specified in Chapter 4.

The implementation and certification of ILUC mitigation measures will come at a financial cost. On the other hand, will resulting additional biomass production also lead to increased revenues. The precise costs and revenues depends on how much additional biomass is produced and what the required investments were to achieve this, which can differ from case to case. In the end, it will be up to economic operators to assess whether a business case exists to pursue low ILUC risk certification.

In preparing this study, Ecofys collaborated with Intertek Certification GmbH, Wageningen University and various independent experts.

1.2 Starting points for ILUC mitigation methodologies

The ILUC mitigation methodologies for yield increase and for unused land are different, yet share certain common starting points. Both methodologies should:

1. Comply with relevant legislation including the existing EU sustainability criteria for biofuels that ensure the direct sustainability of feedstock production;
2. Effectively result in mitigation of indirect greenhouse gas emissions by enabling the identification and demonstration of additional, above-reference biomass production;
3. Include a credible calculation methodology of the reference situation and criteria to demonstrate additional production, including on a link between additionality and biofuel demand;
4. Ensure that ILUC mitigation can be implemented in a systemic and lasting way;
5. Minimise fraud risks by requiring robust auditing requirements and transparency;
6. Be compatible with the use of existing certification systems or national systems for biofuels;

In addition, it is important that ILUC mitigation is relevant in terms of potential and cost-effectiveness and can be used in principle by biofuel producers both within and outside the European Union. The cost-effectiveness cannot be easily estimated as it varies from case to case.

Ex-post auditing to claim past yield increases as low ILUC risk is challenging from a practical perspective. It is also unclear whether post yield increases were triggered by biofuels policies. From a ILUC modelling perspective, all yield increases up to 2010 have been included in the baseline and had a lowering effect on ILUC values. Past yield increases up to 2010 thus are already part of the baseline.

Yield increase and unused land were chosen among other potential ways to achieve ILUC mitigation because we assume a significant higher potential for both mitigation options than for alternatives.

2 General methodology design choices

This chapter describes the general rules and process that can be used to demonstrate low ILUC risk biomass production. Additional specific requirements and guidance is provided in subsequent chapters and annexes.

2.1 Level of certification – single farm or group of farms

Certification of low ILUC risk biomass can be achieved at various levels. As explained in Section 1.1, a global-scale solution focusing on stopping deforestation and peatland drainage is desirable. However, such a solution cannot be achieved by the biofuel supply chain actors alone and is therefore not considered in this study. Instead, this report focuses on ILUC mitigation achieved at either the level of an individual farm or plantation level or at the level of a group of farms. We define both levels as follows:

Farm level certification: certification takes place for a single farm (or plantation) or fields within a farm. A reference scenario is established at individual farm level and actions leading to low ILUC risk biomass/biofuels are implemented and audited at this level.

Group certification: certification takes place for a group of farms on which the same target crop is cultivated in the same geographical region using similar agricultural management practices. A reference scenario is established at group level and actions leading to low ILUC risk biomass/biofuels are coordinated at group level. Implementation and auditing takes place at individual farm level using a sample.

The methodology for yield increase including multi-cropping focuses on group-level certification for reasons explained in Section 3.4. We recommend that the methodology for unused land focuses on certification at the level of a specific plot of land (farm-level certification), because this measure can involve land conversion. Due to the sensitivities around land conversion it makes sense that all projects are audited rather than a sample of participating group members.

2.2 Definitions

The following definitions are relevant in the certification process and play a role in the methodologies included in the following chapters.

1. **Crop component**: an elementary material contained in feedstocks, e.g. protein.
2. **Biofuel feedstock**: the biofuel component included in agricultural crops, e.g. rapeseed oil is a component and a biofuel feedstock.
3. **Forage Unit**: a measurement used to quantify the feed value of different feed crops. A forage unit is 1,700 kcal of metabolizable energy and thereby provides a standardised value to compare different feed crops.
4. **Crop component group**: Group of the same agricultural crop components. Three different groups are distinguished, based on most important biofuel feedstock components: sugar, starch and vegetable oil groups. Low ILUC risk certification can be applied for a quantity of

above-reference biomass achieved within a certain feedstock group. When implementing and quantifying ILUC mitigation for a particular crop component group, the protein crop component should also be taken into account (further explained in Section 4.2)

5. **Target crop:** Specific agricultural crop (biofuel feedstock) for which low ILUC risk certification is applied. This feedstock can be part of a crop rotation system. Our understanding of a crop rotation system is that usually all crops are cultivated in the same harvest season but on different plots of the same farm. In a wheat-barley-rape crop rotation, each crop is cultivated on a third of the plot used for the crop rotation system. In the next harvest season each crop moves to the next plot and in 3 years the crop is at the same plot as 3 years before;
6. **Economic operator:** entity that applies for certification and wishes to produce certified low ILUC risk biofuel feedstock. This can be a farm, plantation or group of farms;
7. **Level of certification:** Geographical scope of certification. Whether certification covers the land area of a single farm or specific plot of (unused) land or whether certification covers a group of economic operators. In case of crop rotation, the geographical scope is the area used for the crop rotation at a farm and not just the single plot of a crop within the crop rotation in a specific year or set of years;
8. **Reference scenario:** Counterfactual scenario describing the development of agricultural production in the absence of (additional) biofuel demand, with which the implementation of the ILUC mitigation measure is compared.
9. **Additionality:** Quantity of biomass that is produced in addition to the reference scenario within the geographical scope of certification. Additional biomass has a low ILUC risk.
10. **ILUC mitigation plan:** Document in which the economic operator describes their low ILUC risk biofuel feedstock approach. This should describe, as a minimum:
    - Specific geographical location in which ILUC mitigation is foreseen;
    - Level of certification (single farm or group of farmers);
    - Amount of hectares involved in the mitigation measure;
    - Designated target crop or crop component group (including protein);
    - Detailed description of the reference scenario;
    - Specific approach foreseen to cultivate above-reference level volumes of biomass;
    - Link to biofuel demand, following the requirements outlined in this report.

We recommend to develop standard templates for ILUC mitigation plans.

2.3 Stepwise approach towards certification – group level

A number of process steps are to be taken to achieve certification of low ILUC risk biomass. We propose two ways in which the certification process can look like, for both certification at single farm level as well as for group certification. Figure 1 below provides a schematic overview of the process, specifying actions to be taken by the economic operator (farm, group of farms) that wishes to cultivate certified low ILUC risk biomass, the voluntary certification scheme owner and the certification body that performs independent audits.

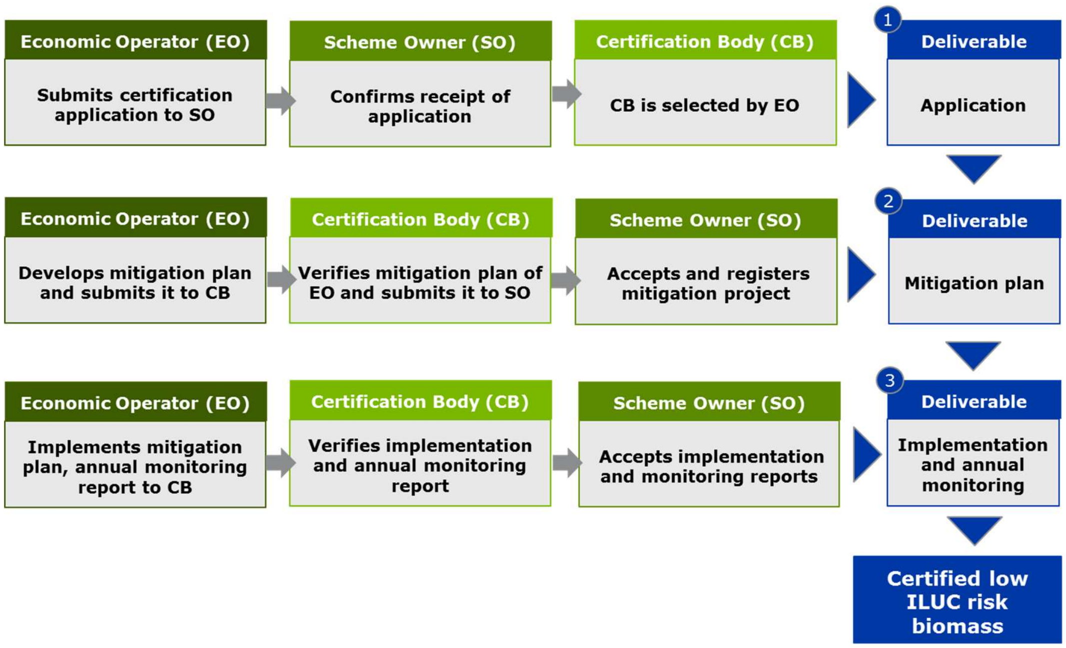

Figure 1. Overview of process steps in the certification of low ILUC risk biomass

A comprehensive audit of the ILUC mitigation plan has to be performed within 1 year after the implementation of the mitigation measure has been started. This allows an auditor to approve an ILUC mitigation plan although not all requirements might be fulfilled at the approval stage, e.g. the new planned equipment needed for the measure is not yet at the farm. However, following this example, within one year the equipment has to be at the farm and the measure has to be implemented as foreseen in the plan otherwise the preliminary approval of the ILUC mitigation plan is null and void.

2.4 Demonstrating additionality

For ILUC mitigation measures to be implemented in a credible manner, the measure should result in *additional* biofuel (feedstock) or should generate the same volume of biofuels at a lower land use impact compared what would have happened in absence of biofuel demand. This involves:

- Demonstrating that a biomass is produced additionally compared to a business as usual or reference scenario, and;
- Demonstrating that the additional production can be linked to biofuel demand.

The reason why low ILUC risk feedstock production relies on creating additionality is the fact that demand for biofuels is not the only driver of agricultural crop yield increases or of sustainable agricultural expansion on unused land. In fact, also the food sector drives increases in agricultural production, which can be assumed to be the case in the future as well. This means that not all increases in agricultural productivity will be low ILUC risk, but only those that are achieved in excess of yield increases driven by the food and feed sectors. In ILUC modelling, yield increases driven by the food and feed sectors are captured in the modelling baseline. ILUC mitigation methodologies can either use such a model-derived reference or (if not possible) a reference based on historical production data. Figure 2. Stepwise approach to demonstrate additionality below shows how the proposed methodology for ILUC mitigation allows economic operators to demonstrate additionality and its link with biofuel demand.

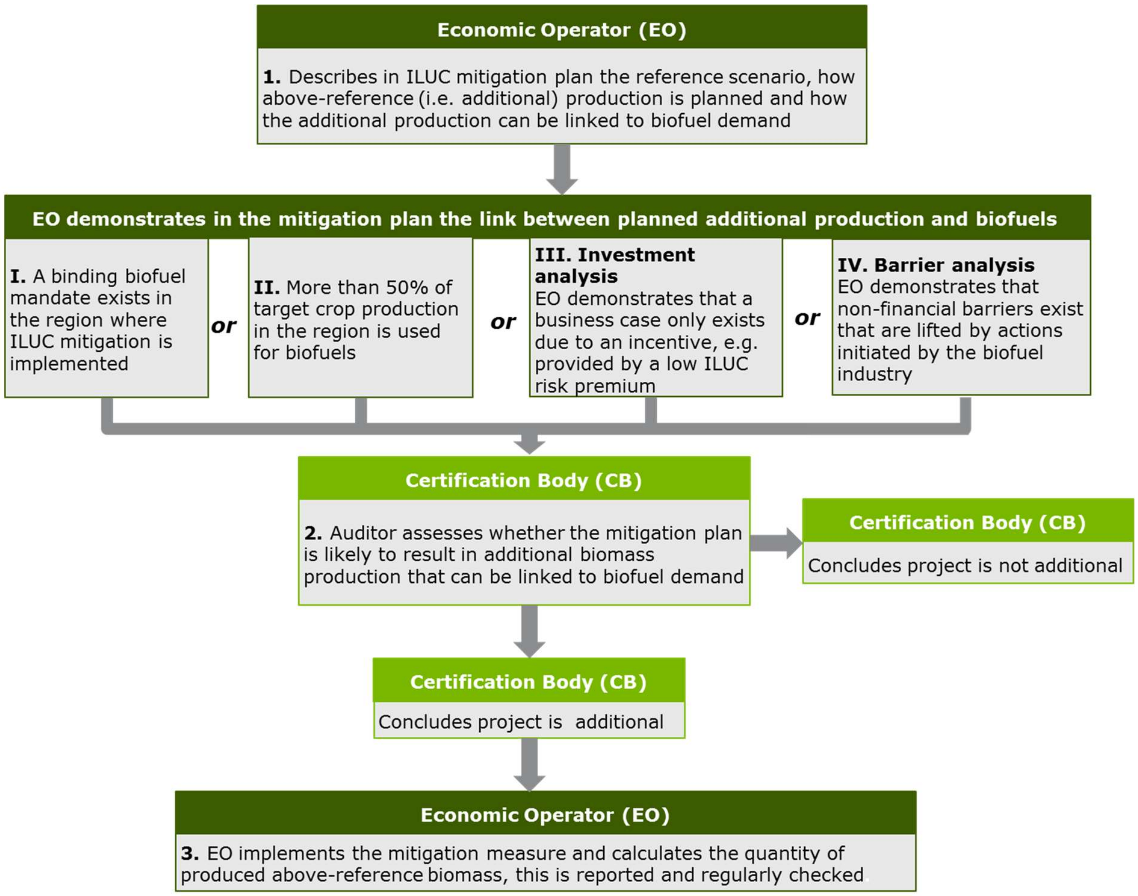

Figure 2. Stepwise approach to demonstrate additionality and its link to biofuel demand

In step 1 the Economic Operator describes in the ILUC mitigation plan the mitigation measure he wishes to apply for a target crop and how above-reference additional biomass production is aimed for. In the mitigation plan, the economic operator also demonstrates the link between the foreseen additional production and biofuel demand. An important assumption in demonstrating additionality is that the reference situation should capture the development of agricultural productivity driven by demand for food and feed. This means that all production beyond this reference development can be deemed additional. Additionality is thus assessed by comparing the reference scenario with the expected and actual yields following the implementation of an ILUC mitigation measure. As described in the next chapter, for yield increase as an ILUC mitigation measure we propose that a linear trendline is established based on historical yields that is used to determine a statistical reference value. It can be assumed that this trendline captures the yield increases triggered by the food and feed sectors and hence it can serve as a reference scenario.

It is then also important to demonstrate that this additionality can be linked to biofuels (and cannot be explained by other drivers). Economic Operators can demonstrate the link between additional production and biofuel demand by either one of the options I to IV as pictured in Figure 2. Stepwise approach to demonstrate additionality and its link to biofuel demand

1. Option I means that a **binding biofuel mandate** is in place in the region where ILUC mitigation is implemented. This mandate can be expected to trigger productivity increases.
2. Option II can be applied if an **agricultural crop** cultivated in a specific region is **used for more than 50% to produce biofuels**, e.g. rapeseed in the EU. We judge this to be sufficient to demonstrate the link with biofuel demand.
3. Options III and IV can be used in regions where biofuel feedstock production takes place but no binding mandates exist and the cultivated target crop is used for biofuels for less than 50%. Both options are based on concepts to demonstrate additionality in the context of the CDM carbon credit programs[2].

Option III. An **investment analysis** can be carried out to demonstrate that the proposed measure is only viable with an additional financial incentive, e.g. additional demand for biofuels or a premium for low ILUC risk biofuel feedstock. If this is the case the measure is additional as it would not have been implemented in the absence of the incentive.[3]

Option IV. A **barrier analysis**[4] can be carried out to demonstrate that one or more barriers exists that prevent the implementation of an ILUC mitigation measure at a specific location and that an action initiated by the biofuel sector aims to lift the barrier(s). Barriers can be non-financial, e.g. lack of knowledge on agricultural management practices.

A challenging aspect regarding options III and IV is that farmers generally do not know in which sectors their products are being used. Farmers are constantly looking to improve the quality of their product and their yields, usually not linked to any specific end-using sector. It is in general not possible to prove that a farmer implements certain yield increase measures due to additional demand for biofuels. The options are therefore mainly suited for very specific yield increase programmes initiated by a biofuel producers or specific project for feedstock cultivation on unused land. We recommend that the European Commission will provide further guidance on how to perform the investment and barrier analyses. Another acceptable manner to demonstrate the link between additionality and demand for biofuels is when additional feedstock is sold directly from farmer to

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[2] The Clean Development Mechanism is a system designed to implement emission-reduction projects in developing countries. Such projects can earn saleable certified emission reduction (CER) credits that can be traded, each equivalent to one tonne of CO2, which can be counted towards meeting Kyoto targets. For more information see http://cdm.unfccc.int/index.html.

[3] An investment analysis aims to demonstrate that the proposed project activity is less economically attractive than one or more alternatives. The rationale being that if other scenarios are more economically attractive, those scenarios would be implemented instead of the project. In CDM, the baseline in such an approach is normally determined through analysing what the most likely alternative scenario would be in absence of the carbon offset project activity.

[4] A barrier analysis one has to demonstrate that one or more barriers exist to the project that would prevent the project from being implemented in absence of the actions taken in the project. The rationale being that the project is additional if the actions taken allow it to overcome barriers that otherwise would have prevented the project to be implemented. In CDM, the baseline in such an approach is often determined through analysing what the most likely alternative scenario would be in absence of the carbon offset project activity.

biofuel producer with clear traceability and in the context of a well-established longer-term client relationship.

After the Economic Operator has built a case for intended additional feedstock production and its link with biofuel demand, a Certification Body (CB) assesses the mitigation plan and whether additionality can be expected and can be linked to biofuel demand. If the CB deems the project to be additional, the EO can implement the mitigation measure and, following this, is able to achieve additional biomass production that can be certified as low ILUC risk, in accordance with the steps as outlined in Figure 1. Overview of process steps in the certification of low ILUC risk biomass above. Further details to set the reference scenario are provided in the following Chapters on yield increase and unused land.

It is clear that the requirement that only above-reference production is low ILUC risk favours feedstock producers in regions with large yield gaps over those that already achieved significant yield gains in the past. This may seem unfair. Yet historical yield increases up to 2010 have been taken into account in the GLOBIOM baseline, leading to lower ILUC emission values. So while past achievements can no longer be used to demonstrate low ILUC risk, they have been taken into account in modelling, lowering the ILUC risk profile of the target crop.

Duration of additionality

For how long should demonstrated additionality be valid for? In ILUC modelling, biofuels are treated as the marginal latest entrance to the market, which means that relatively large relative negative LUC effects are associated with biofuels compared to the food and feed sectors. The concept of ILUC mitigation as taken in this report centres around the concept that a consignment of biofuels is low ILUC risk if it demonstrates its additionality compared to demand for food and feed as included in the reference scenario. Once additionality is demonstrated, the consignment of biofuels made its way into the global agricultural system in a sustainable manner. Once being in, it seems illogical that the consignment of sustainable low ILUC risk biofuels would revert back to having a high ILUC risk after a certain period of time because this would mean that it would again be considered as a new entrant into the global agricultural system that would have to demonstrate additionality for the second time for the same consignment. It could be argued that additionality should be capped in time duration because global demand for food is increasing. However, is it not fair that the food sector should be responsible to meet future additional food demand by creating its own additional supply? Why would future additional food demand be allowed to displace other existing biomass uses such as the consignment of low ILUC risk biofuels that made its way into the global agricultural system in a sustainable, additional manner? In principle, Ecofys considers that additionality should be limitless in duration. This does not mean however that the reference scenario is flat as farmers can be expected to continue to invest in productivity increases. There still is a reason to limit the duration of additionality of ILUC mitigation measures. Biofuels cannot be expected to receive endless political support. At some points we should expect costs of biofuels to be sufficiently low compared to the cost of fossil fuels, assuming that externalities such as a carbon price will be increasingly factored in. Besides this, from the perspective of ILUC modelling, after a certain period the ILUC emissions have been accounted for and a certain consumption level of biofuels becomes low ILUC risk, whereas fossil fuels with their much longer carbon cycle are not amortised during the same period. Because all biofuels in the end become low ILUC risk, there is no need for limitless duration of ILUC mitigation. Based on this, Ecofys recommends that **certification of low ILUC risk biofuels is valid for a 10-**

year period. After this period, the low ILUC risk certificate expires and the project does not longer result in low ILUC feedstock.

Additionality for target crop(s), crop component groups or forage units

ILUC mitigation can be applied for single crops. This is relevant if for example a plot of unused land is taken into agricultural production for one crop or yield increase measures are taken that affect the production of one particular crop. In this case, the calculation of the reference scenario and above-reference biomass is relatively straightforward, focusing only on one crop.

Additional, above-reference production can also be achieved for multiple crops at the same time. This is the case for example if a farmer starts cultivating two crops in rotation on a plot of unused land. In this case the calculation of additionality is still simple, since on unused land no previous production took place on the land so all crop production from various crops are additional. many cases, Yield increase measures can result in higher crop yields for multiple crops produced on a farm. If all of these crops were already produced in the past, the above-reference yields can be easily calculated by establishing separate yield references for the different crops produced on the farm. The calculation of additionality gets more complicated if a farmer changes the cultivation of crops, making it more difficult to establish a reference based on historical crop yields and compare this to current and future crop yields after the implementation of an ILUC mitigation measure. Such a situation asks for a mechanism that allows a comparison of different crops. We propose here two of such mechanisms:

1) Reference setting and calculation of above-reference biomass based on **crop component groups**
2) Reference setting and calculation of above-reference biomass based on **Forage Units**

Calculating additionality based on crop components

Each crop consists of various components such as cellulose, lignin, protein, fats and sugar or starch. Of these, sugar, starch and fats are used to produce liquid biofuel. It is possible to compare the availability of any of these components in various different crops. We propose to focus the calculation of additionality for liquid biofuels only on available protein and the 'biofuel feedstock component', i.e. starch, sugar or vegetable oil. This is because these are the components that mainly determine the market value of crops for the purpose of liquid biofuels and animal feed co-product. It is important to note that within liquid biofuel production there is always protein and the respective biofuel feedstock component being produced. Such an approach allows to compare different sugar, starch and vegetable oil crops while still respecting the very different ILUC risk profile which modelling shows for various crops and crop groups.

ILUC modelling shows that each specific biofuel feedstock has its own ILUC risk profile. Feedstock-specific model runs lead to different outcomes in terms of the LUC emission impact of a certain biofuel shock. The recent GLOBIOM and earlier IFPRI-MIRAGE modelling studies also show that vegetable oil crops have a higher ILUC risk than sugar and starch crops that are used to produce ethanol. The differences in ILUC risks between sugar and starch on one hand and vegetable oils on the other are in most cases much larger than differences within the sugar and starch crop groups. Based on this Ecofys recommends that ILUC mitigation should be possible not only for individual crops but also for biofuel feedstock groups. When applying for low ILUC risk certification for additionality created for a certain feedstock group within a certain geographical scope, it is important that no only additionality for the biofuel feedstock component is achieved but to also ensure that protein yields are not lowered as a result of the application of ILUC mitigation methods.

The crop component approach can also be used in specific cases when multicropping is introduced. Multicropping can lead to a situation in which a new additional crop is cultivated with high additional biomass yields but at the same time triggering a (slight) lowering of yields of the (previous) main crop compared to the reference, either because less land is available for the cultivation of the previous main crop (as is the case with intercropping) or because the harvest of the main crop is brought forward to allow the seeding of an additional winter crop (as is the case with sequential cropping). In such situations, the crop component approach can be used to calculate the net-additional biomass yield in the multicropping situation compared to the previous single crop situation, taking into account also the net additionality of protein.

Calculating additionality based on Forage Units
The crop component approach works well for cases in which the additional crop is used to produce liquid biofuel with an animal feed co-product. However, if the additional crop is used for biogas the crop component based approach does not seem immediately appropriate because the entire crop is useful feedstock instead of just a single component. And also, silage crops used for feed, are not just valued as feed for their protein value but also for their other components (e.g. fibre, starch, etc.). In order to reflect the full market value of silage crops and crops mainly used for feed or biogas, we propose to use Forage Units to calculate the reference and above-reference biomass. A forage unit is 1,700 kcal and thereby provides a standardised value to compare different feed crops.

2.5 Rules for auditors

The EU Renewable Energy Directive (2009/28/EC) requires that information which demonstrates that economic operators comply with the EU sustainability criteria is independently audited. Some guidance is set out in the EC Communication on voluntary schemes[5] and this is further elaborated by the voluntary schemes that have been recognised by the EC[6].

Certain rules for auditors are provided including that auditors should be external to the economic operator and the scheme and independent of the activity being audited and free from conflict of interest. In addition, the auditor should have the appropriate generic (auditing) skills and specific (scientific or technical) skills relevant to the auditing activity[7]. For the purpose of audits for ILUC mitigation, auditors shall have demonstrated expertise with agricultural production systems and, in the case of Unused land, auditors should have demonstrated expertise with analysing remote sensing data.

2.6 Rules for group certification

It is important that the implementation of ILUC mitigation measures is independently audited to ensure the credibility of the scheme and prevent fraud. Third party certification can either take place

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[5] Communication from the Commission on voluntary schemes and default values in the EU biofuels and bioliquids sustainability scheme (2010/C 160/01). Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:160:0001:0007:EN:PDF
[6] https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes
[7] Section 2.2.2 EC Communication on voluntary schemes

in the context of a voluntary certification scheme or a national system for biofuels. We start our methodology development from the premise that it should be possible to use the methodologies as much as possible together with existing voluntary certification schemes.

Existing schemes often include rules for group certification. Ecofys foresees a central role for group certification in the ILUC mitigation methodology for yield increase including multi-cropping. In order to ensure a sufficiently high level of robustness in the scheme we propose a number of requirements for group certification. We note that all voluntary schemes are assessed according to ISEAL standard P035 establishing Common Requirements for the Certification of Producer Groups which includes some of the requirements below. Still, we recommend that for the purpose of ILUC mitigation all voluntary schemes shall implement requirements for group certification as included below that we deem necessary.

Specific requirements for a group:

- A group can only be created by farmers cultivating the same crop in the same region with similar characteristics regarding soil and water (e.g. NUTS 3 in the EU);
- A group should be sufficiently large to ensure a relevant number of data points are available, e.g. at least 5 members;
- A group manager has to be defined, who is responsible for data collection from all group members and is the main contact during the certification process. The group manager draws up a ILUC mitigation plan together with the group;
- The group manager can be a farmer but also a biofuel producer or first gathering point of feedstock collection. To minimise the administrative burden related to this it can make sense to appoint the first gathering point, such as the oil mill or aggregator, as the group manager;
- The group manager is responsible that each group member complies with the ILUC certification process. This requires regular internal monitoring of group members. First gathering points already have to provide the documentation for certification of standards to demonstrate compliance with the RED. We therefore propose that first gathering points also deal with low ILUC risk certification. Self-declaration by farmers that the ILUC mitigation plan has been implemented combined with sample checks by auditors is a way to monitor the proper implementation;
- The group is free to allocate certified low ILUC risk biomass over its members as it sees fit;
- ILUC mitigation measures can be implemented by all group members or by part of the group, allowing a knowledge transfer between group members;
- Not all group members have to be audited. Following a desk-based check of all documentation, a sample of group members has to be audited on-site. The minimum sample size is determined by the square root of the number of group members. To ensure that the number of audited farms is not too small, based on advice by Intertek we propose at least 8% of participating farms in the group should be audited. In case of non-compliance by one group member the sample size is doubled. If more than 10% of the group members do not comply, we recommend that the complete group is invalidated and cannot claim any low ILUC risk biomass until this situation is improved.

2.7 Mass balance chain of custody

In the certification process, biofuel (feedstock) as well as sustainability information travels through the feedstock cultivation and biofuel production chain to fuel suppliers. The EU RED requires that at least a mass balance approach is used to organise this information flow. While it is not necessary for low ILUC risk biofuel feedstock to be physically segregated from other feedstock, there has to be some connection between the low ILUC risk feedstock and the actual biofuel produced. A mass balance approach works well for the certification of low ILUC risk biomass that is used to produce low ILUC risk biofuels.

When developing methodologies for ILUC mitigation it is possible to rethink why a mass balance approach would be the most fitting way for low ILUC risk biofuel (feedstock) and its corresponding sustainability information to be transferred through the chain of custody. One could argue that it should be possible to apply a book and claim approach for low ILUC risk biofuel feedstocks given that ILUC is a global international phenomenon that is not directly but indirectly linked to biofuels, so it should also be possible for actions to avoid negative ILUC impacts to take place elsewhere in the world, outside the direct biofuel supply chain. This could take the form of an ILUC mitigation measure, such as a yield increase project or cultivation on previously unused land, being implemented somewhere in the world according to the methodologies as specified in this report, the resulting above-reference, additional biomass could be used for food or feed while the 'low ILUC risk claim' is transferred to EU biofuels. Such a transfer would only cover the claim that a consignment of biofuels has a low ILUC risk. The consignment still has to be physically produced from feedstock cultivated in compliance with the EU sustainability criteria, for which the mass balance chain of custody approach applies.

A potential benefit that such a book and claim type transfer of the 'low ILUC risk claim' would give EU biofuel producers is the possibility to invest in ILUC mitigation in parts of Europe or the world where the potential is largest, while the mitigation projects should be implemented and independently audited in compliance with the criteria as outlined in the methodologies proposed in this report. A potential downside of the book and claim option is that its credibility could be perceived to be lower compared to the mass balance approach, especially if limited transparency exists on which ILUC mitigation projects are certified for which biofuel feedstock type in which location, by which certification scheme.

Three steps can be taken to limit the credibility risk of using a book and claim approach:

1. Compliance with the EU RED sustainability criteria for all ILUC mitigation measures, even if resulting additional biomass ends up in the food sector. This could increase the coverage of the sustainability criteria to partly cover biomass for food;
2. Low ILUC risk claims can only be made if mitigation measures have been implemented for the same target crop (group);

3. A central register could be established by an independent party such as the EC or the combined voluntary schemes in which all certified projects are included with information on target crop(s), specific cultivation location, specific mitigation measure(s) applied, certification date, certification scheme, certification body used and amount of certified feedstock. For yield increase, the registry allows to get better insights along the way on the effectiveness of certain measures implemented in certain regions. The registry should be accessible for all stakeholders.

The consultation process for this report clearly revealed a strong preference of the stakeholders for a mass balance which is not combined with a book and claim system. This means that the ILUC claim can only be made for the area where the ILUC mitigation strategy was applied.

We recommend the establishment of a central registry regardless of the chain of custody type that is applied because the registry increases the transparency of the system and allows economic operators to learn from best practices. Such a central registry could be administered by the European Commission or by voluntary schemes.

3 ILUC mitigation methodology for yield increase

This chapter describes how economic operators can demonstrate low ILUC risk biomass production through increased agricultural crop yields. Requirements described in the previous chapter also apply. An overview of criteria, indicators and guidance is provided in Annex I and Annex II.

3.1 Introduction

Increase in crop yield is one of the main focus areas of agriculture research, which helps to reduce the yield gap between actual and theoretical maximum yield potential[8]. Despite significant efforts through development of new varieties and improved management practices, the gap between potential and actual yields is still very large. There are two main factors that influence crop yields: 1) site specific conditions and 2) crop management practices. Site specific conditions such as climatic and soil conditions cannot be modified, therefore the potential to increase yield lies in crop management practices especially in regions where crop yield is mainly low because of poor management practices. Additional yield increases above the reference scenario, induced by the biofuel sector, implies additional biomass feedstock without associated land use change. This additional biomass therefore has a low ILUC risk. It is important to note that the yield increase has to be achieved in a sustainable manner and has to be in line with the EU Renewable Energy Directive (Directive 2009/28/EG).

3.2 Potential estimate

Yield increase can be achieved in any region of the world, either inside or outside the EU. In western Europe, the yield gap between potential and actual yields is low compared to eastern Europe where actual crop yields are low. In a recent study for the European Commission Ecofys together with University of Hohenheim concluded that there is yield increase potential of 8% and more in the EU by applying crop specific strategies for yield increase (Ecofys, 2016).

Similarly, outside the EU the potential of this measure is significantly high, especially in regions with a less developed agricultural sector in terms of machinery and know how. Overall, the mitigation measure has a high potential depending on the specific area in which it is applied. There is very large opportunity for EU biofuel producers via indirect mitigation when yield is increased in regions with at present poor management practices.

[8] Theoretical maximum yield is defined as the upper physical limit for a specific crop in a specific region, which can be achieved only under defined best crop management measures without any limitations.

3.3 Examples for yield increase measures

Site and climate conditions are responsible for up to 50% of crop yields. However site and climate conditions cannot be changed, so the focus for yield increase is on crop management measures. The feasibility to implement a certain crop management measure varies from region to region. Yield increase measures can include for example for the following:

- Choice of crop varieties (i.e. higher yielding variety, better adaption to eco-physiological or climatic conditions)
- Sowing (e.g. improved drilling machine)
- Soil management (e.g. mulching instead of ploughing, low tillage)
- Fertilisation (e.g. optimisation of fertilisation, use of better fertiliser)
- Crop rotation (e.g. change in crop rotation, cultivation of catch crops)
- Crop protection (i.e. change in weed, pest and disease control)
- Pollination (e.g. by using bees)
- Harvest (e.g. new harvest machine, harvest at optimal time)
- Precision farming[9]

Yield increase measures which fall into one of these categories are eligible for applying for low ILUC risk biomass certification, provided that the measures are conducted in a sustainable manner and comply with the RED. A simple land use change within the agricultural area of the applicant is not sufficient for an application. This exclusion is necessary to prevent that low ILUC risk biomass production is simply achieved by cultivating the target crop on the best soil where previously another crop was cultivated and the additional biomass of the target crop is thereby achieved at the expense of the yield of the previous crop. Shifting one crop to a more productive other crop is also not a permitted yield increase measure, as the yield increase measure has to be applied to an already cultivated target crop, i.e. a crop that has to be cultivated for at least for 3 years.

Simple land expansion for the cultivation of the target crop is also no measure for low ILUC risk biomass production as the yield increase needs to improve the yields per hectare. Within the cross compliance system in the EU the land area used per crop and the respective yields are reported to the collector or commodity trader. Any auditor can therefore easily check how much land is used for by a group of farmers in a region.

3.4 Certification process requirements

In order to demonstrate that a certain quantity of biofuel feedstock is produced with low ILUC risk, the certification requirements as described in Chapter 2 apply. Main elements are that the economic operator submits an application for certification to the scheme owner prior to the actual implementation of the ILUC mitigation measure. The economic operator drafts an ILUC mitigation plan that is verified by an independent auditor. Once the ILUC mitigation plan is approved, the mitigation measure is implemented and when this results in additional feedstock cultivation, certificates are granted.

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[9] Precision farming is a farming management concept based on observing, measuring and responding to inter and intra field variability observed in crops. The precision farming system can lead to increase in crop production with minimum environmental implications.

Specifically for yield increase, we recommend that certification for low ILUC risk biomass achieved through yield increase should be applied by a **group of farmers** as it has the following advantages compared to a **single farm** certification:

- It is challenging to prove the statistical significance of the impact of yield increase measures on one farm only. This makes it difficult to prove additionality at farm level. More data points from several farmers increase the statistical relevance;
- Based on discussions with traders and collectors we think that most of them do not know the concept of ILUC and cannot be expected to initiate ILUC mitigation strategies;
- It is too expensive and burdensome to draft a yield increase ILUC mitigation plan for a single farm and get it audited. Farmers face a high administrative burden already.

In a group, multiple data points are available per year which allow an increased statistical significance of the result of the yield increase measure. Still single farm should not necessarily be ruled out completely in order to deal with specific circumstances. For instance, the introduction of sequential cropping can be a game-changer in terms of crop yields, with a, above-reference yield increase that can be clearly demonstrated.

For group certification, the group manager can be a biomass collector, agricultural commodity trader or any first gathering point who is tracking parts of the necessary information from the farmers or group members anyhow.

The economic operator applies for low ILUC risk biomass certification at the voluntary scheme owner. Following this, he drafts an ILUC mitigation plan according to the definition as provided in Section 2.2 and following the analysis as specified in Section 2.4. Specifically for yield increase, the ILUC mitigation plan also includes data records on land used per crop to enable verification that yield increase is not due to land expansion for target crop. An independent auditor verifies the ILUC mitigation plan, following the guidance as included in Annex I and Annex II.

If the auditor approves the ILUC mitigation plan, the economic operator can start implementing the yield increase measures, with all above-reference biomass being eligible for low ILUC risk certification. It’s important to note that not all biomass is eligible for low ILUC risk certification but only the quantity of additional biomass beyond the reference.

Determined low ILUC risk biomass at group level is allocated to individual group members according to their specific contribution in total target crop production. In case of single farm certification, all low ILUC risk biomass is allocated to the farmer.

The certification period is 10 years as explained in Section 2.4. During this period, regular verification takes place in line with the general certification rules that voluntary schemes for compliance with the EU sustainability criteria for biofuels.

A regional approach to demonstrate low ILUC risk biofuel production is also possible. Such regional approach would mean that certification takes place for an entire geographical region. The reasoning behind the regional approach is that additional yield increases above a reference scenario, linked to biofuel demand, generates additional biomass. However, the regional production of biomass feedstock should not be at the expense of food and feed production required to fulfil global food demand. Therefore, the regional approach for low ILUC risk biomass production could only work as long as it is corrected by the future global food demand. A reference scenario for specific crop(s) is established based on future increases of crop yields. Crop yields above this reference are additional. If achieved in regions with a binding biofuel mandate in place, additional biomass can be claimed as low ILUC risk biofuel feedstock. The option of a regional approach is not developed further in this report.

3.5 Establishing the reference scenario

As described in Section 2.2, the reference scenario is a counterfactual scenario against which the yield increase is measured. The reference scenario is built upon historical yields that are expressed in a trendline. Note that only biomass produced above the baseline can be claimed as low ILUC risk. We foresee that as a default situation separate references are being calculated for all crops being produced on the farm that benefit from yield increase measures and that can be used to produce biofuel. After the introduction of a yield increase measure, the actual yields per crop are compared to the specific reference yields for each crop.

Crop yields typically fluctuate quite significantly from year to year. However a constant average yield increase can be seen, both in the EU as well as globally. In a simplified manner this historical yield increase that is happening anyhow can be expressed in linear trendline. A more precise representation of historical yield requires complex crop and region specific regression analysis. However the assumption of a linear increase covers reality sufficiently for the purpose of mitigating ILUC. The example of wheat yields from 1961-2013 demonstrates clearly that a linear assumption could be made:

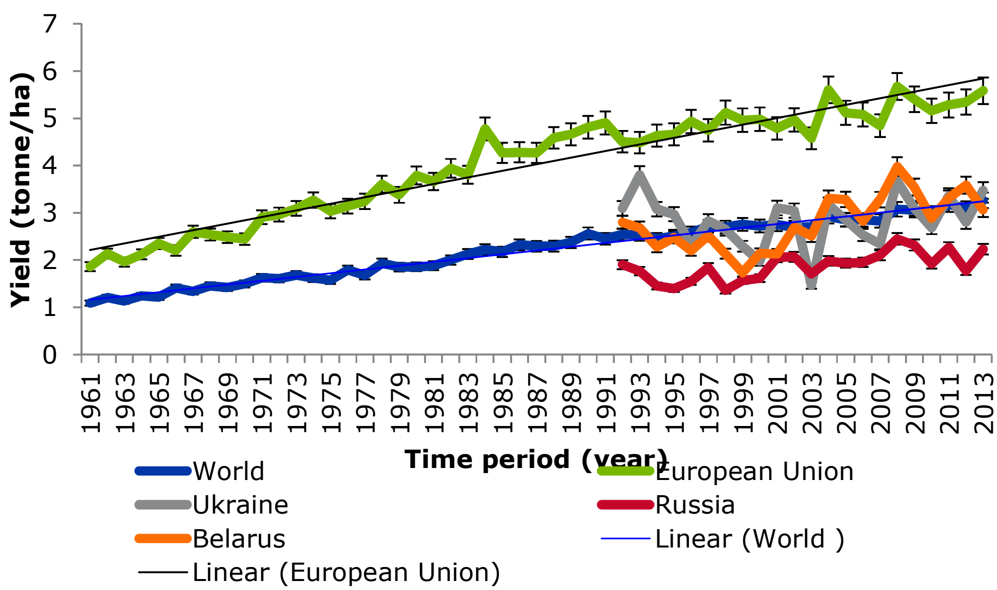

Figure 3. Grain yield development of wheat 1961-2013 (Ecofys, 2016)

A linear trendline is covers the historical yield development of oil crops and sugar beet well. The yield increase according to the trendline is business-as-usual and can therefore not be considered as additional. As an entrepreneur each farmer can be expected to continuously keep on investing with the aim to increase his yields. The additionally achieved from the yield increase in the ILUC mitigation plan has to be above the yields that are happening anyhow, i.e. without a demand for biofuels with low ILUC risk. The proposed measure by the farmer or group of farmer to achieve low ILUC risk biomass production will stay above the trendline and will always add to the business-as usual yield increase. If for instance a farmer or group of farmers invests in a field sprayer with a wider range as an ILUC risk mitigation measure, thereby resulting into 2% yield increase, this 2% will remain additional even if yields are further improved by other measures in the future that are not part of the yield increase ILUC mitigation plan for low ILUC risk biomass production.

Based on the assumption of linear yield development, the reference scenario is established as follows.

1. The historical yields of the last 10 years of the target crop of the farmer or group of farmers are used to determine the linear trendline. In case of a group the median of the yields of each group member is calculated for each year. The median is more robust to outliers as the average, as 50% of values are below and 50% are above the median;
2. The linear trendline is calculated by using the statistical method of least squares. This method basically identifies the least distance for all input values to the trendline. The outcome is a linear function that best fits a data set. Due to this approach all yields within the last 10 years are equally represented in the trendline;
3. This trendline is used to calculate the reference point.

Equation 1: Linear trendline

$$Y_{ref,\ t=x} = \text{Statistical starting point} + \text{slope} * \text{year}$$

Whereas:

Statistical starting point is the beginning of the linear trendline in year 1, which is 10 years before the application for low ILUC risk

Slope is the annual yield growth of the last 10 years

Year is the year for which the point on the linear trendline is to be calculated. Year 1 is 10 years ago, whereas the previous year before the application is year 10.

Reference Point is the statistical point on the trendline yields in year 10, i.e. before the ILUC mitigation action is implemented.

Calculation the linear function with the least square method[10] from actual values is not easy, we therefore propose to create an Excel tool that any economic operator can easily use. The economic

[10] The method of least squares is a standard approach in regression analysis to the approximate solution of overdetermined systems, i.e., sets of equations in which there are more equations than unknowns. "Least squares" means that the overall solution minimizes the sum of the squares of the errors made in the results of every single equation. The most important application is in data fitting. The best fit in the least-squares sense minimizes the sum of squared, a residual being the difference between an observed value and the fitted value provided by a model. (see also: https://en.wikipedia.org/wiki/Errors_and_residuals)

operate would only need to enter the actual yields of the last 10 years as input parameters. Within this tool the median will be calculated from each group member.

For a better understanding establishing the reference for a group of wheat farmers is explained below. In this example a group of farmers had the following median annual yields for wheat in 2005-2014:

YIELD/TIME	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Median yields of group	4.4	3.5	4.3	3.9	4.7	4.6	4.1	4.1	4.9	5.2

Following the method of least squares these values are best matched by a linear trendline with this function:

$Y_{ref, t=x}$ = 3.8107 + 0.1004 * year

Whereas

a. is the statistical starting point in year 1 (i.e. 2005)

0.1004 is the annual yield growth in the period 2005-2014

Year is the year for which the statistical yield has to be calculated with 2005 being year 1.

This trendline is used to calculate the reference point for 2014, i.e. the year before the ILUC mitigation action is implemented.

In the example for wheat farmer the reference point is below the actual yield in 2014.

$Y_{ref, 2020}$ = 3.8107 + 0.1004 * 10 = 4.8

Any wheat yield above 4.8 t/ha is low ILUC risk in this example.

Under specific circumstances it will be difficult to provide historical data for the last 10 years. We therefore recommend to allow the following exemptions from this requirement. An auditor will have to check whether the exemptions really apply, to avoid that economic operators play around with the yield data, pretending not to have less suitable data leading to a higher trendline:

- For newly developed crops or newly cultivated crops historical data of the last 3 years have to be provided.
- Farmers lacking proper records of yield data have to track their data for 3 years before they can apply for low ILUC certification.

The figure below illustrates how the quantification of above-reference biomass can look like when using a target crop(s)-specific way of reference setting.

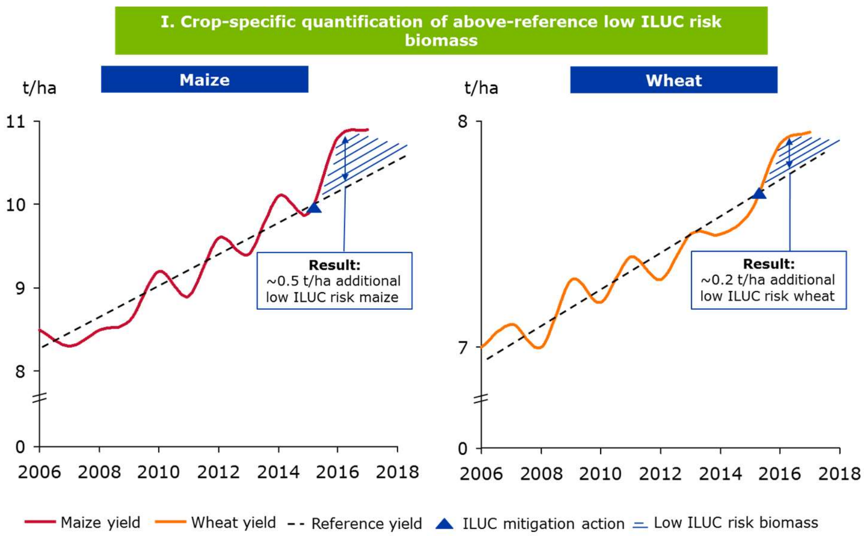

Figure 4 - Example of reference and above-reference biomass in target crop(s)-specific approach and the crop-component and Forage Unit alternative approaches

As explained in Section 2.4, we propose that in addition to the target crop(s)-specific reference setting and calculation of additionality, we propose to alternatives that can be more fitting in certain circumstances: the crop component approach and the Forage Unit approach. Both approaches are explained in more detail in the next chapter.

3.6 References

Ecofys, 2012, Low Indirect Impact Biofuels (LIIB) Methodology

Ecofys, 2016. Maximising the yield of biomass from residues and agricultural crops and biomass from forestry.

Gützloe, Lewandowski, 2014. Rapeseed yield increase at farm level, University of Hohenheim.

4 Specific yield increase measure: multicropping

This chapter describes how economic operators can demonstrate low ILUC risk biomass production through increased agricultural crop yields, applying intercropping. This chapter builds on the requirements provided in the previous chapter and Chapter 2. An overview of criteria, indicators and guidance is provided in Annexes I and II.

4.1 Intercropping and sequential cropping

If the ILUC mitigation methodology for yield increase is applied, many potential yield increase measures focus on increasing yields for single crops. It is also possible to increase agricultural yields by combining various crops in a single cropping system. This is called multi-cropping. This chapter describes how multi-cropping can be applied as a specific yield increase measure.

Multi-cropping is an umbrella term for all systems growing several crops consecutively or at the same time on the same plot within a period of one year. The main aim of multi-cropping is to increase the productivity per unit area with farmers not seeking to optimize production of a single crop but rather of an entire system that includes several crops. This makes it a very specific form of yield increase. Multi-cropping is also applied to maintain soil fertility and soil nutrients, protect against pests and suppress weeds. A challenge is to select the most beneficial combination of crops where competition for light, nutrients, and water is kept to a minimum. Examples of crops which are often combined are maize and wheat, rice and wheat and maize and pumpkin and a leguminous cover crop. Most examples today are found outside the EU.

As can be seen in Figure 6, the two main types of multi-cropping are intercropping and sequential cropping. Both will be briefly explained below.

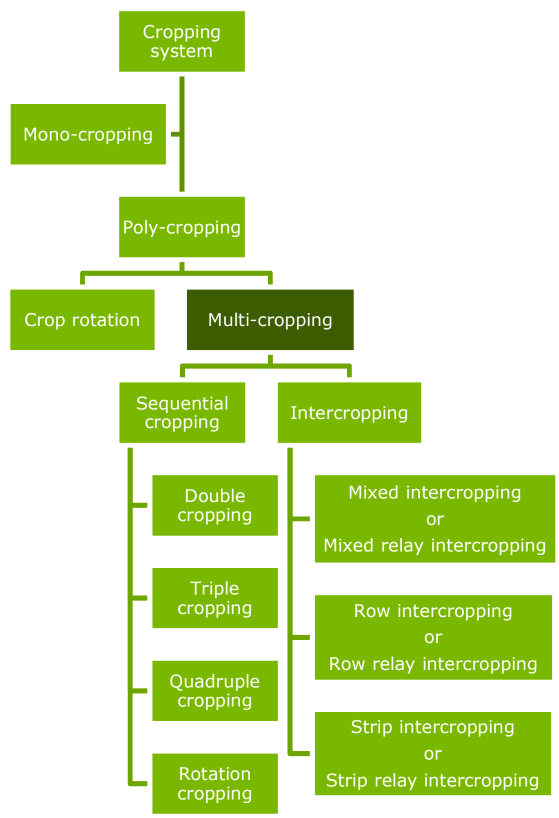

Figure 5. A systematic overview of cropping systems.
Source: Ecofys based on Gliessmann (1985)

Sequential cropping refers to a cropping system in which a second crop is cultivated and harvested after a first crop has been harvested on a plot of land within a period of one year. Intercropping means that multiple crops are grown at the same time on the same land, using resources differently in space and time making intercropping perform better than mono-cropping. This chapter focuses both on intercropping as well as on sequential cropping.

Sequential cropping – two crops on the same field after each other

In many regions including most of Europe, the dominant crop cultivation practice is to grow a summer crop and leave the land fallow during winter time. This winter fallow period stems from the fact that weather conditions often hamper crop growth during winter time but, equally important, the fallow period allows the soil to rest and often a winter cover crops that is mulched into the soil helps to maintain the soil nutrients balance. Today, we see the first examples of sequential cropping being applied with the aim to produce additional biomass for biofuel feedstock.[11] This means that the winter fallow period is replaced by crop production, as shown in the figure below.

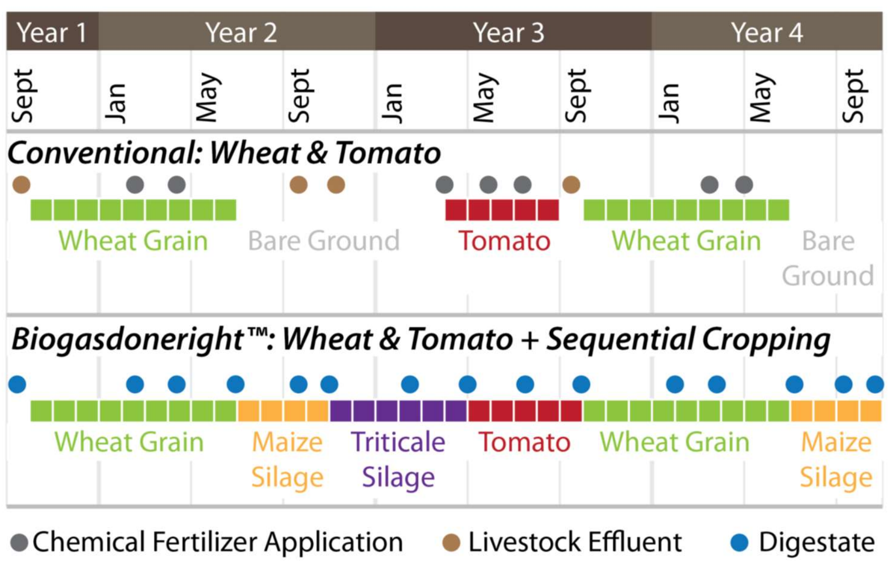

Figure 6 - Example of sequential cropping compared to conventional agriculture. In the sequential cropping situation triticale silage is added as a winter crop during the previous winter fallow period (source: Prof. Bruce Dale and CIB, Italian Biogas Consortium)

One immediate question that arises from this practice is whether the introduction of sequential cropping is possible in a sustainable manner, maintaining soil quality and without adverse impacts on

[11] A group of Italian farmers and biogas producers organised in the Italian Biogas Consortium CIB started with sequential cropping to produce silage maize and triticale to feed the biogas installation while maintaining agricultural production for food and feed purposes. Outside Europe, UPM performs trails with the cultivation of Brassica Carinata as a winter cover crop as biodiesel feedstock, while maintaining the existing soybean production.

biodiversity and water availability. While our low ILUC risk quantification methodology as proposed in this report does not specifically focus on these sustainability aspects, we do recognise the need for a full sustainability assessment in order to ensure that sustainable agricultural intensification is designed in a truly sustainable manner. Based on recent Ecofys assessment we believe that sequential cropping can be introduced in a sustainable manner.

Various types of intercropping

There are different types of intercropping. **Mixed intercropping** is the growing of two or more crops simultaneously without a distinct row arrangement. **Row intercropping** is the cultivation of different crops at the same time and at least one crop is planted in rows. **Strip intercropping** is the growing of two or more crops in the same field, planted in strips close enough for the crops to interact. **Relay intercropping** is a technique in which two or more crops are planted in the same field and the crops spend at least part of their season growing together in the field and part of it growing alone. Thus, the relay intercropping technique refers to the different moments in the season of planting the respective crops in an intercrop. This design option can be combined with mixed, row, and strip intercropping (FAO, 2016).

Barriers and opportunities for intercropping

Although limited historical data on multi-cropping is available, literature shows several advantages of intercropping over mono-cropping, emphasizing that intercropping tends to mitigate certain negative environmental impacts of agricultural monocultures. Main environmental benefits are:

- Intercropping uses land and other resources more efficiently compared to mono-cropping (Zhang and Li, 2003).
- Intercropping has positive effects on biodiversity and ecosystem services due to biological suppression of pests, diseases and weeds (Banik et al., 2006).
- Intercropping can be more stable than mono-cropping, if one of the components fails due to a disease or pests. The other component of the inter-crop in this scenario is then likely to use the environmental resources for plant growth, not utilized by the component which failed (Jensen, 1996).
- Intercropping increases soil organic carbon storage over time and improves nitrogen retention. Thus, there is scope for moderate improvements of nutrient use efficiency in inter-crops as compared to sole crops, especially for nitrogen when using legumes in the mixture. Cong et al. (2015) However, for this analysis we expect fertiliser inputs used in multi-cropping to be identical to the level of input in mono-cropping.

The main challenge for the adaptation of intercropping by farmers is the compatibility of the technique with current agricultural practices and equipment. A short term solution to overcome this barrier is to adopt the mixed intercropping technique, in which crops are fully mixed, sown and harvested simultaneously and where post-harvest separation of seeds is feasible. This solution can be applied under current agricultural equipment standards in the EU. Current mechanization also allows intercropping in three meter wide strips in a strip or strip relay intercropping design. In these more complex inter-crops, modern mechanization is not yet readily available. This is particularly the case for operations on single strips with companion crops that are too tall for a tractor to pass. This means that simultaneous design of machines, strip width, crop combination and management practices is necessary (Yu, 2016).

4.2 Crop component or Forage Unit approaches to quantify above-reference biomass

Calculating the reference scenario

Intercropping or sequential cropping can be implemented as a specific yield increase measure. This means that the reference scenario is calculated in line with the methodology as outlined in Chapter 3. The yield increase reference gives the trendline yield of a certain crop produced in monocrop on a certain harvested area. A specific feature of intercropping is that absolute yields decrease of the crop previously cultivated on the land in mono-crop rather than increase. This could be the case as well for sequential cropping, although less likely. If for example one hectare of wheat in mono-crop is transformed into one hectare of wheat and maize intercropping, the absolute yield and protein stemming from wheat decreases while the overall yields increase due to the additional maize production. This means that in order to calculate the yield benefit of multicropping, both the yield figures per hectare but also the crop protein level needs to be taken into account. This means that special attention is required for the reference setting.

Ecofys recommends that reference setting and calculation of additional biomass for intercropping and sequential cropping is based on a crop component approach or a Forage Unit based approach. This means that for both biofuel feedstock component as well as for protein. Note that replacing one crop by another is not a valid yield increase measure.

Calculating above-reference biomass using a crop component approach

A multicropping is applied with two biofuel crops as target crops that belong to the same crop group (starch, sugar, vegetable oil). A single reference is established for both crops combined including their combined average level of protein. Table 1 shows the composition of conventional biofuel feedstocks according to the main component categories. Actual production levels in the multicropping situation are compared with the yields in the ‘single crop’ reference levels, resulting in a figure for net additional biomass production in starch, sugar or oil as well as protein.

Table 1: Composition of biofuel feedstocks – main categories[1] (average[2], % as fed)

Feedstock	Water [3]	Protein	Fats	Sugars	Starch	Fibre (NDF)	*Cellulose*	*Hemicellulose*	*Lignin*
						Fibre			
Wheat	13.2	10.5	1.5	2.4	60.5	12.4	*2.1*	*9.3*	*1.0*
Maize	13.6	8.1	3.7	1.6	64.1	10.4	*2.1*	*7.8*	*0.5*
Sugar beet	81.2	1.5	0.1	13.6	0.0	3.8	*2.0*	*1.4*	*0.4*
Sugar cane	77.4	0.9	0.4	9.9	0.0	11.3	*5.8*	*4.6*	*0.9*
Rapeseed	7.8	19.1	42.0	5.1	0.0	17.6	*6.9*	*5.2*	*5.5*
Palm fruit bunch	15.5	3.5	37.7	0.2	0.0	38.8	*18.0*	*9.5*	*11.3*
Soybeans	11.9	34.8	17.9	7.7	0.0	11.0	*5.4*	*4.6*	*1.0*
Sunflower seed	7.0	16.0	44.6	2.4	0.0	28.8	*13.0*	*10.1*	*5.7*

Note: [1] Categories do not sum to 100% because of issues with under- or double counting of components.

[2] Average based on number of samples tested. [3] Water calculated on the basis of dry matter percentage of feedstock.

Source: Agra CEAS Consulting; adapted from Ecofys et al. (2016). Decomposing biofuel feedstock crops and estimating their ILUC effects. The Netherlands: Utrecht. A study commissioned and funded by the European Commission.

As explained in Section 2.4, the crop component approach stems from the notion that ILUC modelling studies like GLOBIOM (2015) and the earlier IFPRI-Mirage study (2011) show that biofuel crops included in the same crop group have a more or less comparable risk on adverse land use change, with vegetable oils having considerably higher associated emissions than starch or sugar crops.[12] Moreover, the study Ecofys and partners[13] and partners did on decomposing biofuel feedstock crops and estimating their ILUC effect shows that it is important to assess the crop component protein because protein is mainly used in the food and feed industry. Table 1 shows that the average level of protein for soybeans is high with 34.8% compared to 19.1% for rapeseed, 10.5% for wheat and 8.1% for maize.

Based on the crop component method, a lowering of the productivity of one crop is compensated for by deducting a proportional production quantity from the additional production of the second crop. It follows that a reduction of the overall protein level of the yield of one crop can be compensated by the additional production of protein from the other crop in the intercrop. It should be noted in this context that GLOBIOM shows that palm oil has a much higher risk on adverse land use change than other vegetable oils. However, palm oil is produced on plantations and will not be produced in combinations with other vegetable oil crops. While in the crop component approach multicropping should be applied with various crops from the same crop group, it could still be acceptable to combine a vegetable oil crop with a starch or sugar crop as long as the vegetable oil crop is the 'newly added' crop, meaning that the previous mono-crop situation on the harvested area consisted of a sugar or starch crop. Moreover, it needs to be ensured that the additional production of the

[12] See the GLOBIOM study (2015) and IFPRI-MIRAGE study (2011).

[13] Ecofys et al. (2016). Decomposing biofuel feedstock crops and estimating their ILUC effects. The Netherlands: Utrecht. A study commissioned and funded by the European Commission.

newly added crop leads to a surplus in protein that can compensate the loss of protein stemming from the first crop. This ensures that additionality is created for the higher ILUC risk vegetable oils.

Calculating above-reference biomass using a Forage Unit approach

As also discussed in Section 2.4, the crop component approach works well for cases in which the additional crop is used to produce liquid biofuel with an animal feed co-product. However, if the additional crop is used for biogas the crop component based approach does not seem immediately appropriate because the entire crop is useful feedstock instead of just a single component. And also, silage crops used for feed, are not just valued as feed for their protein value but also for their other components (e.g. fibre, starch, etc.).

For crops that are mainly used for feed or biogas, such maize silage, we propose to use Forage Units to calculate the reference and above-reference biomass. This approach allows to compare various starch crops while reflecting their full market value. Forage Units are used in feed formulation and are based on 1,700 kcal of metabolizable energy, thereby providing a standardised value to compare different feed crops. Various starch crops can be transferred to Forage Units by calculating the metabolizable energy of all crop components. Where possible, the crop composition table above can be used as a first step and for silage crops the decomposition is based on best available literature. Metabolizable energy of crop components is calculated using the method as described in 'Nutrients requirements of dairy cattle', by National Research Council (NRC 2001) and aggregated to a single number of Forage Units per crop. In order to provide an order of magnitude, the table below gives the Forage Units as calculated for various feed crops by the Italian Research Centre for Animal Production (CRPA) for a farm in northern Italy.

Crop	Forage Unit per tonne fresh matter
Maize	1120
Maize silage	308
Wheat	1050
Wheat silage	249
Barley	1013
Barley silage	270
Triticale silage	256
Soybean	1350

Table 2 - Example of Forage Units for various crops

As with the crop component approach, the Forage Unit approach should only be used for crops within the starch, sugar or veg oil crop groups respectively, with also the exception that creation of additional vegetable oil production compared to a sugar or starch based reference should be allowed.

The three ways of reference setting and calculation of above-reference biomass as proposed in this report are presented in the figure below.

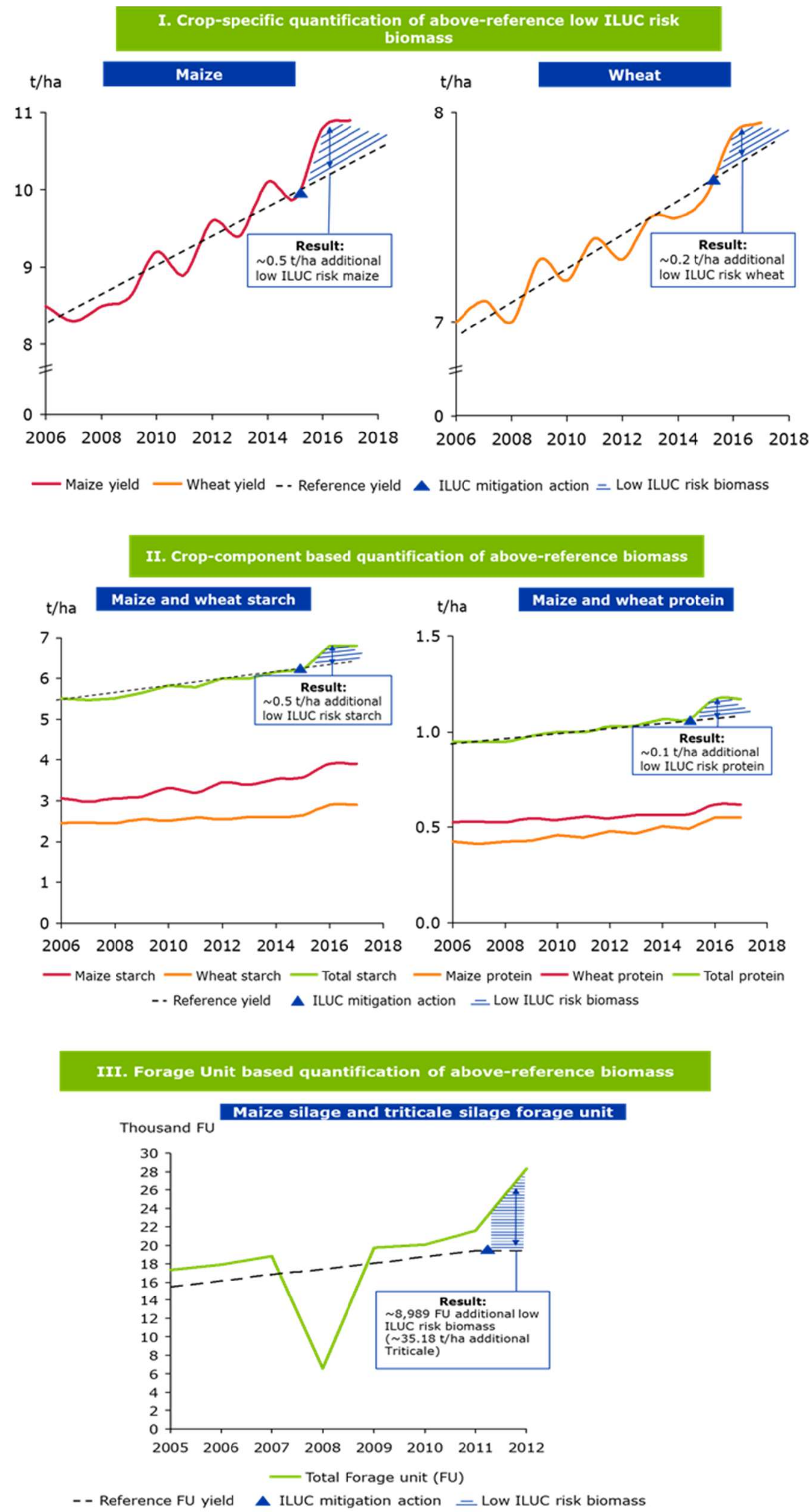

Figure 7 - Example of quantification of above-reference biomass using a crop(s) specific approach, a crop component approach and a Forage Unit approach (featuring thousands of FU per hectare)

5 ILUC mitigation methodology for unused land

This chapter describes how economic operators can demonstrate low ILUC risk biomass production through biomass cultivation on unused land. Requirements provided in Chapter 2 also apply. An overview of criteria, indicators and guidance is given in Annex A.III.1 Overview of criteria, indicators and guidance*.*

5.1 Definition of unused land

Unused land is defined as a plot of land which is not under cultivation because of biophysical or socio-economic limitations and not used for other provisioning services[14] currently and during the past 5 years, with low carbon stocks and limited biodiversity value. The period of 5 years is chosen in order to differentiate from fallow land as part of crop rotation. Biofuel feedstocks that are produced on unused land can be categorised as low ILUC risk biomass since it does not lead to displacement of food production. Agricultural production on unused land can involve sustainable direct land use change in order to avoid unsustainable indirect land use change. Compliance with the EU RED sustainability criteria for biofuel production ensures that direct land conversion does not lead to substantial carbon stock or biodiversity losses. Two main categories of unused land can be distinguished, both of which are included in this methodology for ILUC mitigation through cultivation on unused land:

1) Transitional abandonment - land abandonment as a result of policy restructuring or land reforms, e.g. former Soviet Union or other parts of Eastern Europe, with areas moved in and out of agricultural use depending mostly on market prices for certain commodities.
2) Actual abandonment, when farmland is no longer used and left fallow because of e.g. declines in soil fertility or off-farm working opportunities.

Land abandonment is a complex process of reduced farming activity over a period of time ranging from land that is temporarily unused (potentially overlapping with fallow or former compulsory set-aside) to land that is entirely abandoned for production, and management is withdrawn completely.

As in many cases land is not completely unused but instead used to a very limited extent (i.e. in an extensive manner such as grassland used by shepherds or wood collection), the definition of unused land may, under certain conditions, also include land that is under such very limited land use. This could only be the case if the limited land use on the specific plot of land under observation is performed by a person/entity that holds no legal, traditional and/or customary land use rights for the respective land. Under these conditions, land can still be classified as unused land that is eligible for the production of low ILUC risk biomass, though being used to a very limited extent.

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14 The Millennium Ecosystem Assessment published in 2005 defines 4 categories of Ecosystem Services, one of them being "Provisioning Services". According to the definition, provisioning services are ecosystem services that describe the material or energy outputs from ecosystems. They include food, water and other resources.

Initially, Ecofys considered to also specifically focus on 'underutilized land'[15] being eligible for the production of low ILUC risk biomass. However, we currently propose not to include underutilized land specifically as it bears the risk that low-intensity smallholder agriculture may in some cases be regarded as underutilized land, also leading to risks of land grabbing. For this reason, underutilized land is excluded from the methodology, with the notion that very low intensity, unmanaged, non-traditional land uses are considered to be excluded from provisioning services.

5.2 Potential estimate

Unused land is expected to be available in various regions globally. It is difficult to obtain precise estimates of how much unused land is currently available. In the EU a process of land abandonment takes place. At the other hand some previously abandoned land in Central-Europe has been taken back into production after the spike in agricultural commodity prices in 2008. At EU-level, IEEP roughly estimated the available land area to be in range of 1 to 1.5 million ha, which could generate about 7.7 to 16.7 million dry tonnes of biomass per annum, with a potential embedded energy content of between 139 to 300 PJ. When putting the figures into perspective, the overall potential could replace around 0.5 to 1 percent of total current EU road transport energy consumption, which is substantial.

5.3 Certification process requirements

In order to demonstrate that a certain quantity of biofuel feedstock is produced with low ILUC risk, the certification requirements as described in General methodology design choices apply. This means that economic operator prepare an ILUC mitigation plan that is verified by an independent auditor. Once the ILUC mitigation plan is approved by the auditor and the scheme owner, the mitigation measure is implemented, all agricultural output from the land can be certified as having low ILUC risk. For unused land, certification takes place at the level of an individual plot of land (farm-level) because it is important for the credibility of the mitigation measure that an on-site independent audit takes place, also given the sensitivities around land conversion. The annual verification could take place at group level as long as the initial certification and auditing is performed at single operator level. The regulatory as well as land cover and utilization assessment of unused land can be conducted at a regional level as long as on-site visits are still performed at individual plot land to verify the assessed data.

The ILUC mitigation plan includes a barrier or investment analysis as specified in Section 2.4 and has to demonstrate that the plot of land meets the definition of unused land as provided in Definition of unused land above as well as certain additional requirements that are part of the reference situation, as described in the next section.

The proposed certification period is 10 years, as is the case for yield increase, see Demonstrating additionality.

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15 Underutilised land refers to land that is not under cultivation or falling out of agriculture/crop production because of socio-economic limitations, but is still used to a limited extent for other purposes (e.g. grassland used by shepherds). Such limited land use could be defined as land not under agricultural cultivation and with low carbon stocks and biodiversity value with a limited land use with an economic value of less than 25% of the output that can be reasonably expected if the land would be under cultivation.

5.4 Establishing the reference scenario

The reference scenario or situation for unused land is that a plot of land meets the following requirements:

1. The plot of land meets the definition for unused land as provided at the start of Definition of unused land above.
2. Agricultural production on the land can take place in compliance with the EU sustainability criteria for biofuels, meaning that the plot of land should have low carbon stocks and biodiversity value, and;
3. The land can be used for agricultural production in compliance with relevant legal and regulatory requirements as well as respecting traditional and/or customary land use rights.

This reference situation is described by the economic operator in the ILUC mitigation plan according to the methodology as outlined in this section and verified by an independent auditor. Point 2 must involve actual carbon calculations based on on-site monitoring of available biomass, biodiversity and taking soil samples. Point 3 must involve Free Prior and Informed Consent of local communities, especially in those countries, where traditional and customary land use rights are lacking. The remainder of this section focuses on the first point, how the unused land status can be demonstrated.

To measure and verify whether a specific plot of land is unused, a regulatory and remote sensing analysis is proposed, as shown in Figure 8. Approach to demonstrate the unused land reference, which is performed by the economic operator and included in the ILUC mitigation plan, plus an on-site audit by an independent auditor, who also verifies the remote sensing and regulatory assessment.

The proposed approach to demonstrate the reference consists of a set of scientifically robust methods to assess the specific plot of land under observation from different angles, each step continuously increasing the probability that the land is truly unused. Annex III – Criteria, indicators and guidance for unused land provides a full overview of the criteria, indicators and guidance.

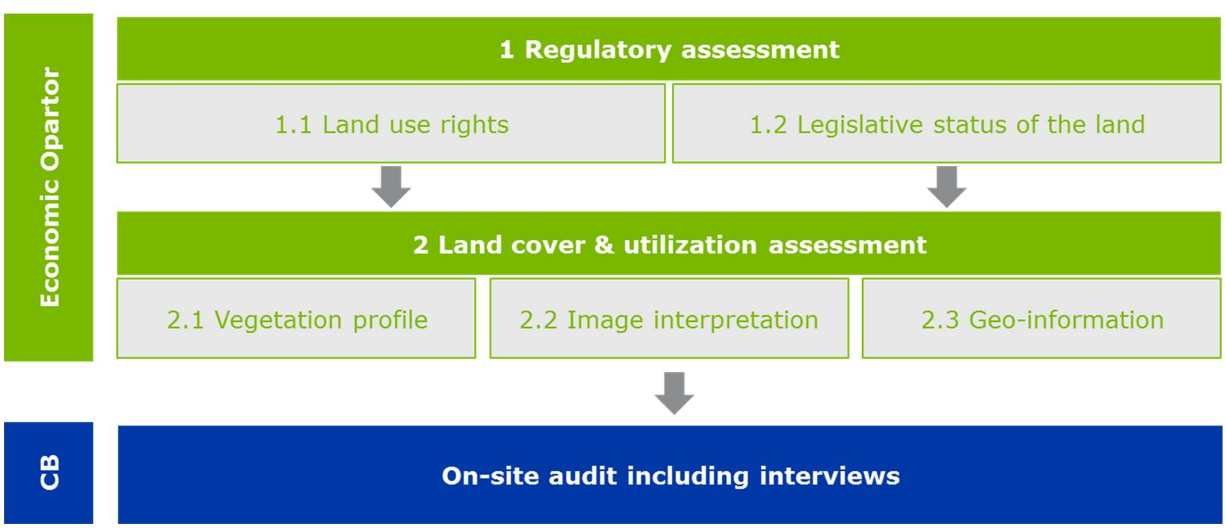

Figure 8. Approach to demonstrate the unused land reference

5.4.1 Regulatory assessment and remote sensing to assess the unused land status

The analysis is used to provide an independent, objective and robust assessment using remote sensing techniques and geo-information as well as land property information to assess whether the plot of land is unused. The economic operator shall include all required data and information under the top-down analysis in the ILUC mitigation plan. The analysis is composed of two parts: **a regulatory assessment** and **a land cover and utilization assessment.**

Regulatory assessment and land use right

The regulatory assessment shall be used to determine whether the plot of land under observation can be legally used for or converted to crop production. In this step the Economic Operator provides information on the eligibility and legality of using the plot of land under observation for agricultural production. Also, the economic operator must demonstrate that he holds the legal right to use the land and that no relevant regulation bans the land from being used for agricultural production. The economic operator also has to demonstrate that no traditional and/or customary land use rights apply that can prevent him from using the land for agricultural production.

Land cover & utilisation assessment

The land cover & utilization assessment shall be followed by the economic operator (or anyone tasked on his behalf) to determine the land cover and land use during the past five years by using remote sensing and geo-information methods and databases. It is composed of three steps.

In the first step the **vegetation profile of the plot of land is assessed** (step 2.1 in Figure 8. Approach to demonstrate the unused land reference) Annual vegetation profiles of the Normalised Difference Vegetation Index (NDVI)[16] shall be used to examine the land cover and utilization of the plot of land during the past five years. The NDVI is frequently used in agriculture, forestry and ecology to assess the healthiness and vegetation growth over a certain time horizon and is calculated by means of satellite data (e.g. from Sentinel satellites). The assessment shall be done by plotting the NDVI value (y-axis) and the time (x-axis) in a diagram and subsequently analysing the smoothness/noise of this temporal vegetation profile for each of the past five years. The NDVI profiles during the past five years each should show a smooth, bell-shaped temporal vegetation profile with one maximum peak. Figure 9. Exemplary NDVI profiles depending on land-use activity below shows some exemplary NDVI profiles and Annex A.III.2 Further guidance on assessing the land cover vegetation profile gives detailed explanations of the NDVI assessment methodology.[17]

[16] The NDVI is a scientific index that was firstly used in 1973 by researchers from Texas A&M University. Vegetation (or chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths while it absorbs more red and blue light at the same time. This is why our eyes see vegetation as the **colour green** and why **more near-infrared** is reflected back into satellite sensors. The NDVI makes use of this reflection to describe the vegetation by showing the difference between near-infrared (which is strongly reflected by vegetation) and red light (which is absorbed by vegetation).

[17] The definition of a clear and objective threshold/cut-off criteria on when land is unused or not is crucial for the applicability and reliability of the methodology. As the remote sensing methodology using NDVI profiles to detect 'unused land' is still fairly recent, there is yet limited evidence on accuracy and applicability. We therefore recommend that further research into the benefits and challenges of NDVI profiles should be promoted and supported. In general, we think that with newer satellite data, e.g. from Sentinel 2, the accuracy and applicability of such NDVI profiles in detecting 'unused land' will significantly improve. Also due to the high time resolution of Sentinel 2, concerns such as cloud cover during remote sensing analysis may be reduced. Nonetheless, further research is needed to improve its overall accuracy.

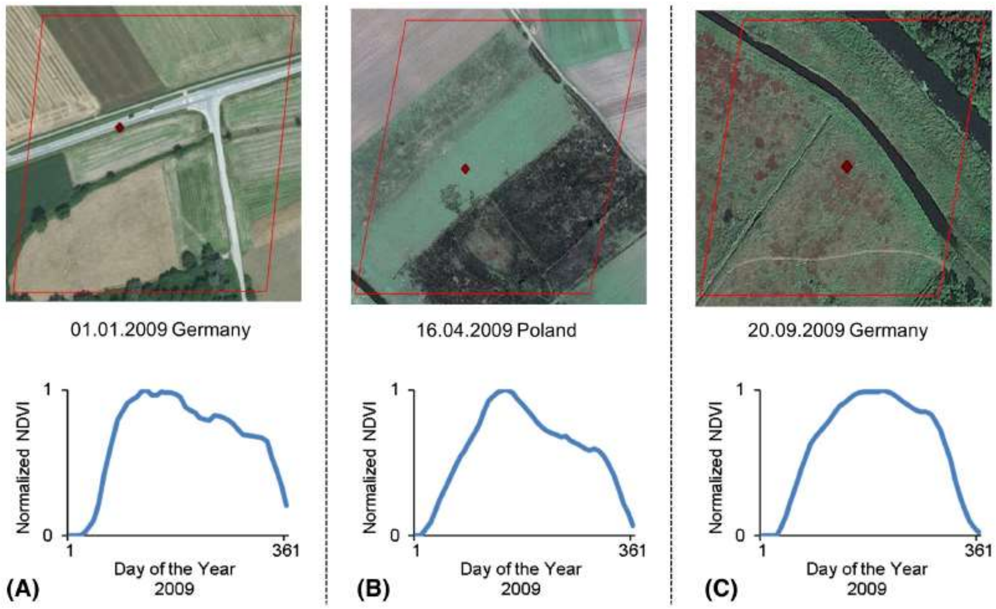

Fig. 5. Three plots (A–C) of the LUCAS survey from 2009 against the background of Google Earth high-resolution images from 2009, the MODIS pixel dimensions (red polygons), the location of the LUCAS plot within the MODIS pixel (red points), and the phenological profile of the corresponding pixel of the MODIS time series from 2009 (blue graphs). All three plots were labeled as fallow, abandoned or unused by the LUCAS surveyors but only plot C shows a typical fallow profile. Examples A and B show managed fields (cropland and grassland) within the MODIS pixel that distort the phenological profile. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Figure 9. Exemplary NDVI profiles depending on land-use activity

Further vegetation indices such as the Enhanced Vegetation Index (EVI) could complement or even substitute the NDVI, thereby improving the accuracy and overall robustness of the assessment. As the NDVI, however, represents the simplest and most commonly used index at the moment, it was decided to only require economic operators to provide NDVI profiles.

The second step focuses on **image interpretation to assess the land cover and utilisation** of the plot of land (step 2.2 in Figure 8. Approach to demonstrate the unused land referenceHigh-resolution imagery from Google Earth, commercial satellites (e.g. Ikonos, QuickBird, Aviris or RapidEye) or aerial images shall be used to assess the land cover and utilization of the plot of land during the past five years. The high-resolution images shall be visually checked by eye, thereby disclosing the land cover and land utilization at different points in time. All available high-resolution imageries during the past five years shall show no sign of managed crop cultivation and/or pasture. Some satellite and aerial images are publicly available, whereas others need to be purchased. Annex A.III.2 Further guidance on assessing the land cover vegetation profile gives further descriptions on the availability, resolution and costs of high-resolution imagery.

The market for satellite images is rapidly progressing, not only in terms of spatial and temporal resolution quality but also in terms of price reductions as publicly available data is increasing and new developments such as less expensive micro satellites are starting to compete with older commercial satellites.

In the third step, land parcel specific geo-information is used to assess the land cover and utilization of the plot of land (step 2.3 in Figure 8. Approach to demonstrate the unused land reference. Any publicly available relevant information such as digital geoportals or cadastre systems from international, national, regional and local authorities shall be used to assess the land cover and utilization of the plot of land during the past five years. The geo-information data should not classify the land as managed cropland and/or pasture.

The land cover and utilization assessment also includes **two optional EU-specific steps** for land situated within the EU. It is important to note that this data may be less accurate and reliable due to low spatial and/or temporal resolution, but, at the same time, it can certainly complement and support the three steps described above.

- Land cover geo-information from the **COPERNIUS Land Monitoring Services** of the European Environmental Agency can be used to examine and assess the land cover and utilization of the plot of land under observation for different years[18]. This includes, inter alia, the CORINE Land Cover database with an inventory of 44 land cover classes, Pan-European High Resolution Layers on land cover characteristics and the Urban Atlas showing detailed land cover and use information in EU cities. Annex A.III.4 Further guidance on geo-informationgives further insights into the land cover and land use services of COPERNICUS. Note that by 2020 there will very likely be better services with high resolution land cover products available at no or low costs.
- In-situ information on the land use publicly available via the EU Land Use/Cover Area frame Survey (LUCAS) of Eurostat can be used to examine and assess the land cover and utilization of the plot of land under observation for different years[19]. LUCAS includes 1.1 million on-ground points across the EU that are photo-interpreted and assigned to different land cover classes, as well as a large number of field samples to verify the land cover. LUCAS is however a limited source of data as there are only around 270 thousand sample points across Europe. Thus the probability that the LUCAS points would fall in the specific plot of land under observation is extremely low.

For countries outside the EU, there may also be other tools not explicitly mentioned here, that may complement and support the three steps of the land cover and utilization assessment above. As far as Brazil is concerned, for example, the country has deployed a national remote sensing sugarcane zoning to guide future sugarcane expansion, an important land use plan tool, respecting socioeconomic and environmental concerns. Any such supporting evidence may be added by the EO to the ILUC mitigation plan.

What to do if conclusions on the unused land status in the different steps conflict?
In case that the different steps conflict with each other (one indicates that land is unused, another indicates that land is used) the independent auditor shall decide whether the land shall be classified as unused land. taking into account also the outcomes of the on-site audit. In general, the legal assessment must always support the unused land status and land use rights should be clear. steps

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[18] The CORINE database currently provides data for the years 2000, 2006 and 2012. According to the remote sensing experts interviewed, CORINE data for the year 2015 is under development and will be published soon.
[19] LUCAS field survey data is currently available for the years 2009 and 2012.

2.1 (vegetation profile) as well as 2.2 (image interpretation) have priority over step 2.3 (geo-information) and the two optional steps, as both are considered more reliable in terms of temporal and spatial resolution.

On-site audit

In addition to checking the top-down analysis, an independent audit shall take place of the unused land reference. This audit includes interviews with relevant local stakeholders as well as direct engagement with affected communities. The auditor shall take GPS coordinates and perform in-situ research (i.e. check for any agricultural activities such as ploughing, mowing or pasture).

5.5 Cost estimate

According to consulted experts and price quotes received, Ecofys estimates that NDVI profiles to assess the vegetation profile of land will cost around €7,000 for a plot of up to 100ha. This assessment is likely to be the most costly part of applying the unused land methodology to certify low ILUC risk biomass (see also Annex A.III.2 Further guidance on assessing the land cover vegetation profile).

A much cheaper approach than requiring each economic operator to calculate the NDVI profiles individually for the plot of land under observation, is to develop an online service that would facilitate the process automatically. It would allow an economic operator to find a parcel, click on it and then generate NDVI or other vegetation indices profiles. The development of such a tool by a specialised agency would cost between €160,000 and €250,000.

As all stakeholders highlighted that the cost of conducting the vegetation profile analysis via remote sensing might be prohibitive, the research team highly recommends to automatize the process in the form of such an online tool. This would reduce the economic as well as time efforts, both for economic operators and auditors, significantly, thereby increasing the viability and acceptability of the proposed approach.

Annex I – General criteria, indicators and guidance for ILUC mitigation

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
1. Economic Operators shall apply for the certification for low ILUC risk biofuels	1.1. Economic Operator sends application to Scheme Owner before implementing the ILUC mitigation strategy	The application should specify the specific ILUC mitigation measure for which certification is applied. Certification for low ILUC risk biofuels is not a stand-alone certification but shall be used in combination with an existing voluntary certification scheme to ensure that direct social and environmental impacts are effectively addressed. Any scheme that has incorporated the criteria for the specific ILUC mitigation strategy can be used for certification. As the ILUC mitigation strategies aim for future additional biomass, the application has to be sent before implementing the respective measures, so that an auditor can check the proper implementation.
	1.2. Scheme Owner confirms receipt of application	
	1.3. Economic Operator selects Certification Body	Any certification body approved by the respective scheme owner for also auditing low ILUC risk biomass production can be used by the economic operator. The auditor should have the appropriate generic (auditing) skills and specific (scientific or technical) skills relevant to the auditing activity. For the purpose of audits for ILUC mitigation, auditors should have demonstrated expertise with agricultural production systems and, in the case of Unused land, auditors should have demonstrated expertise with analysing remote sensing data.
2. Economic Operators shall develop a ILUC mitigation plan for registration at the Scheme Owner	2.1. Economic Operator describes the project location and level of certification	The Economic Operator describes in the ILUC mitigation plan the specific geographical location in which ILUC mitigation is foreseen, the Level of certification (single farm or group of farmers), the amount of hectares involved in the mitigation measure and the designated target crop or target crop group.
	2.1. Economic Operator establishes the reference scenario and outlines how additional production is planned.	The Economic Operator establishes the reference scenario according to the criteria for the chosen mitigation strategy and describes how above–reference (i.e. additional) production is planned.
	2.2. Economic Operators demonstrates in the ILUC mitigation plan the link between planned additional	A link to biofuel demand can be demonstrated by **one** of these four options: 1. A **binding biofuel mandate** exists in the region where the ILUC mitigation is implemented

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
	production and biofuel demand	2. **Dedicated biofuel feedstock**: In case more than 50% of target crop production in the region is used for biofuels production, it can be concluded that the additional biomass is produced because of biofuel demand. 3. **Investment analysis:** Economic Operator demonstrates that a business case for implementing the ILUC mitigation plan only exists due an incentive by the biofuel industry, e.g. premium for low ILUC risk biomass 4. **Barrier analysis**: Economic Operator demonstrates that a non-financial barrier exists, which is lifted by actions initiated by the biofuels industry by for instance providing trainings for capacity building. An additional link that could be acceptable is a direct sale of additional feedstock from farmer to biofuel producer with clear traceability in the context of a well-established longer term client relationship.
	2.3. Certification body verifies ILUC mitigation plan and submits it to Scheme Owner	There are specific criteria for each ILUC mitigation strategy which have to be met by the respective ILUC mitigation plan (see Annex II - III). The auditor assesses whether the ILUC mitigation plan is likely to result in additional biomass production that can be linked to biofuel demand. In case the auditor concludes that the project produces additional biomass the ILUC mitigation plan is submitted to the Scheme Owner.
	2.4. Scheme Owner accepts and registers mitigation project	
	2.5 The ILUC mitigation plan is valid for 10 years, after which a new ILUC mitigation plan has to be developed	The certification of low ILUC risk biofuels is valid for a 10 year period. After this period, the applied mitigation measure is no longer considered as additional and therefore does not longer result in low ILUC feedstock (see chapter 2.4 for more information).
3. Economic Operators shall implement the ILUC mitigation and monitor it annually	3.1. Economic Operator has to send annual monitoring reports on the implementation of the ILUC mitigation plan to Certification Body	Economic Operator implements the ILUC mitigation plan and calculates the quantity of produced above-reference biomass. This is annually reported and checked by the auditor.
	3.2. Certification Body verifies implementation of ILUC mitigation plan and annual monitoring reports	The Economic Operator will be assessed against the ILUC mitigation plan by the auditor.

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase

Criteria	Indicators	Guidance
	3.3 Scheme Owner accepts implementation and monitoring reports	If the Scheme Owner accepts the proper implementation of the ILUC mitigation plan, the Economic Operator can claim the produced above-reference biomass as low ILUC risk biomass.
4. Auditors have to follow defined rules for auditing Economic Operators	4.1. Economic Operators have to be independently audited by qualified auditors	It is important that the implementation of ILUC mitigation measures is independently audited to ensure the credibility of the scheme and prevent fraud. Third party certification can either take place in the context of a voluntary certification scheme or a national system for biofuels. For the purpose of audits for ILUC mitigation, auditors shall have demonstrated expertise with agricultural production systems and, in the case of Unused land, auditors should have demonstrated expertise with analysing remote sensing data
	4.2. The production of the target crop by the Economic Operator has to be certified by a voluntary scheme or national system approved by the EC for demonstrating compliance with the RED	The certification for low ILUC risk biomass covers indirect effects only and can therefore only be used in combination with an approved voluntary scheme for demonstrating compliance with the EU Renewable Energy Directive to ensure that direct sustainability aspect of the biomass production are covered as well.
	4.3. Auditor have to be licensed to audit for the voluntary scheme or national system which is used by the Economic Operator	E.g. if the Economic Operator is ISCC certified and ISCC has incorporated the criteria for ILUC mitigation
5. Voluntary schemes or national systems shall implement specific requirements for group certification	5.1. A group can only be created by farmers cultivating the same crop in the same region with similar characteristics regarding soil and water	
	5.2. A group should be sufficiently large to ensure a relevant number of data points are available, e.g. at least 5 or 10 members	The group is free to allocate certified low ILUC risk biomass over its members as it sees fit. ILUC mitigation measures can be implemented by all group members or by part of the group, allowing a knowledge transfer between group members

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
	5.3. A group manager has to be defined, who is responsible for data collection from all group members and is the main contact during the certification process.	The group manager also draws up an ILUC mitigation plan together with the group.
	5.4. The group manager can be a farmer but also a biofuel producer or first point of feedstock collection	To minimise the administrative burden related to this it can make sense to appoint the first gathering point, such as the oil mill or aggregator, as the group manager
	5.5. The group manager is responsible that each group member complies with the ILUC certification process.	Group manager is responsible for regular internal monitoring of group members
	5.6. Not all group members have to be audited. Following a desk-based check of all documentation, a sample of group members has to be audited on-site.	The minimum sample size is determined by the square root of the number of group members. To ensure that the number of audited farms is not too small, at least 8%of participating farms in the group should be audited
	5.7. In case of non-compliance by one group member the sample size is doubled. If more than 10% of the group members do not comply, the complete group is invalidated and cannot claim any low ILUC risk biomass, until this situation is improved	

Annex II - Criteria, indicators and guidance for yield increase

<table>
<tr><th colspan="3">Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase</th></tr>
<tr><th>Criteria</th><th>Indicators</th><th>Guidance</th></tr>
<tr><td>1. Economic Operators shall determine a reference scenario for the next 10 years.</td><td>1.1. The trendline yield Y_{ref} is is defined as reference scenario (ref) yield per target crop, which is to be exceeded by the Participating Operator. Y_{ref} is calculated using Equation 1</td><td>Economic operator describes the reference scenario in the ILUC mitigation plan. The reference is established as follows.

a) The historical yields (either in tonnes of product, tonnes of component or forage unit) of the last 10 years for the target crop(s) of the farmer or group of farmers are used to determine the linear trendline. In case of a group the median of the yields of each group member is calculated for each year. The median is more robust to outliers as the average, as 50% of values are below and 50% are above the median;
b) The linear trendline is calculated by using the statistical method of least squares. This method basically identifies the least distance for all input values to the trendline. The outcome is a linear function that best fits a data set. Due to this approach all yields within the last 10 years are equally represented in the trendline;
c) This trendline is used to calculate the reference point.

Equation 1: Linear trendline

Y_{ref} = Statistical starting point + slope * year

Whereas:

Statistical starting point is the beginning of the linear trendline in year 1, which is 10 years before the application for low ILUC risk

Slope is the annual yield growth of the last 10 years

Year is the year for which the point on the linear trendline is to be calculated. Year 1 is 10 years ago, whereas the previous year before the application is year 10.

Reference Point is the statistical point on the trendline yields in year 10, i.e. before the ILUC mitigation action is implemented.</td></tr>
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Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase

Criteria	Indicators	Guidance
		See below

Calculation the linear function with the least square method from actual values is not easy, we therefore propose to create an Excel tool that any economic operator can easily use. The economic operate would only need to enter the actual yields of the last 10 years as input parameters. Within this tool the median will be calculated from each group member.

Auditor shall check the calculations in the provided Excel tool.

Example:

In this example a group of farmers had the following median annual yields for wheat in 2005-2014:

YIELD/TIME	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Median yields of group	4.4	3.5	4.3	3.9	4.7	4.6	4.1	4.1	4.9	5.2

Following the method of least squares these values are best matched by a linear trendline with this function:

$Y_{re} = 3.8107 + 0.1004 * year$

Whereas

- ○ is the statistical starting point in year 1 (i.e. 2005)

0.1004 is the annual yield growth in the period 2005-2014

Year is the year for which the statistical yield has to be calculated with 2005 being year 1 and 2014 being year 10.

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
		This trendline is used to calculate the reference point for 2014, i.e. the year before the ILUC mitigation action is implemented. In this example the reference point is below the actual yield in 2014. $Y_{ref,\ 2020}$ = 3.8107 + 0.1004 * 10 = 4.8
	1.2. In case of a group the group manager shall calculate the median yield from the yields of group members over the last 10 years during which the target crop is cultivated	Auditor shall check yield records for each target crop(s) from the Economic Operator and review calculation of the median yield. The yields shall be measured in tonnes per hectare.
	1.3. The determined reference is only valid for 10 years, after which a new baseline shall be calculated	
	1.4. If a yield increase measure affects more than one crop, an economic operator can choose to calculate the above-reference biomass production using a crop(s) specific, crop	The yield increase reference must include all crops produced on the plot(s) of land or farm on which a yield increase measure is applied. If a yield increase measure affects multiple crops, an economic operator can choose between three ways to calculate the reference: a crop(s) specific, a crop group or a Forage Unit approach. For each approach goes that replacing one crop by another is not a valid yield increase measure. In the **crop(s) specific approach**, separate references are calculated for one or more crops affected by the yield increase measure. When calculating the additional above-reference biomass production, actual yield for each crop is compared to the specific reference per crop. In a **crop component group approach**, a single reference is calculated for multiple crops from the same crop group

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
	component group or forage unit approach.	(starch, sugar, vegetable oil) that are produced on a plot of land or farm. Net additional above-reference biomass production is calculated by comparing the total yield in sugar, starch or oil, and total yield of protein achieved after the application of the yield increase measure, with the reference yields. It is possible to achieve net additionality in vegetable oil at the expense of sugar or starch but not the other way round. In the **Forage Unit approach**, a single reference is calculated for multiple crops using Forage Units. These are calculated based on metabolizable energy for crop components. When applicable, the crop composition table by Ecofys and AgraCEAS (2015) as included in Chapter 3 of this report will be used for the decomposition, followed by a calculation of metabolizable energy using the method as described in 'Nutrients requirements of dairy cattle', by National Research Council (NRC 2001). For silage crops the decomposition is based on best available literature. Net additional above-reference biomass production is calculated by comparing the total yield in Forage Units achieved after the application of the yield increase measure, with the reference yields. It is possible to achieve net additionality in vegetable oil at the expense of sugar or starch but not the other way round.
2. Economic Operators shall develop additional yield increase measures for one or more specific crops ('target crop')	2.1. The Economic Operator shall document an ILUC mitigation plan in which yield increase measures are described as well as their expected contribution to increased yields of the target crop(s). The Economic Operator shall provide evidence that the expected yield increase of the target crop(s) is justified	Location and site factors are responsible for up to 50% of the yield. Whereas these factors cannot be changed, yield increase can be achieved through changes to the following management practices: • Crop varieties • Sowing • Soil management • Fertilisation • Crop rotation • Crop protection: Weed, pest and disease control • Pollination (e.g. by using bees) • Harvest • Precision farming This list provides an overview of example yield increase measures and is not exhaustive. The expected yield increase of the intended measures can for instance be demonstrated by reference to scientific literature, experience from field trials, and information from breeders or simple calculations (e.g. reduced number of tram lines due to increased operation width of field sprayer leads to higher yields in the same field). It is important to note that some yield increase measures might influence the yield impact from other measures. These interactions should be taken into account when estimating the total expected yield increase resulting from all measures.

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
	2.2. The Economic Operator shall demonstrate that developed yield increase measures are not yet applied in current management practices	All already implemented management practises of the Economic Operator already implemented can be verified (e.g. available machinery). This means for example that the Economic Operator is able to provide for instance documents on: • the use of fertilizers, pesticides, herbicides and fungicides • the crop rotation system • the sown seeds • the land used for the cultivation of the target crop Other management practices might not be well documentable like for instance the way of tillage or drilling. This will however be verifiable by checking the available machinery.
3. Economic Operators shall demonstrate that yield increase measures are expected to lead to an yield increase above the baseline	3.1. The Economic Operator shall demonstrate that the expected yield is higher than the reference point	**Example:** As shown in the guidance for indicator 1.1, $Y_{ref,\ 2020} = 3.8107 + 0.1004 * 10 = 4.8$ The expected yield increase has to lead to yields of more than 4.8 tonnes per hectare.
4. Economic Operators shall demonstrate that the developed yield increase measures have been implemented	4.1. The Economic Operator demonstrates that developed yield increase measures have been implemented	Whereas the effect of developed yield increase measures on the achieved yield cannot be traced, the implementation of the measures can be verified by checking the documentation and the machinery. See also guidance on indicator 2.2.

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
5. Economic Operators shall calculate the amount of additional feedstock produced through yield increase above the baseline scenario to determine	5.1. The Economic Operator shall document the actual amount of harvested feedstock	The Economic Operator tracks its yields and provides evidence that this yields have been realised, by for instance overall amounts sold or stored.
	5.2. Actual yields of the Economic Operator are higher than the reference point	**Example:** Any yield above 4.8 t/ha are low ILUC risk. If the actual yields of the participating farmer are 5.2 tonnes per hectare, 0.4 tonnes per hectare are low ILUC risk.

Certification methodology to demonstrate low ILUC risk biofuels achieved through yield increase		
Criteria	**Indicators**	**Guidance**
the amount of low ILUC risk biomass	5.3. The actual amount of low ILUC risk biomass is calculated by the difference between the actual yield and the baseline scenario yield multiplied by the land cultivated with the specific crops for which yield increase measures ae applied.	Equation 2: $Y_{\text{Low ILUC } t=x} = (Y_{,t=x} - Y_{b,t=x}) \times A$ $Y_{\text{Low ILUC },t=x}$ = Volume of low ILUC risk compliant biomass in year x [t/ha] $Y_{,t=x}$ = Actual yield in year x [t/ ha] $Y_{ref,t=x}$ = Reference scenario yield A = System boundary area (ha) **Example:** If the actual yields of the participating farmer are 5.2 tonnes per hectare and the reference yield is 4.8 tonnes per ha for the respective crop cultivated on 80ha, equation 2 is as follows: $Y_{\text{Low ILUC },2020} = (5.2 \text{ t/ ha} - 4.8 \text{ t/ha}) \times 80 \text{ ha}$ $Y_{\text{Low ILUC },2020} = 32 \text{ t}$ In this example 32 tonnes can be certified as low ILUC risk biomass.

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Annex III – Criteria, indicators and guidance for unused land

A.III.1 Overview of criteria, indicators and guidance

Certification methodology to demonstrate low ILUC risk biofuels achieved through cultivation on unused land		
Criteria	**Indicators**	**Guidance**
1. Land can legally be used for agricultural production	1.1. Economic Operator holds legal rights to use the land for crop production and land can be legally used for crop production.	As part of the ILUC mitigation plan, the Economic Operator shall demonstrate that it holds legal rights to use the land.
	1.2. Land can be legally used for crop production.	As part of the ILUC mitigation plan, the Economic Operator shall perform a regulatory assessment to demonstrate that the land under observation can be legally used for crop production. This requires information relevant international, national, regional and local regulation.
2. Land <u>not</u> used for its provisioning services	2.1 The Economic operator shall demonstrate that the land is currently <u>not</u> used for its provisioning services, and has <u>not</u> been used for its provisioning services during the past five years.	As part of the ILUC mitigation plan, the Economic Operator shall check the land cover & utilization status of the land. The land under observation shall be checked during the past five years, using the following tools: 2.1. **Vegetation profile analysis** based on satellite data (e.g. Sentinel) to derive annual profiles of the Normalised Difference Vegetation Index NDVI: The NDVI profile must show a smooth, bell-shaped temporal profile with maximum one peak. 2.2. **Image interpretation** based on high-resolution imagery from Google Earth, commercial satellites (e.g. Ikonos, QuickBird, Aviris or RapidEye) or aerial images: 2.3. **Geo-information** of the land plot (e.g. digital geoportals, cadastre systems) from local/regional authorities. As an **optional** additional step, the Economic Operator can use the following data sources that may strengthen the ILUC mitigation plan. 1.1. **Land cover geo-information from the COPERNICUS Land Monitoring Services** of the European Environmental Agency (e.g. CORINE Land Cover database, Pan-European High Resolution Layers on land cover, Urban Atlas):

Certification methodology to demonstrate low ILUC risk biofuels achieved through cultivation on unused land		
Criteria	**Indicators**	**Guidance**
		Land cover data shall not classify the land as managed cropland and/or pasture. 1.2. In-situ information on the land use publicly available via the **EU Land Use/Cover Area frame Survey (LUCAS)** from Eurostat. The LUCAS data shall show no sign of managed crop cultivation and/or pasture. Land not used for its provisioning services (i.e. unused land) can comprise natural landscapes such as land with sparse vegetation as well as anthropogenic landscapes (i.e. formed by humans) such as abandoned or degraded agricultural land. For example: • Bare land • Non-biodiverse grass land • Herbaceous vegetation land • Wood land: o Shrub land o Sparse forest land In particular, land less suitable for agricultural production such as: degraded land, sloped land, difficult to access land infertile land. It is to be further assessed by the Commission whether ecological focus areas under the EU Common Agricultural Policy can be eligible.
	2.3 On-site audit is to be performed	An independent certification body shall perform an on-site audit. At least, one site visit during the typical growing season taking GPS coordinates and doing in-situ research (i.e. check for any agricultural activities, e.g. ploughing, mowing, pasture) shall verify the unused land reference criteria. The auditor shall perform interviews with the land owner/tenant, local/regional authorities and other local people of interest shall verify the top-down analysis of the land under observation.
3.Land conversion in compliance with the EU sustainability criteria for biofuels	3.1. the Economic Operator demonstrate compliance with the sustainability criteria as laid down in Directive 2009/28/EC and related EC Communications.	

Certification methodology to demonstrate low ILUC risk biofuels achieved through cultivation on unused land		
Criteria	**Indicators**	**Guidance**
4. Land conversion in compliance with land use rights (i.e. social safeguard)	4.1. The Economic Operator shall demonstrate that it traditional and customary land use rights are respected, following Free Prior and Informed Consent of local communities.	

A.III.2 Further guidance on assessing the land cover vegetation profile

What is the NDVI?

Normalized Difference Vegetation Index or NDVI maps are being used in agriculture, forestry, ecology and more. Healthy vegetation (or chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths. It absorbs more red and blue light. This is why our eyes see vegetation as the **colour green**. This is also why **more near-infrared** is reflected back into satellite sensors. The NDVI is an index describing vegetation by showing the difference between this near-infrared (which is strongly reflected by vegetation) and red light (which is absorbed by vegetation), thereby measuring the healthiness of vegetation. Figure 10. Formula to calculate the NDVI shows how the NDVI is calculated.

$$\frac{(NIR-red)}{(NIR+red)}$$

Figure 10. Formula to calculate the NDVI

More information on NDVI can be found on the following websites:
http://earthobservatory.nasa.gov/Features/MeasuringVegetation/
http://gisgeography.com/how-to-ndvi-maps-arcgis/
http://www.agrimotion.net/ndvi-normalized-difference-vegetation-index/

Why should NDVI be used?

The Unused Land Methodology heavily relies on clearly defining and distinguishing (1) managed cropland and (2) managed grassland (e.g. pasture) from (3) fallow/unused land. This is, in particular, a challenging task, as vegetation is continuously changing intra-annually as well as annually and as there are no clear cut-off criteria for defining the land use characteristics.

Estel et al. (2015) developed a methodology to detect managed cropland and grassland (e.g. pasture) as well as fallow/unused land on a European scale using a fairly robust approach that can also be applied to demonstrate the unused land status of a plot of land. They analysed annual NDVI profiles for the three land types above for a number of past years across Europe, validated them with ground data using high-resolution satellites as well as LUCAS agricultural survey data (the latter contains survey points for fallow, unused and abandoned as well as active farmland for 2009 and 2012), and came up with "typical" phenological profiles (i.e. mostly referred to as vegetation profiles within this study) depending on the land use. Figure 11. Phenological profiles selected from different locations across Europe (Source: Estel et al. (2015) below shows such phenological profiles for selected locations across Europe.

They concluded that phenological profiles of unmanaged farmlands are characterized by a smooth, bell-shaped temporal NDVI profile. Management, such as grazing or mowing on grassland or ploughing on cropland, leads to abrupt changes in this temporal profile. Therefore, managed cropland is characterized by more irregular temporal NDVI profiles with one or more narrow peaks, with the highest peak often shifted substantially compared to the peak of natural vegetation and fallow land. Intensively grazed or mowed grasslands (i.e. managed grassland) differ from the smooth, bell-shaped fallow profiles by their plateau-shaped form, often with multiple peaks. Managed cropland and managed grassland also result in profiles with substantially smaller growing season NDVI integrals (i.e., area under the curve), deviating strongly from the smooth, bell-shaped profile of fallow fields.

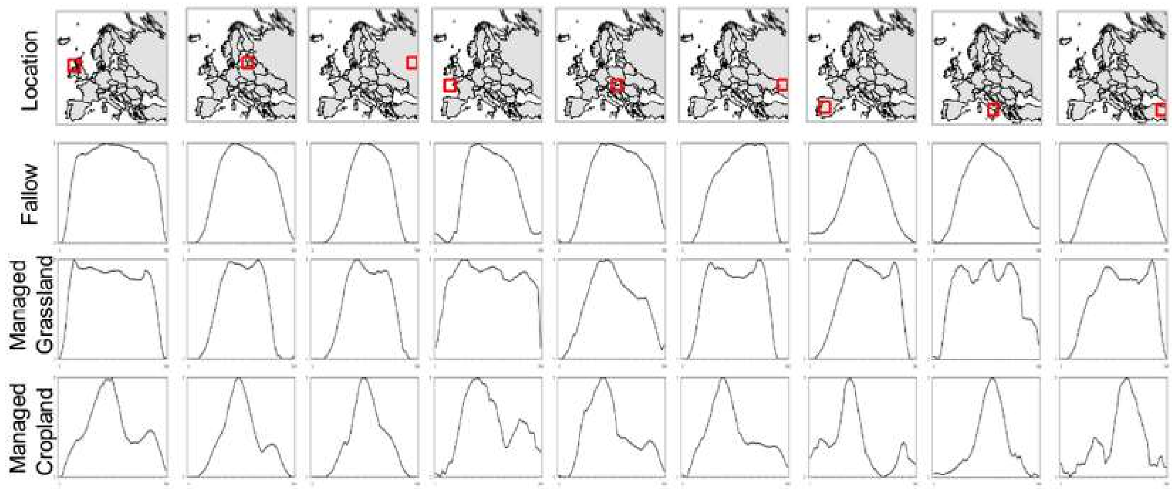

Fig. 2. Phenological profiles selected from different locations across Europe (first row) based on the 2009 LUCAS survey for fallow farmland (second row), managed grassland (third row) and active cropland (fourth row). The phenological profiles displayed here were built from the normalized NDVI time series with values between one and zero (y-axis) using 46 images from 2009 (x-axis).

Figure 11. Phenological profiles selected from different locations across Europe (Source: Estel et al. (2015)

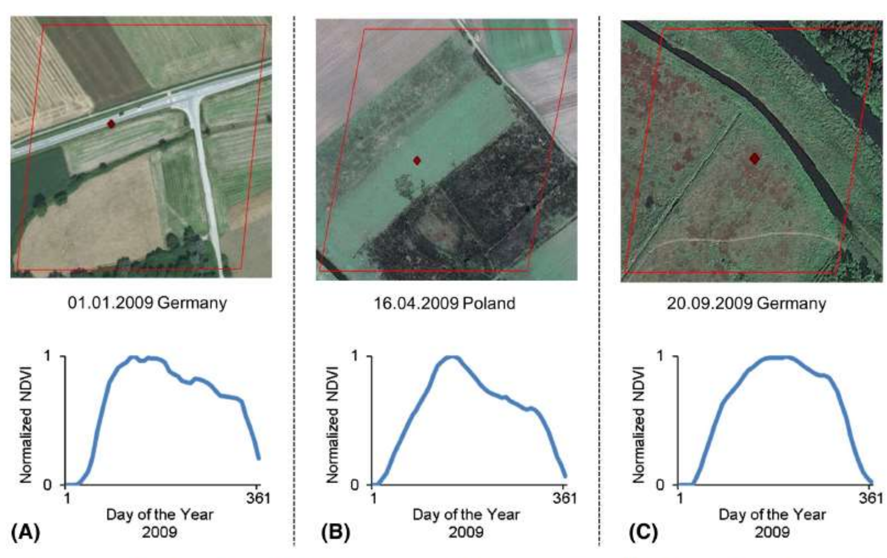

Fig. 5. Three plots (A–C) of the LUCAS survey from 2009 against the background of Google Earth high-resolution images from 2009, the MODIS pixel dimensions (red polygons), the location of the LUCAS plot within the MODIS pixel (red points), and the phenological profile of the corresponding pixel of the MODIS time series from 2009 (blue graphs). All three plots were labeled as fallow, abandoned or unused by the LUCAS surveyors but only plot C shows a typical fallow profile. Examples A and B show managed fields (cropland and grassland) within the MODIS pixel that distort the phenological profile. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Figure 12. Exemplary NDVI profiles depending on land-use activity

What are the limitations of NDVI?

NDVI has a big advantage: is simple and can be well understood by non-remote sensing experts. However, it has also been criticized as being limited as it only uses two bands to derive the vegetation index. There are many other more complicated indices available that use more than two bands, which could possibly deliver more accurate profiles for distinguishing between cultivated, grassland and fallow/unused land. Other vegetation indices are, for example, indices such as the Enhanced Vegetation Index (EVI), Fraction of Absorbed Photosynthetically Active Radiation (fAPAR) and Dry Matter Productivity (DMP).

According to consulted remote sensing experts, the very distinct and quite easily distinguishable vegetation profiles in Figure 114 shows a more perfect situation than what you would get in most real-world cases. Consulted experts had some reservations about the paper by Estel et al. (2015) as the vegetation profiles seem to be too "good". It seems as if the authors would only have presented good examples and there may be other examples where the discrimination did not work so well (and therefore are not presented in the paper). In other words, further testing of NDVI profiles is needed. As soon as there are pixels with mixed land cover/land use, for example, the signal may not be as clear as those shown in the figure above. If the field under question is located in a pixel that is relatively homogenous, e.g. all unused land or the field under consideration is larger than the pixel, this approach may be well suited so the need to answer this question could be part of the methodology.

Three options to perform the NDVI analysis

Option1. Do it yourself. This approach consists of the following three steps:

(1) Acquisition of satellite data

Firstly, it is necessary to acquire/download satellite data. The following table gives an overview of most relevant satellites that could be used. Remote sensing experts indicate that the Sentinel-2 is the preferred satellite for future NDVI analysis as it is costless and as it has a high temporal (5 days) and spatial resolution (10 m), available from 2015 onwards.

(2) Data processing

- Import the satellite data into a GIS/remote sensing software: e.g. QGIS (OpenSource), ArcGis (commercial), ERDAS (commercial), ENVI (commercial).
  More open source software to be found here:
  http://gisgeography.com/open-source-remote-sensing-software-packages/
- Establish the correct spectral bands (RGB) to create either the visible/true/natural colour or the NDVI one.
- Check the cloud coverage.
- Calculate the NDVI with integrated tools in the software over the entire year (roughly 40 values per year; this is however depending on the satellite used) and over the past years.
- More information on the calculation to be found here:
  http://gisgeography.com/how-to-ndvi-maps-arcgis/
  https://www.youtube.com/watch?v=dH0eH8rcS-s
- Add a step for filtering the NDVI using a filter such as the Savitsky-Golay.

- Classify/interpolate and then visualize the NDVI in the GIS software.
  More information to be found here:
  http://earthobservatory.nasa.gov/Features/MeasuringVegetation/

(3) Data analysis and evaluation

a) Export the values to Excel to analyse the data and visualise the NDVI profiles.
b) Visually interpret data and classify it into unused/fallow, managed cropland and managed grassland.

Option2: Purchase NDVI profiles directly from third party

Ecofys contacted several companies for a cost quote to perform the analysis explained above. We asked to provide a rough cost estimation giving each consultancy the following task description:

- The land area will be roughly 20 to 100 ha and based in the EU (area and coordinates not known yet);
- We need annual NDVI profiles (16 day resolution) for the last 5 years, with output:
  - 5 annual NDVI profiles with the x-axis showing the time (January-December) and the y-axis showing the NDVI value;
  - One map for each of the 5 years at the point in time when the NDVI is at its maximum.

We asked for a rough price indication for different spatial resolutions: (1) eModis data: spatial resolution of 250m, (2)Landsat data: spatial resolution of 30m, and (3) any better resolution (other satellites such as RapidEye etc., which would have to be commercially acquired).

Based on quotes received and talking to remote sensing we expects that the NDVI profiles can be performed for €7000 or less.

Option 3: Purchase NDVI data from third party

A possible third option would be to offer an online service to users that could facilitate the process, i.e. allow an individual to find a parcel, click on it and then generate NDVI or other vegetation indices profiles. The service would also step the user through the process, allowing them to apply online. They could also upload their evidence of unused/underutilized land collected via a smartphone app or tablet and then submit their application.

A specialised agency could develop such an online service for an estimated €160k to €250k, that allows users to register their land for consideration as unused/underutilized, providing access to NDVI/other vegetation index profiles and integrate this with information from a self-declaration app.

The table below gives an overview of relevant available satellite data sources

Satellite (program)	Spatial resolution	Temporal resolution	Availability/costs	Pros	Cons	Sources
Landsat	15 to 30m	16 days	Direct download possible. Open source. NDVI values have to be calculated	Free. High temporal resolution but not all imagery are cloud free	Medium spatial resolution. By 2020, Landsat might be replaced by a newer satellite	Infos: http://landsat.usgs.gov/landsat8.php Download: http://earthexplorer.usgs.gov/
Sentinel-2	10m	5 days	Available since 2015. Direct download. Open source. NDVI values have to be calculated	Free. High temporal resolution. High to medium spatial resolution	Large dataset may cause long download	Infos: http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2/Introducing_Sentinel-2 https://scihub.copernicus.eu/ Download: http://gisgeography.com/how-to-download-sentinel-satellite-data/ https://scihub.copernicus.eu/dhus/#/home
Modis (eModis NDVI)	250m	1-2 days	Direct download possible (not for every region). Open source Can immediately deliver NDVI values without having to calculate the NDVI values oneself	Free. High temporal resolution. Direct NDVI export possible	Coarse spatial resolution. Unclear how long the Terra and Aqua satellites will continue.	Infos: http://modis.gsfc.nasa.gov/data/dataprod/mod13.php https://lta.cr.usgs.gov/emodis Download:https://scihub.copernicus.eu/dhus/#/home
ASTER (AST_L1T)	15 to 90m	16 days	Freely available as of 1 April 2016. NDVI values have to be calculated	Free	Unclear how long the Terra satellite will continue. Coarse temporal resolution	Info: https://lpdaac.usgs.gov/node/713 Download: http://earthexplorer.usgs.gov/
VIIRS	370m	Daily	NDVI values have to be calculated	High temporal resolution	Coarse spatial resolution	https://ladsweb.nascom.nasa.gov/
Proba-V NDVI	100m, 333m, 1km	Daily but can also get 5 and 10 day synthesis products	Can be ordered and downloaded from the VITO/ESA website	High temporal resolution	Commercial product (expensive)	https://earth.esa.int/web/guest/data-access/browse-data-products/-/asset_publisher/y8Qb/content/proba-v-1km-333m-and-100m-products
Sentinel-3	300m to 1 km	1 to 2 days	Will be freely available	High temporal resolution	Coarse spatial resolution	https://sentinel.esa.int/documents/247904/685236/Sentinel-3_User_Handbook

A.III.3 Further guidance on image interpretation

There are many sources where to find and how to acquire high-resolution imagery. Some are publicly available whereas others need to be purchased at high cost. In general, it is important to note that the temporal resolution significantly differs by location and that it is in most cases fairly low. The following table provides an overview of possible sources on where to find high-resolution imagery. Note that there are many more but these are the most commonly used ones.

Options	Spatial resolution	Temporal resolution	Availability/costs	Pros	Cons	Sources
Google Earth	Differs by location (high)	Differs by location (low)	• Directly accessible via Google Earth, Google maps, by open source GIS (e.g. using QGIS) and APIs • Open source but there are restrictions on use	• Free • Very high spatial resolution in places	Coarse temporal resolution but historical data exist	https://www.google.de/intl/de/earth/
Bing	Differs by location (high)	No dates provided	• Directly accessible via Bing Maps and APIs, Open Layers, open source GIS (e.g. QGIS) • Open source but no restrictions on use like in Google Earth	• Free • Very high spatial resolution in many places • Sometimes higher quality than images in Google Earth	Only one date and it is not known. Sometimes worse quality than images in Google Earth	http://www.bing.com/maps/
ArcGIS Online	Differs by location (high)	Not clear	• There is some very high resolution data available, particularly for cities • Some data are free but not all are free	• Repository of many different online data sources, including Landsat	Proprietary so there will be some costs involved	https://www.arcgis.com/home/
Aerial images	Differs by location (usually high)	Differs by location (usually low)	From regional authorities/geoportals: • Partially directly accessible • Partially open source • Each region with own database • From other third party/ consultant	• Sometimes free, e.g. Austria • Very high spatial resolution	Sometimes costly and coarse temporal resolution	Example for North-Rhine-Westphalia: http://sg.geodatenzentrum.de/web_dop_viewer/dop_viewer.html

Options	Spatial resolution	Temporal resolution	Availability/costs	Pros	Cons	Sources
Images from UAVs (unmanned aerial vehicle)	Can be very high	Depends what is available	New initiatives appearing like Open Aerial	High resolution imagery but still in early stages so need to build up a time series to be useful	Need to process the data. Requires a lot of storage space Cost involved	http://openaerialmap.org/
Commercial satellites: See the different examples below and many more here: http://www.satimagingcorp.com/satellite-sensors/						
QuickBird	Up to 61 cm	Tasking so need to see if images are in the archive	16–22 USD/km.sq.	High spatial resolution	Switched off on 27 Jan 2015 so only historical data available. Expensive	http://www.satimagingcorp.com/gallery/
RapidEye	5m	Tasked and archive	1.28SD/km. sq. to 2.80 USD/km.sq.	High spatial resolution	Expensive	http://www.satimagingcorp.com/gallery/
WorldView	30cm 50cm	Tasked and archive	12 USD to 30 USD/km.sq. but this will vary and depend on a number of things: 1. Type of satellite sensor 2. Number of bands (4 or 8 especially for Digital Globe) 3. Institution type 4. License type (internal or external) 5. Archive purchase or satellite tasking 6. Type of data product (i.e. level)	Very high spatial resolution	Expensive	http://www.satimagingcorp.com/gallery/
Pleiades-1A and 1B	50cm	Tasked and archive	500 Euros per minimum 100 km.sq. in Austria but varies by country	Very high spatial resolution	Expensive	http://www.satimagingcorp.com/satellite-sensors/pleiades-1/

A.III.4 Further guidance on geo-information

The following table gives an example of two regional digital geoportals in Germany. Many other EU MS have developed such geo-information portals, which are publicly accessible and represent a reliable data source.

Options	Spatial resolution	Temporal resolution	Availability/costs	Pros	Cons	Sources
Geoinformation from local/ regional authorities	Differs by location (usually high)	Differs by location (usually low)	• Partially directly accessible • Partially open source • Each region with own database	Sometimes free. High spatial resolution	Can be costly. Coarse temporal resolution	Examples for North-Rhine-Westphalia and Saarland: http://sg.geodatenzentrum.de/web_dop_viewer/dop_viewer.htm https://www.geoportal.nrw.de/search/index.php?suche=Nrw+atlas http://geoportal.saarland.de/mapbender/geoportal/mod_index.php?mb_user_myGui=Geoportal-SL

Consulted experts pointed to a few constraints to this data source:

- Data are only currently publically available in a few EU countries (e.g. Netherlands, Germany, Czech Republic)
- Data are based on farmer declarations and not an entirely independent check meaning that declarations might be incorrect. This degree of uncertainty will vary from country to country.

Land cover geo-information from the COPERNICUS Land Monitoring Services

For more information on the services under the COPERNICUS program, please see http://land.copernicus.eu/.

Options	Spatial resolution	Temporal resolution	Availability/costs	Pros	Cons	Sources
CORINE Land Cover database (CLC)	Based on high resolution but minimum mapping unit of 25 ha	2015 (soon) 2012 2006 2000	The CORINE Land Cover (CLC) inventory was initiated in 1985. It consists of an inventory of land cover in 44 classes. CLC uses a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena. It provides land use data on crop cultivation, pasture, agro-forestry, forestry etc.	• Recognized • Direct accessible • Open source	• Coarse temporal resolution • Spatial resolution less precise	Information and data access: http://land.copernicus.eu/pan-european/corine-land-cover http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/agricultural-areas-in-europe
Pan-European High Resolution Imagery	20 m (covering the EEA39 countries)		Pan-European High Resolution Layers (HRL) provide information on specific land cover characteristics, and are complementary to land cover / land use mapping such as the CORINE CLC. Not yet available for download as they are still being validated	• High spatial resolution • Open source	Coarse temporal resolution	Information and data access: http://land.copernicus.eu/pan-european/high-resolution-layers/view

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