Causal-descriptive modelling of the indirect land use change impacts of biofuels

Introduction and draft methodology

December 2009

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Introduction

- E4tech has been commissioned by the UK's Department for Transport to develop indirect land use change (ILUC) factors for four different biofuel chains: bioethanol produced from sugar cane or wheat; biodiesel produced from rape seed or palm.
- The ILUC factors will be a measure of all the greenhouse gas (GHG) emissions resulting from indirect land use change caused by a particular biofuel per unit of energy – i.e. kg CO_2e / MJ
- The study aims to further the understanding of factors causing ILUC, management factors that can mitigate ILUC, and the magnitude of their effects.
- Causal-descriptive models will be used to develop ILUC factors. These models use cause and effect logic to describe the behaviour of a particular system, based on observations of how it functions.
- Crucially, these models provide a more transparent analysis compared to other economic modelling approaches, enabling input and review from stakeholders, which will be a key component of the study. They can then potentially serve as input to other model work.
- Further information on the project can be found on www.ilucstudy.com

Purpose of this document

- This document presents the methodology developed to calculate ILUC factors. E4tech is now seeking review by stakeholders on the completeness of the methodology and the specific approaches taken for the quantification of ILUC effects. Management factors that can mitigate ILUC will be looked at in more detail later in the project.
- A **consultation meeting** will be held in Central London on **January 14th 2009** between 10.30am and 1.00pm for discussion of the methodology outlined here. The location will be announced on the project website (www.ilucstudy.com) nearer the time
- **Written responses** are welcome at the following email address: ilucstudy@e4tech.com prior to the consultation meeting if possible, and before **January 22nd 2009** at the latest.

Specific questions for stakeholders

- E4tech is especially seeking responses to the following questions:
  - Have we identified all the factors that could lead to indirect changes in land use?
  - Is our proposed approach for understanding the magnitude of ILUC caused by the different factors reasonable, given information and time constraints?
  - Are you aware of any additional data that could be useful in answering the questions identified?
  - Do you agree with our approach to the boundary definitions? Is it appropriate to set a threshold for the smallest area for which we should analyse in detail land displacements, beyond which the impacts of the displaced land will have negligible impact on the overall ILUC factor?
  - Do you think it will be possible to assess the additional demand for feedstock, caused by biofuels, that will be met by an increase in the efficiency of the supply chain and/or by reduced wastage?
  - Are there management factors that can influence the causes of ILUC and mitigate the risk of ILUC?

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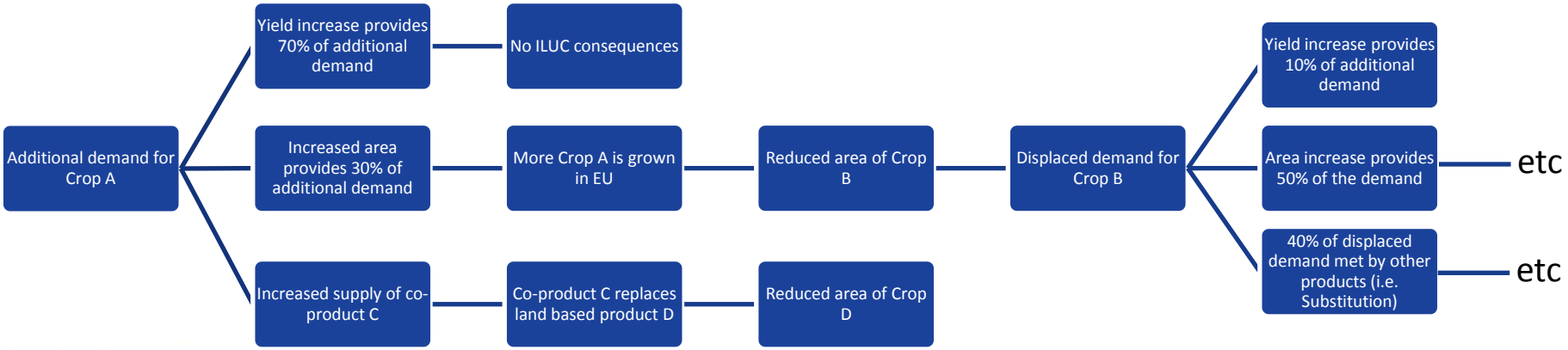
Introduction to the methodology

- The methodology is based on consequential, rather than attributional, analysis .
- Two scenarios will be defined in order to assess the ILUC impact of biofuels:
  - Baseline scenario – in which no additional biofuels are supplied
  - Biofuels scenario – in which additional biofuels are supplied to meet known government targets that exist globally (cross checked with projections by, for example, IEA, etc.)
- The ILUC impacts of the four biofuel chains will be assessed based on their forecast impact in 2020. This timeframe was selected because it will provide an indication of the marginal impact of biofuels of achieving stated biofuels targets.
- A causal-descriptive approach will be used (see next page for further explanation).

A causal-descriptive approach will be used to identify and quantify GHG emissions caused by ILUC

- Modelling ILUC using causal-descriptive techniques requires mapping out all of the impacts a biofuel has on the broader agricultural and land use systems – see below for a hypothetical example of the impacts of biofuel produced from Crop A. The aim of this process is to identify all the possible land use change that a biofuel can *cause*.
- The indirect *effects* of the biofuel can then be established by estimating the quantity and type of land use change which occurs.
- There may be other indirect effects, not land related, which could also be attributed to the increase in biofuel demand. For example, yields that rise in response to increased biofuel demand may be achieved through increased N fertiliser application, and the GHG impacts of using that additional fertiliser would need to be taken into consideration.



Specific approach

- A three step approach will be taken to assess the magnitude of the ILUC effects at each stage of the consequential analysis:
    1. **Statistical analysis of historical trends** in econometric data will be used to quantify the market-induced impacts of ILUC
    2. **Economic Analysis** (e.g. projections of the marginal cost of producing crops in different countries, if available) will be used to understand the extent to which it supports the trends projected through extrapolation of historic trends.
    3. **Expert input and literature review** will provide qualitative validation of the results of the statistical analysis.
- Exploring uncertainty: It is expected that there will be cases in which there is insufficient information to identify the most likely outcome of a particular ILUC effect. In these cases, we will use scenario analysis to explore each of the possible outcomes. As a result we anticipate that there will not be one ILUC factor for each biofuel but several, which will depend on the scenario used.

Boundary definition

- Considering the potentially large chain of knock-on land displacement effects that could result from using agricultural land to grow crops for biofuels and given the time constraints on the project, it will be necessary to set a limit on the number of "land displacement consequences" that we review in detail. The proposed approach is as follows:
  - If the amount of displaced land is small, we would make a first evaluation of their ILUC induced GHG impacts by considering the *largest* land use change possible.
  - If this *largest land use impact* contributes more than a certain threshold (e.g. 10%) to the total ILUC factor, then we would recalculate the GHG impacts caused by that land displacement using the detailed methodology explained in greater detail on the following slides.
  - If the *largest land use impact* contributes less than 10% of the total ILUC factor, then we would not analyse the ILUC impacts in more detail and assume the largest ILUC impact for that portion of displaced land.
- As the total ILUC factor can potentially be composed of many small effects, a limit would have to be put on the amount of the ILUC factor calculated in this way (e.g. maximum 20%).
- **Example**: A small amount of land for barley has been identified as being displaced by biofuel feedstock agricultural land expansion. The worst ILUC factor is calculated by identifying the worst ILUC situation possible. The impact of this worst ILUC situation is smaller than 10% of the total ILUC factor, so the worst ILUC factor is kept for the small amount of displaced barley.

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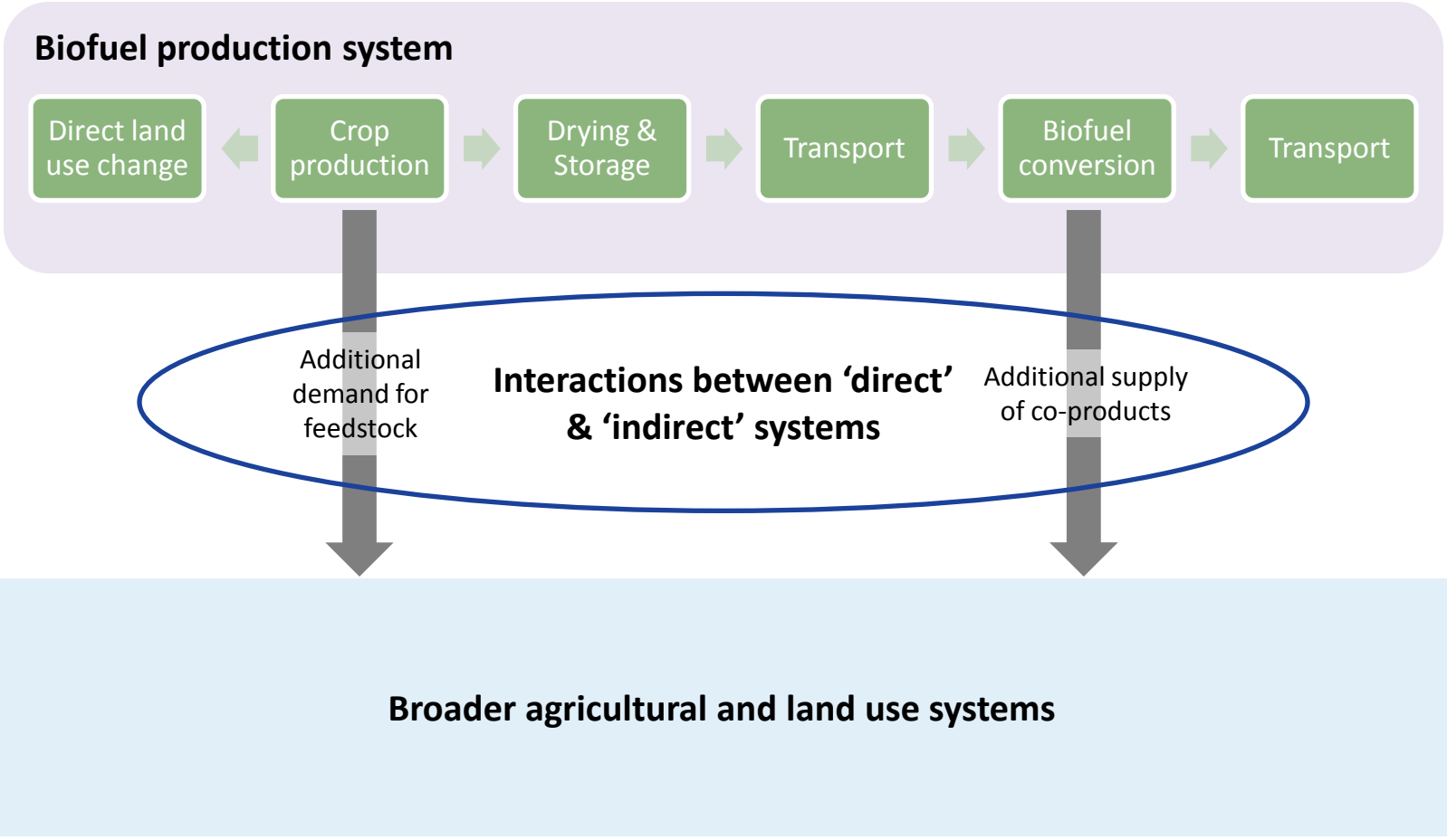
The land use effects of both additional demand for feedstock and additional supply of co-products need to be investigated



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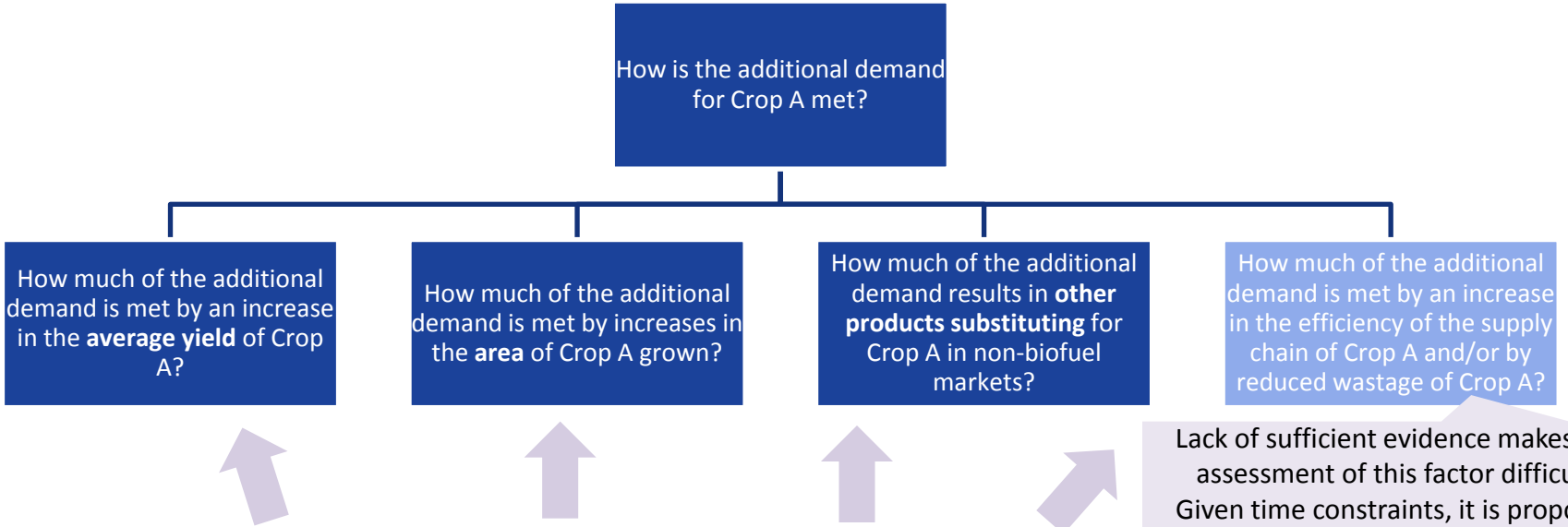
To understand ILUC effects, we need to understand how the additional demand for a crop is met



Lack of sufficient evidence makes the assessment of this factor difficult. Given time constraints, it is proposed not to consider this factor as a market response to increased demand. However, it will be considered as a way of "managing ILUC".

Additional demand for Crop A could have broader effects if it causes an increase in the price of other agricultural products (e.g. food). Price increases could lead to **decreased demand**, which, in turn, would reduce land use pressure. E4tech recognises that effect, but because this is an undesirable consequence of using biofuels, it is felt that the ILUC factor should not be credited for that consequence, and as such we propose that the ILUC factor calculated should not take into account reduced demand for food and feed products.

Note: these questions assume that land use change caused *directly* by biofuel feedstock production either has not occurred, or, if it does occur, that the resulting GHG emissions are counted as part of the direct GHG emissions assessment.

How will we quantify the amount of additional crop that is supplied by yield increases, area expansion and product substitution? (1/2)

Question	Approach	Description
How much of the additional demand is met by an (above baseline) increase in the **average yield** of Crop A?	Statistical analysis of historical trends	Analysis of historical trends to estimate the relationship between worldwide changes in demand for a certain crop and changes in worldwide average yield for that crop. Pros: • A direct relationship between demand and yield could be found • FAO data is freely available and comprehensive Cons: • Causality difficult to prove • There may be temporal changes in the relationship between demand and yield • Variability in the quality of FAO data for different regions
	Economic analysis, expert input and literature review	• Can the yield increases suggested by statistical analysis be achieved? • Are they reasonable compared with theoretical yield potentials? • Where might the yield increases occur? Are there resource constraints (e.g. sunshine hours, water, temperature) which might limit yield potential? • Do farmers in these regions have the technical and economic capacity to increase yields? Would they "see" the international price increases? • Can the potential additional production reach markets with growth demand?
How much of the additional demand is met by increases in the **area** of Crop A grown?	Statistical analysis of historical trends	Analysis of historical trends to estimate the relationship between worldwide changes in demand for a certain crop and changes in the area used for the cultivation of that crop. Pros and Cons as for yield, above.
	Economic analysis, expert input and literature review	• Can the area increases in the geographic regions suggested by statistical analysis be achieved? • Can they be supported by projections of the marginal cost of producing that crop on that land in that country? • Is there sufficient technically suitable land available? • Would Crop A be the most competitive use of that land? • Are there any political or policy constraints that might affect this expansion? • Can the additional production reach markets with growth demand?

How will we quantify the amount of additional crop that is supplied by yield increases, area expansion and product substitution? (2/2)

Question	Approach	Description
How much of the additional demand results in **other products substituting** for Crop A in non-biofuel markets?	Statistical analysis of historical trends	Analysis of historical trends in imports, consumption and prices, to estimate the amount of substitution taking place due to an increased demand for Crop A in the biofuel market. Pros: • No obvious other ways of statistically analysing this effect Cons: • Difficult to obtain historical data on product substitution

	Economic analysis, expert input and literature review	• Can the product substitution effects suggested by statistical analysis be achieved?
		  • Are the substitutes suggested technically suitable for the non-biofuel market from which Crop A is removed?
		  • Would the substitute products be economic in the non-biofuel markets?
		  • Are there any political or policy constraints that would prevent this substitution?
		  • Are there any examples to illustrate that these product substitutions occur?

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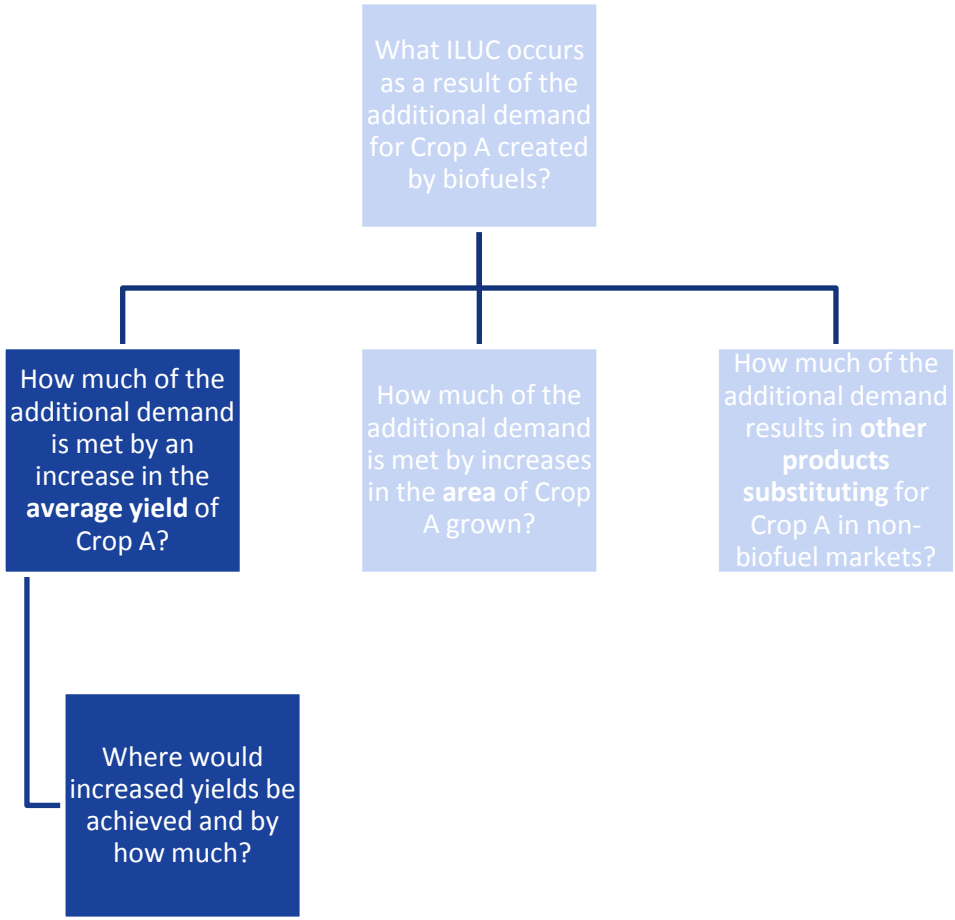
Understanding the ILUC impacts of yield increase (1/2)



It should be considered how yield increases would be met, e.g. Increased fertiliser application, varietal improvement etc. The GHG implications of this are discussed later in the methodology. However, the materiality of this source needs exploration.

Understanding ILUC impacts of yield increase (2/2)

Question	Approach	Description
Where would above BAU yield increases occur in response to extra demand and by how much?	Statistical analysis of historical trends	Extra product from yield increases comes from countries already supplying to international markets in the ratio they already supply the market

	Economic analysis, expert input and literature review	• Can the yield increases suggested by statistical analysis be achieved?
		  • Are they reasonable compared with theoretical yield potentials?
		  • Where might the yield increases occur? Are there resource constraints (e.g. sunshine hours, water, temperature) which might limit yield potential?
		  • Do farmers in these regions have the technical and economic capacity to increase yields?

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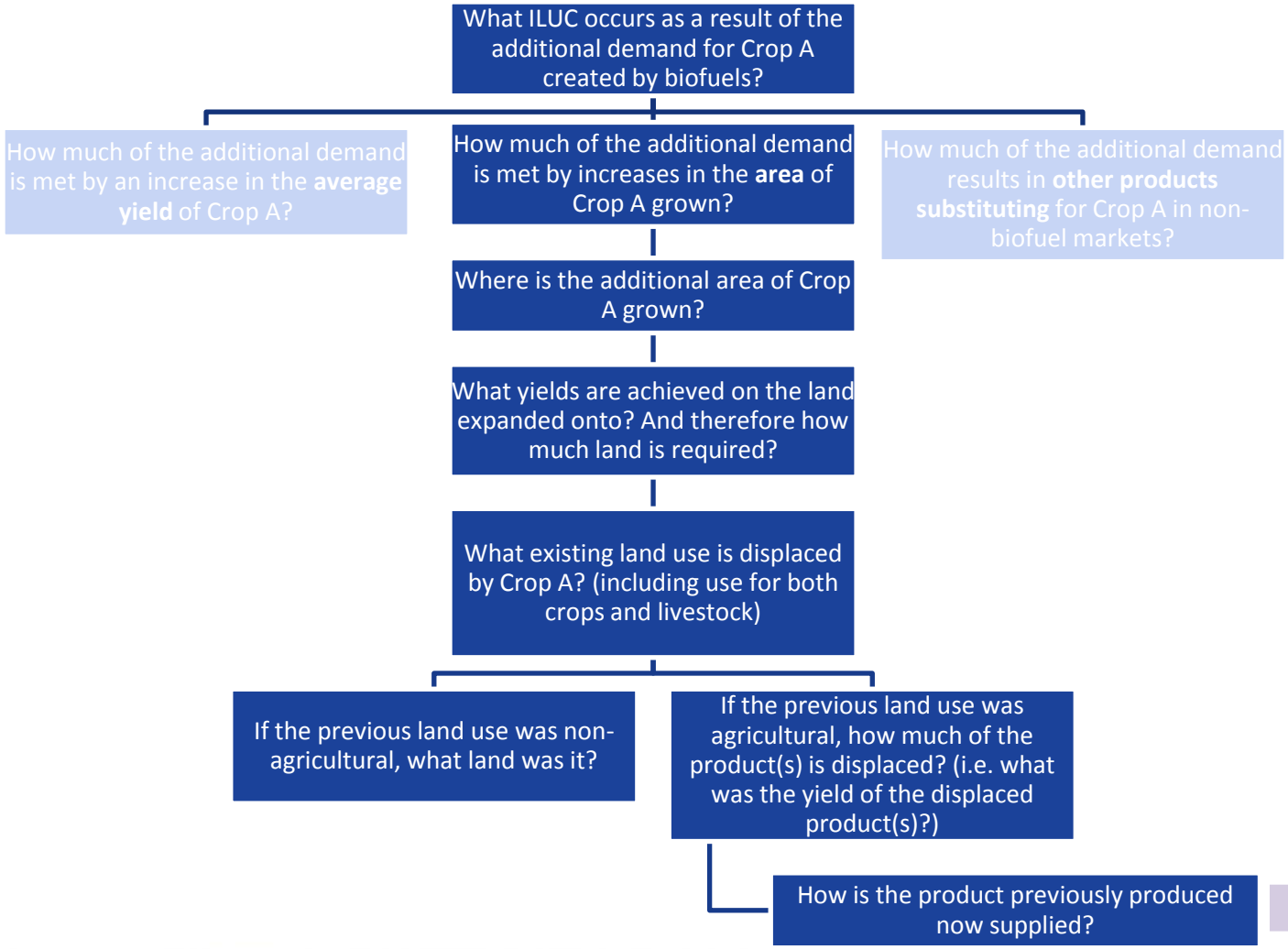
Understanding the potential causes of ILUC resulting from area expansion will require analysis of separate product systems (1/4)



A separate analysis to establish the impact on yield, area, substitution and co-products for the affected product system(s) is required. This can be carried out using the same framework applied to biofuel feedstocks

Understanding the potential causes of ILUC resulting from area expansion will require analysis of separate product systems (2/4)

Question	Approach	Description
Where is the additional area of Crop A grown?	Statistical analysis of historical trends	Review historic trends of increases in total area of land used for product A over time to identify the countries currently expanding the amount of land cultivated for feedstock A.
	Economic analysis, expert input and literature review	• Is there sufficient technically suitable land in the areas identified? • Are there policy or political constraints that would affect this expansion?
What are the yields on the land expanded onto? And therefore how much land is required?	Statistical analysis of historical trends	Review historic trends in yields in the countries/regions where additional production occurs.
	Economic analysis, expert input and literature review	• Are there resource/other constraints that might limit yield potentials on that type of land? • Do farmers in these regions have the technical and economic capacity to achieve the projected yields?

Understanding the potential causes of ILUC resulting from area expansion will require analysis of separate product systems (3/4)

Question	Approach	Description
What existing land use is displaced by Crop A?	Statistical analysis of historical trends	Review the type of land that is increasing/decreasing in the countries/regions identified, and link this to the most likely type of land that Crop A is expanding into, taking into account production cost and suitability of land. It will be necessary to look at where that additional amount of crop will be grown; i.e. how much will be grown on previously agricultural land, how much on pasture land and how much on non-agricultural land. Satellite data is likely to be helpful in identifying the type of land converted to agricultural production.
	Economic analysis, expert input and literature review	• Are the trends identified representative of the trends observed? • Are they typical of what is likely to continue to happen in the future? • How might the trends in the type of land displacement change as a result of likely political and economic developments in the future? • Would Crop A be the most competitive use of that land?
If the previous land use was agricultural, how much product(s) is displaced (i.e. yield of these product(s))?	Statistical analysis of historical trends	Review trends in yields of products in the countries / regions where additional production occurs.
	Economic analysis, expert input and literature review	• Are the historic trends used appropriate for understanding typical yields of the product displaced from the land expanded onto by Crop A?

Understanding the potential causes of ILUC resulting from area expansion will require analysis of separate product systems (4/4)

Question	Approach	Description
If the previous land use was agricultural, how is the displaced product(s) now supplied?	Repeat method to assess how demand for displaced product met	A separate analysis is required to establish how the displaced product would otherwise be supplied. If only a small amount of land is expected to be displaced, calculate the contribution to the whole ILUC factor calculated at the end, if all of that displaced product is now grown on the highest Carbon stock land. If the contribution is below 10% of the total ILUC factor calculated at the end, assume all of the displaced product replaces the high C stock land. If above 10%, begin the methodology again for the displaced product in order to analyse the effect in more detail. As an example, this analysis would end up attempting to quantify the impact on the ILUC factor of trends such as livestock intensification freeing up pasture land onto which other uses, including growing agricultural products displaced by biofuel feedstocks, can expand.
	Economic analysis, expert input and literature review	• Review of boundaries set • Separate review of the other production systems included within the boundaries

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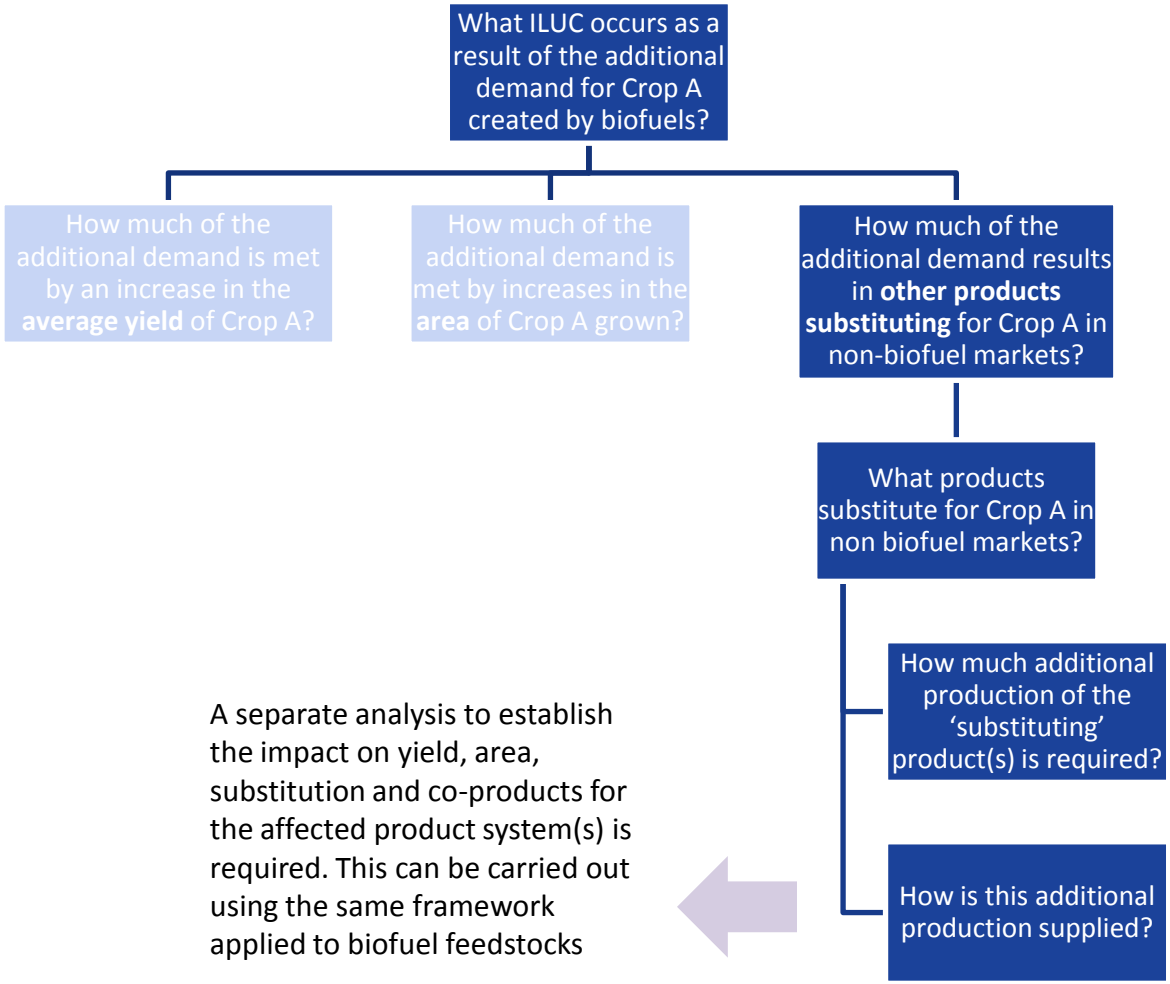
Understanding the potential causes of ILUC from substitution effects will also require analysis of separate product systems (1/3)



Understanding the potential causes of ILUC from substitution effects will also require analysis of separate product systems (2/3)

Question	Approach	Description
What products substitute for Crop A in non biofuel markets?	Statistical analysis of historical trends	Identify the amount of substituting product for crop A into traditional markets through import or consumption data and historic price data.

	Economic analysis, expert inputs and literature review	• Have all the current uses for Crop A in non-biofuel markets been identified?
		• Are the suggested substitutions likely to take place considering technical compatibility, availability of supply and relative economics?
		• Are the substituting products likely to change over time?
		  • Are there constraints in the traditional markets for Crop A?
		  • What is the future evolution of these markets likely to be?

How much additional production of the substituting product(s) is required?	Technical equivalence	Based on the amount of substituting product being imported into the key market of interest relative to the price increase in Crop A, estimate the substitution ratio between Crop A and the other product.
	Economic analysis, expert inputs and literature review	• Is there consensus on the technical equivalence of Crop A and its substitute product(s)? • Review of the substitution ratio(s) – are they in an acceptable range?

Understanding the potential causes of ILUC from substitution effects will also require analysis of separate product systems (3/3)

Question	Approach	Description
How is this additional production supplied?	Repeat method to assess how demand for displaced product met	A separate analysis to establish the impact on yield, area, substitution and co-products for the affected product system(s) is required. This can be carried out using the same framework applied to biofuel feedstocks. The same boundary issues as described on the slide about area substitution would also apply.
	Economic analysis, expert inputs and literature review	• Review of boundaries set. • Separate review of the other production systems included within the boundaries

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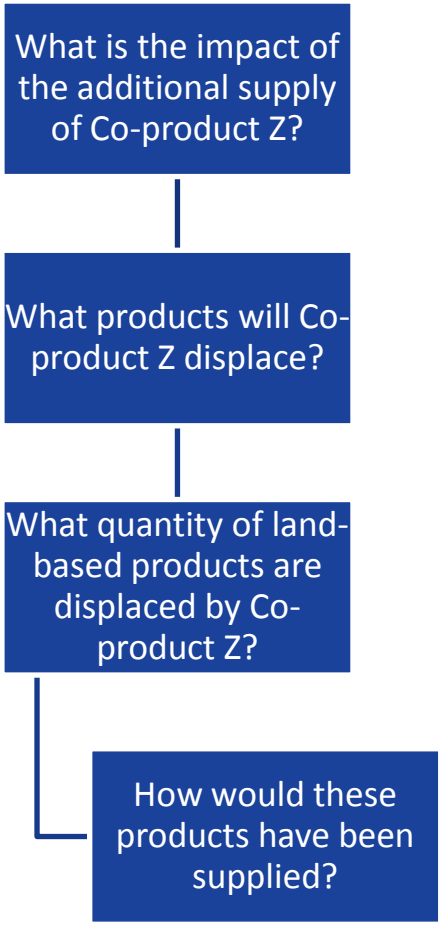
    - **Understanding the impacts of additional supply of co-products on land use**
    - GHG emissions due to ILUC effects

Understanding the potential avoidance of ILUC from co-products also requires analysis of separate product systems (1/2)



A separate analysis is required to establish how the displaced product would otherwise have been supplied. If demand for the product is growing the same framework would be used. If not, a simple area saving would be assumed.

Note: any increase in GHG emissions which occurs as a result of preparing a co-product for a certain market will be included in the analysis

Understanding the potential avoidance of ILUC from co-products also requires analysis of separate product systems (2/2)

Question	Approach	Description
What products will Co-product Z displace?	Statistical analysis of historical trends	Identify the marginal product(s) that Co-product Z is likely to displace, taking into account technical and economic considerations, based on analysis of historical trends in prices
	Expert inputs and literature review	• Is the suggested displacement likely given consideration of technical and economic considerations?
What quantity of land-based products are displaced by Co-product Z?	Technical equivalence	Based on the equivalence of co-product Z and the substituted product, estimate the substitution ratio between Z and the other product.
	Experts inputs and literature review	• Is there consensus on the technical equivalence of Co-product Z and the displaced product(s)? • Review of the substitution ratio(s) – are they in an acceptable range?
How would these products have been supplied?	Repeat method to assess how demand for displaced product met	A separate analysis is required to establish how the displaced product would otherwise have been supplied. If demand for the product is growing the same framework would be used. If not, a simple area saving would be assumed.
	Expert inputs and literature review	• Review of boundaries set. • Separate review of the other production systems included within the boundaries.

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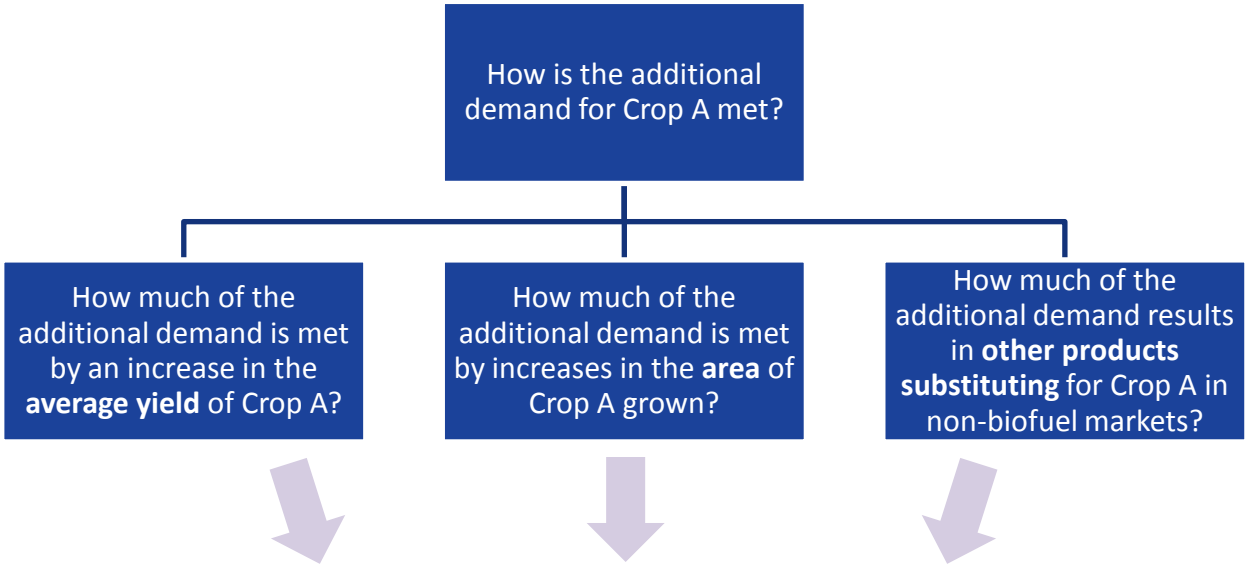
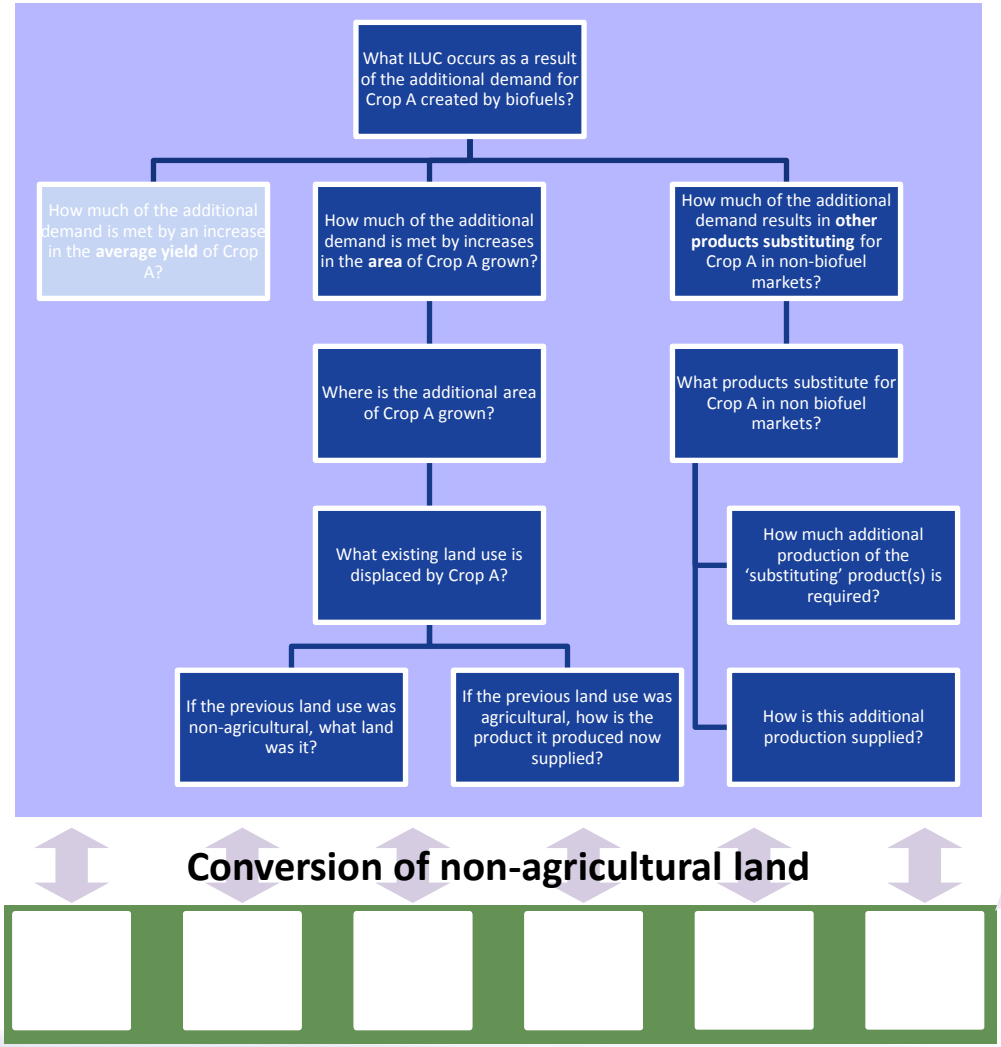
The GHG impacts of each ILUC effect will then be explored



Exploration of the impacts additional demand for Crop A has on a range of product systems ultimately leads to the identification of land use changes that result in **non-agricultural land being converted to agricultural production**.

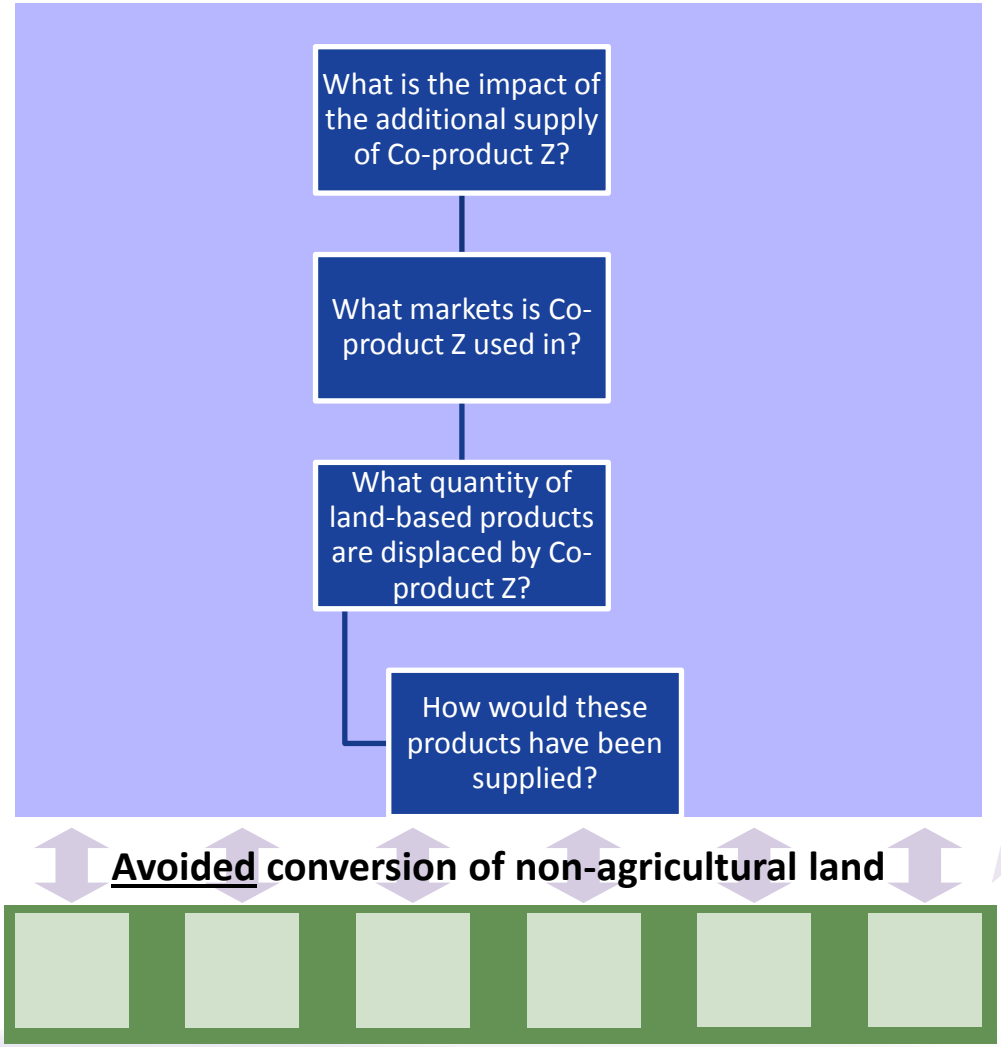
This land conversion entails **loss of carbon stocks** which then needs to be converted to an estimate of the resulting **GHG emissions**. The amount of carbon stock loss depends heavily on the geographical regions, the type of land converted and the management practices after conversion.

Estimating GHG emissions from ILUC requires identification of carbon stock loss caused by any of the affected product systems



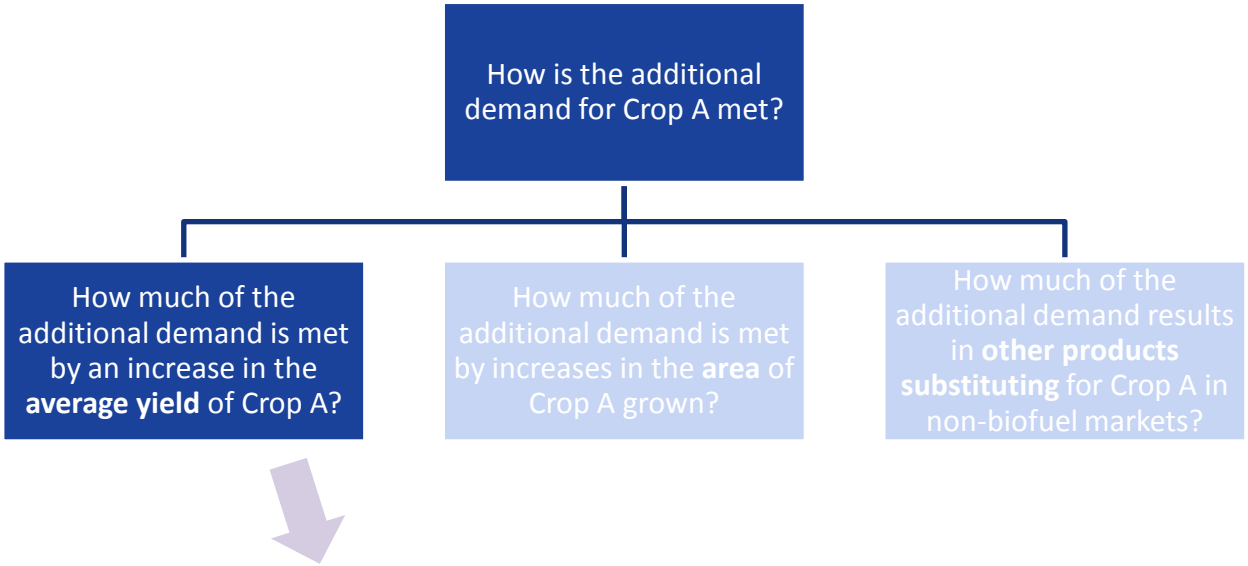
- In determining the GHG emissions released as a result of land use changes, we propose to use published studies (e.g. work by Winrock International for the EPA) that quantify carbon sequestration of the geographic land types we project to experience ILUC.
- IPCC methodology for calculating carbon stocks can complement this literature

Co-products could result in 'avoided' GHG emissions from reduced land use requirements



- Exploration of the impacts additional supply of Co-product Z has on a range of product systems may ultimately lead to the identification of avoided land use changes that would have resulted in non-agricultural land being converted to agricultural production.
- A biofuel could be credited with any resulting GHG savings, based on the quantity and type of any carbon stock loss that has been avoided.
- The total carbon stock saving then needs to be converted to an estimate of the saved GHG emissions.

Increased yields could result in additional GHG emissions due to intensification of farming



GHG emissions due to intensification?

- Increasing yields may require additional or different inputs. The GHG impact will depend on whether there is a change in the efficiency of an input used, and whether a new input is more or less carbon intensive than the old.
- Changes in inputs to biofuel feedstocks may be captured by measuring carbon intensity of the 'direct' system. However, there is no obligation to do this under the Renewable Energy Directive.
- In addition, biofuels may cause intensification across all production of a certain crop (e.g. feed wheat). Any such increase in GHG emissions would not be captured by measuring direct effects.