Low ILUC-risk certification: Pilot report and recommendations

France, Sequential cropping, September 2022

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Table of Contents

List of Tables

List of Figures

1. Pilot Introduction

This pilot tests the low ILUC-risk certification methodology for yield increase through **sequential cropping**[1] for biogas on arable farms in France. It is a follow up to the pilot in phase 1 of the project, which also focused on sequential cropping on different example farms in France.

This pilot was led by Guidehouse in close collaboration with Arvalis, a French research institute specialised in arable farming. Arvalis are working on the "RECITAL" project, which is exploring different crop rotation combinations to introduce energy cover crops in five regions of France, with the aim to make recommendations and develop agricultural guidelines for suitable crop rotations in each region. The Arvalis team bring significant expertise in technical aspects of sequential cropping, as well as contact with the farmers implementing sequential cropping in France.

1.1 Reflections on Phase 1

In phase 1, a sequential cropping pilot was conducted in the Centre-Val de Loire region of France, led by consortium partner the Institute for European Environmental Policy (IEEP) and also in collaboration with Arvalis. The pilot identified issues with applying the dynamic yield baseline methodology and additional biomass calculations in practice, especially related to the units to be used to measure and compare yields of different crops in the rotation, and the variability of crops (and therefore yields) in the rotation. A second sequential cropping pilot was also conducted in phase 1, investigating Brassica carinata grown following a main crop of soy in Uruguay.

As a result of the lessons learned from the two phase 1 sequential cropping pilots, adjustments were made to the methodology to determine the baseline and additional biomass when implementing sequential cropping. This fed into the text in Annex VIII of Implementing Regulation (EU) 2022/996 on voluntary schemes and low ILUC[2]. Based on that text, revised approaches to calculating additional biomass from sequential cropping are with the French farms in this phase 2 pilot. The fundamental difference is that the approach tested in phase 2 involves calculating **several crop-specific dynamic yield baselines** (rather than averaging historical yield data from different crops), which allows the main crop yield after sequential cropping to be compared to the historic yield of that specific crop. The final version of the Low ILUC Certification Guidance is updated with insights from this pilot.

1.2 Feedstock and Geography

The pilot audit was conducted to test the low ILUC-risk certification methodology for yield increase from sequential cropping for biogas on arable farms in France.

Arvalis have documented typical sequential cropping rotations that introduce energy crops for five different regions of France. Examples of different crop rotation combinations before and after the introduction of sequential cropping, for different regions of France, can be seen in Appendix A.

Guidehouse worked with Arvalis to select two farms which matched the "Option 1" and "Option 2b" dynamic yield baseline methodologies, as defined in Annex VIII of Implementing

[1] Sequential cropping refers to growing a second crop, before or after a main crop, on the same agricultural land, when the land would have been fallow.
[2] https://eur-lex.europa.eu/eli/reg_impl/2022/996/oj

Regulation 2022/996. This was done to test whether the methodology could work to demonstrate no impact on the main crop ("Option 1") and to calculate the dynamic yield baseline and additional biomass in the most complex scenario where the main crop varies ("Option 2b", as opposed to "Option 2a", where the main crop type is consistent). This led to the selection of two sites in different regions of France.

Site 1 (Option 1): "Earl la Cour" in Andel, Brittany, is a 105 ha pig farm producing wheat or barley as a main crop, in rotation with a **summer energy crop of sunflower and sorghum**. The site is part of a group of three farms operating as a collective. Site 1 produces biogas to fuel a combined heat and power (CHP) unit which produces grid-connected power and provides heat for the digesters and farm buildings. The anaerobic digestion (AD) plant began operating in 2014 and was the first biogas collective.

Figure 1 Site 1 location

Figure 2 Anaerobic digestion plant and solar panels at Site 1

Site 2 (Option 2b): "Les Terres Noires" in Villiers, near Poitiers, Nouvelle Aquitaine, is part of a 1000 ha cooperative (a group of farms which pool together their resources and machinery; or *CUMA – cooperative d'utilisation de materiel en commun*) producing wheat or barley as a main crop, in rotation with a **winter energy crop of rye or a summer energy crop of maize or sorghum**. Site 2 produces biomethane by upgrading biogas from the anaerobic digester using membrane separation. The biomethane is injected into the gas grid. The anaerobic digestion plant began operating in 2019.

Figure 3 Site 2 location

Figure 4 Anaerobic digestion plant at Site 2

1.3 Audit

An on-site audit was conducted at each farm: the first on **20 September 2022** at Site 1 in Andel, Brittany, and the second on **27 September 2022** at Site 2 in Villiers, Nouvelle Aquitaine. The lead auditor was William Rey, an ISCC-trained auditor from Control Union, France. The farmers and members of the Guidehouse, ISCC and Arvalis teams were also present.

1.4 Key issues tested

Two pilot audits were carried out (one on each site), testing all aspects of the Low ILUC-risk certification methodology. The issues that the pilot aimed to test are:

- **Data availability.** To test whether sufficient historical yield data is available and the degree of granularity (e.g., parcel, whole farm, region).
- **Additionality test.** Note that biofuel or biomass fuels made from sequential crops[3] can be counted outside the food and feed cap without passing the Low ILUC additionality test, but nevertheless we reflect on whether this situation could address the additionality test options.
- **Determining the dynamic yield baseline for sequential crops.** To test the use of separate dynamic yield baselines for different main crops and if farm or regional level data is available where there is insufficient historical data for the specific plot.
- **Calculation of additional biomass.** To test if allowable yield deviation thresholds are needed to account for natural yield variations and different approaches to calculate the additional biomass (absolute or relative).
- **Sustainability of additionality measure.** To test that the additionality measure is conducted in a "sustainable manner", as required by Delegated Regulation 2019/807.

For these sequential cropping pilots, there was a particular focus on **data availability** at the plot level, determining the **dynamic yield baseline** and the **additional biomass calculation**.

1.5 Relevant documents

During the audit, the following documents were developed including:

- Management plan (Site 1), the farmer did not fill in a Management plan for Site 2
- Audit checklist for each farm (prepared by Control Union)
- Audit report covering both farms (prepared by Control Union)

[3] "Intermediate crops" are outside the food and feed crop definition in REDII Article 2(40)

2. Additionality Measure

2.1 Sequential Cropping CIVE as an Additionality Measure

The additionality measure tested in the French pilot is **sequential cropping with CIVE**[4]. The term sequential cropping is used here to describe the practice of **planting a second crop before or after a main crop, on the same plot of agricultural land, when the land would have been fallow**. This reduces the amount of time the land is left fallow and is considered an additionality measure because it produces additional biomass from a parcel of land that is already under cultivation, by maximising the time in which the parcel produces biomass. Sequential crops can be grown during the summer or winter, depending on the main crop type, overall crop rotation and local climate.

Note that for the purposes of this pilot, we assume that the term “sequential crop” means the same as the term “intermediate crop”, which is used in REDII Article 2(40) to describe a crop grown on agricultural land that is not the main crop. A detailed definition of main crop or intermediate crop is not given in the REDII. The final report Low ILUC-risk pilot report includes recommendations on these definitions.

2.2 Site 1, Brittany (Option 1)

Prior to the introduction of sequential cropping, the main Site 1 rotations was a 5-year rotation of wheat, barley, maize, and rapeseed. The farm also grew some sugar beet and perennials. The farm introduced sequential cropping after the installation of the biogas plant in 2014. The sequential cropping rotation evolved since its first introduction, and the rotation choice is highly dependent on weather and soil conditions.

The main sequential crop rotation is currently a 4-year rotation of barley, followed by a summer energy crop, followed by wheat. The barley is typically harvested in July, after which the summer energy crop is sown and harvested by mid-October so that the wheat can be sown at the beginning of November. However, the choice of rotation is highly dependent on conditions. For example, one year, the soil became too compacted after harvesting the summer energy crop during a rainy period, and the farmer had to plant a winter energy crop instead of wheat. **Figure 5** displays the main crop rotation before and after sequential cropping.

The summer energy crop is typically a mix of sunflower (~65% as sown) and sorghum (~35% as sown). The sorghum has little biogas potential value in itself but acts as a structural support for the sunflower, to prevent it from breaking or falling in high winds. The crops are harvested together when the sunflower reaches around 1.5 m tall.

The main crop before the summer energy crop is harvested without impact on the production as the length of the growing period is unchanged, although timings of sowing and harvest may be pushed back slightly depending on conditions in a specific year. The main crop after the summer energy crop is also expected not to be impacted for the same reason.

Of the 105 ha of land on the Site 1 farm, the sequential cropping rotation has only been implemented on 9 ha of land. The remaining land is split between wheat production followed by mustard/buckwheat cover crops which are incorporated into the soil, rapeseed production, beetroot production (for biogas), maize silage production (for biogas), perennial crops and rye intercropping (for biogas).

[4] Cultures Intermédiaires à Valorisation Énergétique (English: Intermediate Crops for Energy Production)

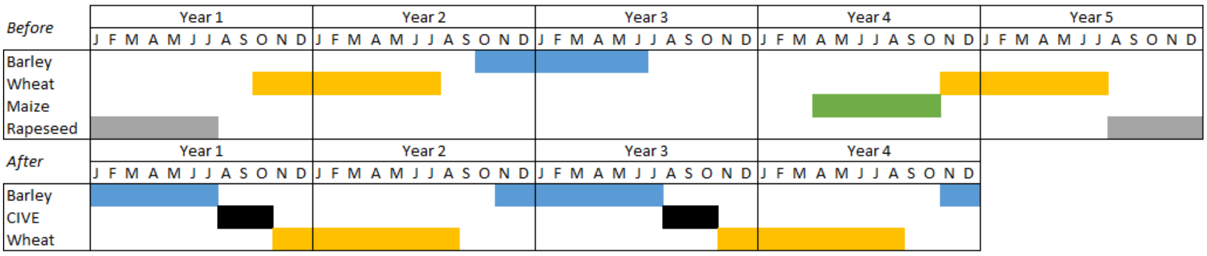

Figure 5 Site 1 rotation, before and after implementation of sequential cropping

2.3 Site 2, Poitiers (Option 2b)

Prior to the introduction of sequential cropping in 2018, Site 2 produced wheat and maize or sunflower. The farm also used to produce melons and tobacco but has stopped this activity. They have now implemented two sequential cropping rotations. The first is wheat, followed by a winter energy crop, followed by maize (as depicted in Figure 6). The second is barley, followed by a summer energy crop, followed by wheat. The farm typically sows mixed varieties for the energy crop, for example, the summer energy crop can include a mix of maize, sorghum, rye, sunflower or triticale. The late harvesting of the winter energy crop leads to a late sowing of the following main crop, hence an impact on its yield is expected. Therefore, the calculation of additional biomass which could be claimed as low ILUC-risk was tested using the Option 2b methodology.

As well as these two rotations, the farm still has some fields under maize monocropping. They also have some seed corn production (to produce seeds for a seed company). The requirements for this type of production are very strict and therefore they are not allowed to implement sequential cropping on those fields.

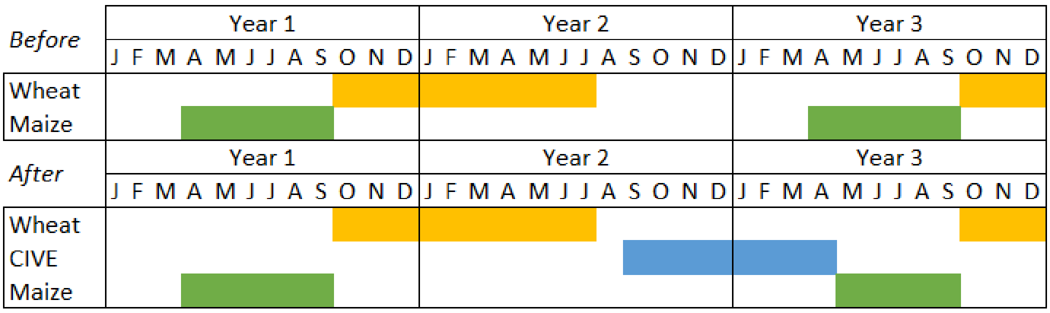

Figure 6 Site 2 rotation, before and after implementation of sequential cropping

3. Findings

3.1 Availability of data and evidence

Data about which crops were grown every year was readily available. Yield data was readily available in fresh matter mass units (tonnes). However, this was sometimes only available as a farm level average yield per crop, rather than specific plot yields. This could be a challenge as sequential cropping was not implemented on all plots, so any effect on yield is dampened by averaging the per crop yield across the whole farm.

Site 1 had paper records from which the farmer could easily find the required information, which seemed fairly complete. However, it would have been difficult and time consuming for the auditor to locate data independently. Site 1 only had average yields per crop for the total farm area. In addition, they did not have yield data for all sequential energy crop harvests. This is due to the costs and time associated with weighing the crop, which the farmer does not consider to be essential as this is not a cash crop but simply an input to their own AD plant. However, this is something they could implement if required for certification.

Site 2 had digital records with detailed information easily available through their farming software. Yield data was available at the plot level from 2018, including sequential energy crop yields. Prior to 2018, yield data was available as farm level averages only.

3.2 Additionality test

3.2.1 Financial attractiveness assessment

A financial attractiveness assessment was not performed. Economic information on the costs of sequential cropping were not available or not obtained.

3.2.2 Non-financial barrier analysis

No specific barriers to sequential cropping were discovered, however it was possible to understand why the farmers decided to implement the measure.

Site 1 produces biogas which is combusted in a CHP unit to provide heat for the site and export electricity to the grid. It was the first collectively owned AD unit in 2014. Initially, the main reason for doing this was for the treatment of pig manure, which is the farmer’s primary activity. This also triggered the implementation of sequential cropping as this was needed as an additional source of feedstock to make the digester effective and profitable. Upgrading to biomethane was not done because the gas grid is too far away and there was no financial support to connect to the grid at the time.

Site 2 historically produced food for supermarket chains, but the income from this was unreliable. They also produced large quantities of melon and tobacco and provided local agrifood markets. This provided better income than producing for supermarkets but was highly labour intensive and therefore unsustainable. The cooperative of farmers came together to build an AD plant with upgrading to produce biomethane for the gas grid from sequential crops as they judged this to be a much more reliable income model.

3.3 Determining the dynamic yield baseline

For each of the sites, we calculated **crop-specific dynamic yield baselines** (rather than the phase 1 approach which averaged historical yield data from different crops). This approach allows the main crop yield after sequential cropping to be compared to the historic yield of that specific main crop.

Site 1, Brittany (Option 1)

For Site 1, we tested setting crop-specific dynamic yield baselines. The issue is only 1 year of data was available for barley before the introduction of sequential cropping, so we tested different approaches using regional data to set the barley baseline.

The sequential cropping rotation analysed at site 1 was barley > summer CIVE > wheat. Figure 7 shows the yield data that was available to perform the calculation and the various baselines calculated in this section. Raw yield data is available in Appendix B. Yield data from before the implementation of sequential cropping was obtained for 2009 to 2014. This was used to determine the dynamic yield baseline. Data for 2015, 2016 and 2017 was not available. Barley was also grown in 2010 and 2011, but yield data was not available, as was the case for the summer CIVE in 2018 and 2019.

Note that the annual global yield increase based on FAOSTAT+ was **<u>not applied</u>** as the pilot was testing several different methodologies, so the global trendline was omitted to simplify the comparison of those different methodologies. In practice, the appropriate global trendlines would need to be added to the crop-specific dynamic yield baselines, which would slightly reduce the volume of additional biomass. The different baselines calculated in this section are summarised graphically in Figure 7.

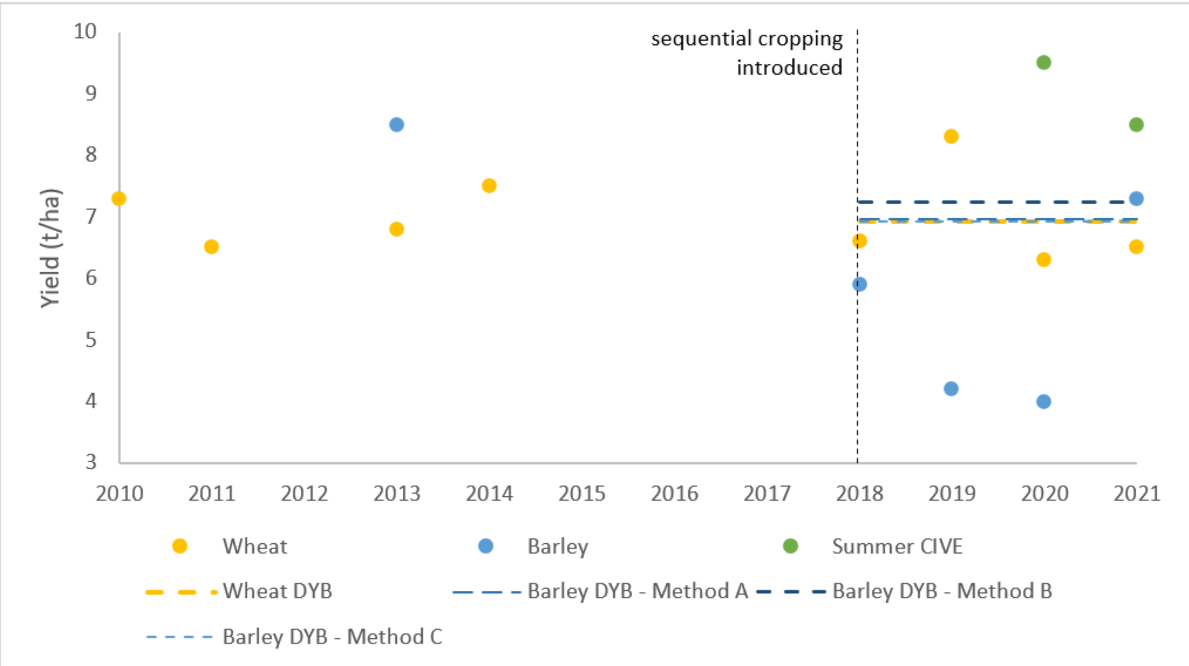

Figure 7 Crop yields at site 1 before and after introduction of sequential cropping.

Wheat baseline calculation

For wheat, the main crop baseline can simply be calculated using the average of the 3 most recent data points in the last 10 years, that is the wheat yields for 2010/11 (6.5 t/ha), 2012/13 (6.8 t/ha) and 2013/14 (7.5 t/ha), which gives a baseline of **6.9 t/ha for wheat**.

Barley baseline calculation

For barley, only 1 data point (2012/13) was available for the last 10 years, as other recent yield data for 2009/10 and 2011/12 were not available. Therefore, regional average data had to be used to set the baseline. Regional wheat and barley yields were obtained from FranceAgriMer reports for the Brittany region of France from 2011 to 2017 and are given in Table 1. Several options were tested to use this to set the barley baseline.

Table 1 Regional yield data (t/ha) for wheat and barley in Brittany, Source: FranceAgriMer

	2010/ 2011	2011/ 2012	2012/ 2013	2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020
Barley	6.4	6.4	7.3	7.4	7.6	6.5	6.7	6.5	7.1	6.1
Wheat	7.2	7.1	7.4	7.5	7.8	6.9	7.8	6.8	8	6.8

Method A: Regional correction factor for unavailable yield data

The draft low ILUC-risk chapter states that the regional data should be adjusted to reflect the farm performance by comparing the regional yields to the historical farm yields for a crop where insufficient yield data is available. To do this, the 3-year farm wheat yield average is compared to the 3-year regional wheat yield average for the same years (2010/11, 2012/13 and 2013/14). This gives a 3-year **regional average of 7.4 t/ha for wheat**, which is 10% higher than the farm average. Therefore, a correction factor of 0.9 (6.9/7.4) was applied to the barley regional yields to adjust them in line with the farm performance based on wheat.

Interestingly, the 2012/13 farm barley yield of 8.5 t/ha is 16% higher than the regional barley average of 7.3 t/ha that year, suggesting that the farm performed better than the overall region for barley. However, as this is only based on 1 data point, it is not possible to determine if this was just a particularly good year for the farm or whether the farm is consistently above the regional average for barley. This highlights a potential issue with using yield data from another crop, in this case wheat, to “correct” regional yield data.

For the purpose of testing the approach, the barley baseline was calculated using a combination of the available farm data and the corrected regional data. As the baseline should use the 3 most recent available data points before the implementation of sequential cropping, the barley baseline was calculated by taking the average of the farm barley yield for 2012/13 (8.5 t/ha), combined with the corrected regional barley yields for 2015/16 (6.1 t/ha) and 2016/17 (6.3 t/ha). This gives a baseline of **7.0 t/ha for barley**.

Method B: No regional correction factor

As Method A demonstrated the potential issues with trying to adjust the regional data to better reflect actual farm performance, we tested a second method to simplify the process by removing the data correction step. For Method B, the baseline was determined simply as the average of the farm barley yield for 2012/13 (8.5 t/ha), combined with the regional barley yields for 2015/16 (6.5 t/ha) and 2016/17 (6.7 t/ha). This gives a baseline of **7.2 t/ha for**

barley, which is higher than Method A because the regional yields were not decreased using a correction factor.

Method C: Use regional data only

Methods A and B involve combining farm data with regional data to obtain an average of 3 data points. This adds complexity to the method and may not be straightforward for farmers to replicate. In addition, it may not necessarily make the baseline more accurate as the farm data may be older (although still within the 10-year limit stipulated in the guidance) and may be more affected by external factors such as weather, specific agricultural methods in a certain year, and natural variations. The regional data could better smooth out these effects while simplifying the method, and so Method C tests the impact of simply using the regional average for the last 3 years of barley harvests. This also means only the most recent available data will be used, rather than looking further back. The Method C baseline is therefore the average of the 2014/15 (7.6 t/ha), 2015/16 (6.5 t/ha) and 2016/17 (6.7 t/ha) regional barley yields, which gives **6.9 t/ha for barley**.

Site 2, Poitiers (Option 2b)

For Site 2, sufficient historic yield data was available at the farm level, so this was used to set crop-specific dynamic yield baselines.

The sequential cropping rotation analysed at Site 2 was wheat > winter CIVE > maize. Farm-average yield data from before (2016 to 2018) and after (2019 to 2020) the implementation of sequential cropping was obtained and is shown in Figure 8. Raw data can be seen Appendix B. This was used to determine the dynamic yield baselines. Note that wheat and maize yields are farm averages, but winter CIVE yields are for single plots where sequential cropping was implemented. As for site 1, the annual global yield increase based on FAOSTAT+ was <u>**not applied**</u>.

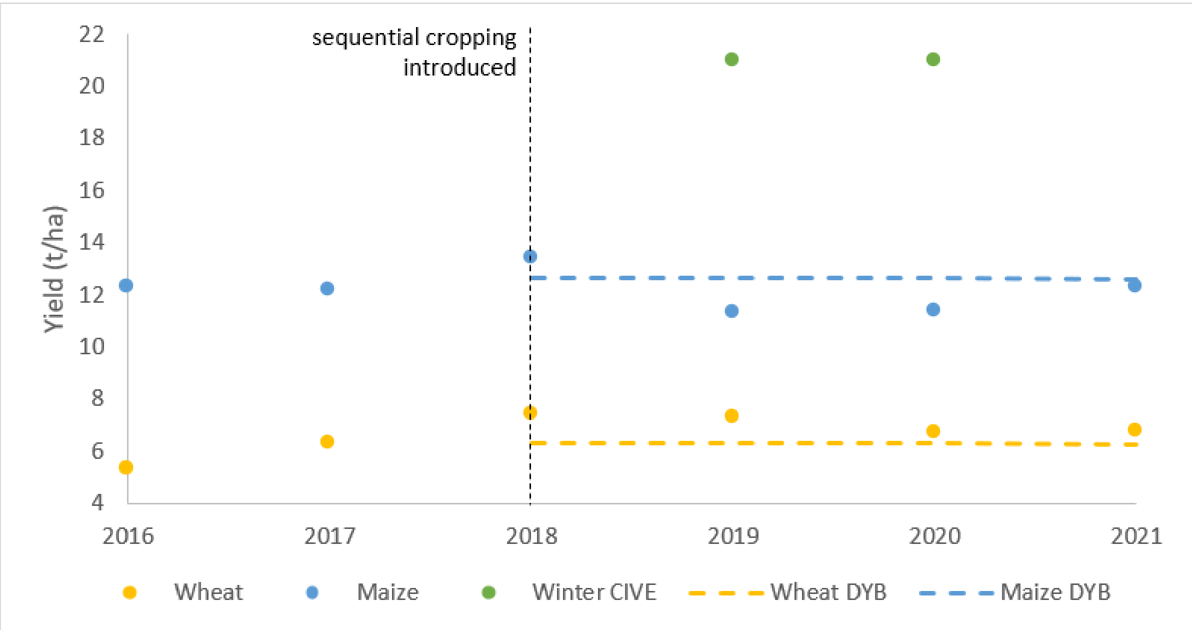

Figure 8 Crop yields at site 2 before and after sequential cropping.

Setting the baseline for wheat and maize was straightforward in this case as data was available for all 3 years prior to the implementation of sequential cropping. For wheat, the baseline was calculated as the average of the yields from 2016 (5.3 t/ha), 2017 (6.3 t/ha) and 2018 (7.4 t/ha), which gives a baseline of **6.3 t/ha for wheat**. For maize, the baseline was calculated as the average of the yields from 2016 (12.3 t/ha), 2017 (12.2 t/ha) and 2018 (13.4 t/ha), which gives a baseline of **12.6 t/ha for maize**.

3.4 Calculation of additional biomass

This section tests the methodology for the calculation of additional biomass. The calculation of additional biomass was initially only intended to be carried out for Site 2 which is an Option 2b farm, whereas Site 1, as an Option 1 farm, would be able to claim all the sequential crop as additional according to the draft guidance. However, given the limited amount of data for Site 2, and the variation in the Site 1 yield data, it was later decided to also test the additional biomass calculation methodology for Site 1.

Site 2, Poitiers (Option 2b)

For Site 2, we tested the calculation of additional biomass using data for two specific fields on which sequential cropping was implemented. Three approaches were tested: absolute change in mass, percentage change in mass and absolute change in energy.

As well as the farm-level average yields which were used to calculate the baseline, plot-level data was also available for 2 fields which implemented sequential cropping, shown in Table 2 and Table 3. It can be seen that a sequential crop was grown on the Chiron Cailla plot in 2018/19, and the wheat yield was the same as the farm average (7.4 t/ha), but the maize yield was significantly lower than the farm average (11.3 t/ha). In 2019/20, a sequential crop was grown on the La Fruitiere plot, and the wheat yield was slightly below the farm average (7.3 t/ha), but the maize yield was slightly higher than the farm average (11.4 t/ha). The calculation may be influenced because we are comparing a baseline set at the farm-level to yields at the plot-level.

Table 2 2018/2019 yields for the Chiron Cailla field (t/ha)

	2018/19
Wheat	7.4
Winter CIVE	21
Maize	9.1

Table 3 2019/2020 yields for the La Fruitiere field (t/ha)

	2019/20
Wheat	7
Winter CIVE	21
Maize	11.9

Figure 9 shows the plot-level yields after sequential cropping is implemented compared to baseline set using farm-level data. It suggests that there is no negative impact on wheat yields, which is as expected as it is the crop before the sequential crop, and its' growing period is not impacted. However, the maize yield is 6-28% lower than the maize baseline. This is expected as the maize is sown after the winter energy cover crop is harvested, which delays the sowing by around 1 month, and hence decreases the maize's growing period. This raises a practical issue of how to compensate for the yield impact of sequential cropping when this is on the crop after the sequential crop. As this cannot be known when the sequential crop is harvested and sold, it is difficult to determine how much additional biomass should be claimed.

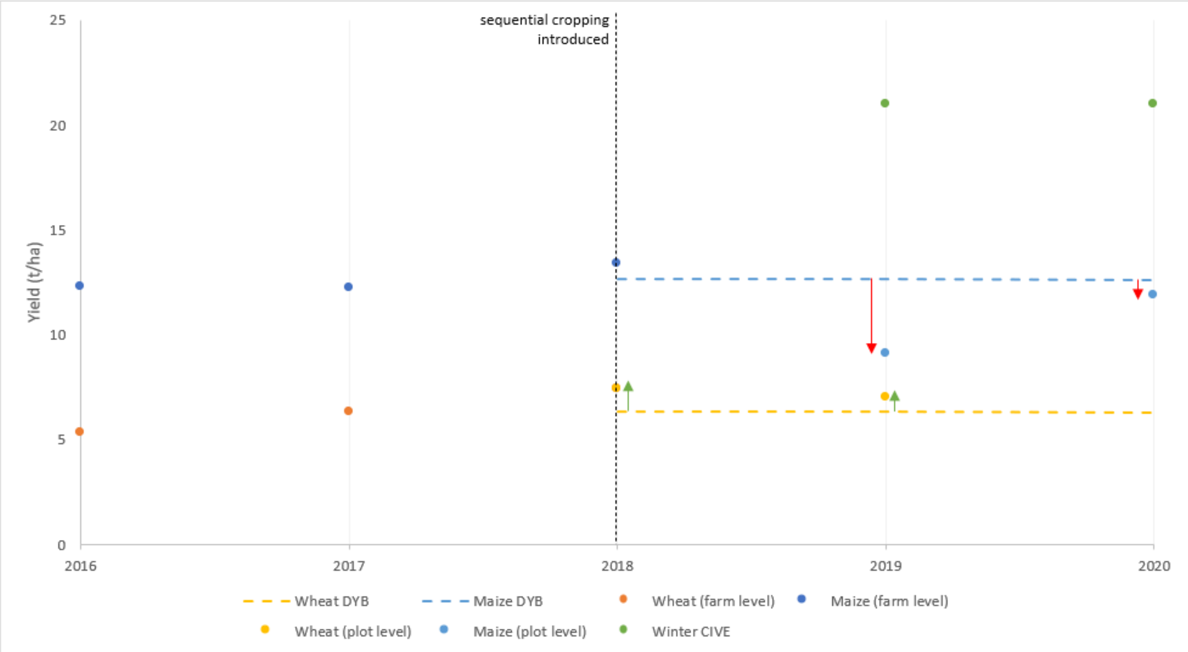

Figure 9 Site 2 yields and dynamic yield baselines for additional biomass calc.

Method 1: calculating the additional biomass using percentage change in main crop yield for compensation

To determine the additional biomass, the observed decrease in yield of the main crop is applied to the yield of the sequential crop.

The draft guidance suggests applying the percentage decrease in the main crop yield to the sequential crop yield to calculate the additional biomass (the amount of the sequential crop yield that can be considered additional). This is referred to as Method 1. This poses a challenge in this case, as the impact on the maize yield is not yet known when the winter CIVE is harvested. This will be the case in any scenario where the crop *after* the sequential crop is impacted. It was proposed to deal with this by allowing the farmer to claim all the sequential crop as additional in the first year of sequential cropping, and to apply the decrease in yield of the main crop after the sequential crop to the following sequential crop harvest. In other words, the farmer will not be penalised for any impact on the main crop in the first year that sequential cropping is implemented. This should have a small impact over low ILUC certification and allow the farmers time to adjust and improve their sequential cropping practices.

Table 5 summarises the output from each of the 3 calculation methods. Looking at the rows for Method 1, it can be seen that a 0% impact was applied in 2018/19 as the 28% decrease in maize yield observed on the Chiron Cailla plot will not have been known until the harvest in September 2019, while the winter energy cover crop was harvested 5 months earlier in August 2019. The 28% impact observed on the 2019 maize harvest was therefore applied to the winter energy cover crop harvest of 2020. The 6% impact observed on the maize harvest of 2020 will be applied to the 2021 winter energy cover crop, for which the yield was not yet known.

It is important to note that this means applying the impact on one field to the yield on another field, as in this case, the 28% decrease in maize measured in 2019 was for Chiron Cailla, but the next sequential crop harvested in 2020 was grown on La Fruitiere. It is common for farmers to shift the position in rotation between different fields. In practice though, these yield impacts will be averaged across all the fields on the farm on which sequential cropping has been implemented in any one year, which should smooth out any cross-field variations.

Method 2: calculating the additional biomass using absolute change in main crop yield for compensation

Using percentage change to calculate the compensation can result in very small or very large net compensation being applied if the magnitudes of the main crop and sequential crop yields are significantly mismatched. Another option which could be appropriate is to use the absolute decrease in main crop yield to calculate the additional biomass. This is referred to as Method 2.

Applying this method to Site 2 means a 0 t/ha impact is applied in 2018/19 as the 3.5 t/ha decrease in maize yield observed on the Chiron Cailla plot was not known until after the winter energy crop was harvested. The 3.5 t/ha impact observed on the subsequent maize harvest was therefore applied to the winter energy cover crop harvest of 2020. The 0.7 t/ha impact observed on the maize harvest of 2020 would be applied the 2021 winter energy cover crop, for which the yield was not yet known. The resulting additional biomass quantities can be seen in Table 5.

Looking at the results for 2019/20, in this case, using the percentage decrease (Method 1, 15.1 t/ha) results in a smaller additional biomass value than using the absolute decrease (Method 2, 17.5 t/ha). However, this would be reversed if the typical main crop yields were larger than the sequential crop yields. Using the percentage decrease has some advantages, it prevents the calculated additional biomass yield from being negative, which could occur if the main crop originally had high yields which decreased significantly (for example sugar beet, which can have a yield of over 80 t/ha).

Method 3: calculating the additional biomass using absolute change in main crop yield in *energy* units for compensation

Another approach is to compare the yields on an energy basis rather than a mass basis. Energy content is logical metric as energy is the useable metric for both food and fuel. The energy content of the harvested crop needs to be considered – in the case of anaerobic digestion, it is therefore the energy content of the whole crop.

This requires data for the energy content of all the crops in the rotation. Annex IX of Implementation Regulation 2022/996 includes energy content values for the main biofuel crops. The energy content of wheat, maize (whole crop) and rye are therefore included. However, it is not clear if these are whole crop values for wheat and maize, and these are averages for a wide geographic region.

Table 4 Data used for Site 2 additional biomass calculation based on energy content

	Energy content	Dry matter
Wheat	18.5 MJ/kg dry matter	87.8%
Maize	18.6 MJ/kg dry matter	86.3%
Rye	18.0 MJ/kg dry matter	86.7%

Therefore, data from a French database (INRAE-CIRAD-AFZ[5]) was used to obtain the energy content values for the winter energy cover crop (rye) and the main crops (wheat and maize) instead. These are given in Table 4. This data is for mature crops, therefore we have to assume that the sequential crop was harvested at full maturity when it may in fact have still been green due to the relatively short growing period. The energy content data was used to convert the yields from t/ha to MJ/h. Figure 10 shows the plot-level *energy* yields after sequential cropping is implemented compared to the baseline *energy* yields set using farm-level data.

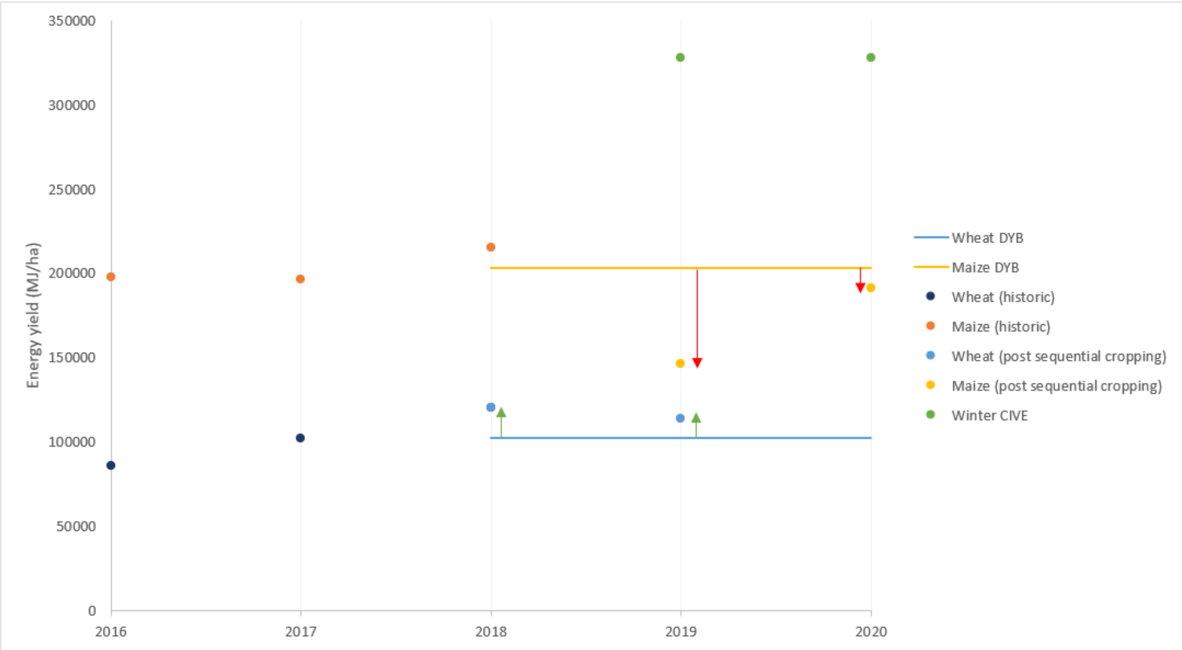

Figure 10 Site 2 energy yields and dynamic yield baselines for additional biomass calc.

Taking the absolute decrease in maize energy yields from the chart and applying them to the sequential crop energy yield allows for the additional biomass to be calculated. The 3.5 t/ha decrease in maize yield observed in 2018/19 is equivalent to a 56,838 MJ/ha decrease in energy. This is applied to the subsequent winter energy cover crop harvest of 2019, meaning only 270,574 MJ/ha of the total 327,726 MJ/ha energy yield can be claimed as additional. Converting this back to a yield in mass (t/ha) gives and additional biomass quantity of 17.3 t/ha. All of the resulting additional biomass quantities can be seen in Table 5.

It can be seen that the outcome is very similar to Method 2 using absolute compensation on a mass basis. This is due to all the crops involved in this rotation having very similar energy contents (see Table 4), therefore the conversion from mass to energy has little impact. This would be very different if the crops had a range of energy contents, for example maize (18.6 MJ/kg dry matter) and rapeseed (27 MJ/kg dry matter). Therefore, using the energy method would be most relevant in rotations with crops of different energy contents, but may add unnecessary complexity when this is not the case, as in this pilot.

[5] https://feedtables.com/fr

Table 5 Additional biomass based on percentage and absolute compensation (Site 2)

		2018/19	2019/20	2020/21
		Chiron Cailla	**La Fruitiere**	***unknown***
	CIVE yield [t/ha]	21.0	21.0	*unknown*
Method 1 - percentage	*Yield impact [%]*	0%	-28%	-6%
	Additional biomass [t/ha]	**21.0**	**15.1**	N/A
Method 2 - absolute	*Yield impact [t/ha]*	0.0	-3.5	-0.7
	Additional biomass [t/ha]	**21.0**	**17.5**	N/A
Method 3 - energy	*Yield impact [MJ/ha]*	0	-56,838	-11,797
	Additional biomass [MJ/ha]	0.33	0.27	N/A
	Additional biomass [t/ha]	**21.0**	**17.3**	N/A

Site 1, Brittany (Option 1)

For site 1, the wheat and barley yields were compared to the baseline to see if these behaved as expected for an Option 1 farm.

All of the wheat and barley yield data collected as part of this pilot were farm level averages, meaning that any impact on yields due to sequential cropping will be dampened by the farm level data, as sequential cropping was not deployed on all plots. This will decrease the accuracy of the additional biomass calculation. As more spatially granular data was not available, the methodology was tested with the farm level data shown in Table 6. Data for sequential crop yield in 2019 and 2020 was not available (shown as N/A in the table), while data for wheat yield in 2022 was not available as this crop had not yet been harvested.

Table 6 Site 1 farm level yields after implementation of sequential cropping (t/ha)

	2018/19	2019/20	2020/21	2021/22
Barley	5.9	4.2	4.0	7.3
Summer CIVE	N/A	N/A	9.5	8.5
Wheat	8.3	6.3	6.5	N/A

The yields of wheat and barley were compared to the baseline yields calculated in section 0 for every year after the implementation of sequential cropping in 2018. This is visually represented in Figure 11. For barley, only the Method C baseline (using regional data only) is shown on the graph for reader clarity.

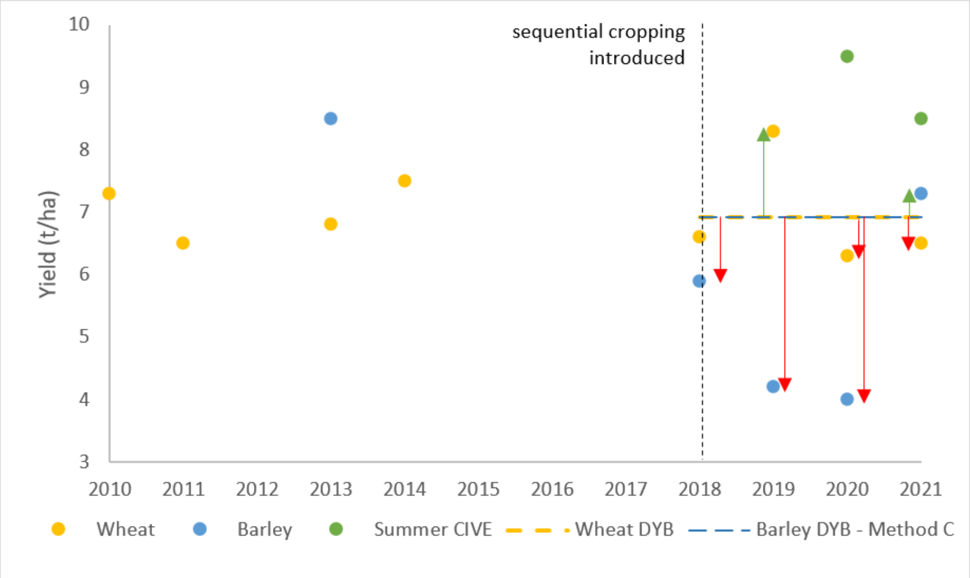

Figure 11 Site 1 yields and dynamic yield baselines for additional biomass calc.

The results for wheat (see Table 7 and Figure 11) show that the yields fluctuated around the baseline from -9% to +20%. This suggests the natural fluctuation in yield is more significant than any impact that can be directly attributed to sequential cropping.

Table 7 Difference between wheat baseline and yields after sequential cropping

	2018/19	2019/20	2020/21
Absolute [t/ha]	1.4	-0.6	-0.4
Percentage [%]	20%	-9%	-6%

However, the results for barley (see Table 8 and Figure 11) show that yield was significantly lower than the baseline for the first three years after the introduction of sequential cropping, regardless of the option used for the baseline calculation. This is surprising as barley is the crop before the sequential crop, and the length of its growing period was not impacted by the introduction of the summer CIVE, although it may have been sown a few weeks later than before (see Figure 5). Comparing the barley yields to more recent data for the region (Table 1), these are also lower than the Brittany averages for 2018 (5.9 vs 6.5 t/ha), 2019 (4.2 vs 7.1 t/ha) and 2020 (4.0 vs 6.1 t/ha).

Table 8 Difference between barley baseline and yields after sequential cropping

Option	Difference in yield	2018/19	2019/20	2020/21	2021/22
A	*Absolute [t/ha]*	-1.1	-2.8	-3.0	0.3
	Percentage [%]	-15%	-40%	-43%	5%
B	*Absolute [t/ha]*	-1.3	-3.0	-3.2	0.1
	Percentage [%]	-18%	-42%	-45%	1%
C	*Absolute [t/ha]*	-1.0	-2.7	-2.9	0.4
	Percentage [%]	-15%	-39%	-42%	5%

It is however difficult to draw conclusions on the impact of sequential cropping on the main crops based on this data due to the variability of crop rotations in previous years, which varied based on weather, field, and soil conditions, as explained in section 2.2. In addition, the sequential crop rotation began in 2015 but has evolved since first implementation, introducing additional inconsistencies in the data. This reflects the reality that farmers are free to adjust crop rotations as they see fit, and that external factors such as prices, weather and other conditions can influence crop rotations. This means rotations may not always be consistent over many years which can introduce complexity when trying to set the baseline and calculate additional biomass for low-ILUC certification.

This pilot shows that despite growing period being minimally impacted, the yield of main crops varied from -45% to +20% when compared to the baseline. This is an important observation considering this was an Option 1 example, for which the draft guidance states that economic operators should demonstrate that the introduction of the sequential crop does not lower the yield of the main crop. This example shows that this could be difficult to do by looking at yield data alone.

Although Site 1 was an Option 1 farm, the additional biomass calculation was also tested for this site as part of this pilot report to see how these large variations in yield would affect the results, and to test the methods developed for Site 2 on another example.

The same three additional biomass calculation methods tested for Site 2 earlier in this section 3.4 were tested for Site 1. All the below calculations were carried out using the Method C barley baseline (using regional data only) for simplicity and clarity.

Method 1: calculating the additional biomass using percentage change in main crop yield for compensation

Similarly to Site 2, there is a challenge as the impact on the wheat yield is not yet known when the summer CIVE is harvested, as it is the crop *after* the sequential crop. However, the impact on the barley yield, the crop *before* the sequential crop will be known. It was therefore proposed to deal with this in the same manner as for Site 2 (by applying the decrease in yield of the main crop after the sequential crop harvest), except that in this case the decrease in yield of the crop before the sequential crop can be applied from the very first year of sequential crop harvest. This is best visualised by looking at the arrows in Figure 11, which represent the impact on main crop yields in each year.

Table 10 summarises the output from each of the 3 calculation methods. Looking at the rows for Method 1, it can be seen that a -15% impact was applied in 2018/19. This is the impact on the barley crop harvested directly before the first sequential crop. In 2019/20, the overall yield impact is -19%. This is made up of a 20% increase in the wheat crop after the first sequential crop, combined with a 39% decrease in the barley crop before the second sequential crop, as represented by the arrows for the year 2019 in Figure 11. The same logic followed to calculate the percentage yield impact for 2020/21 and 2021/22. However, the total additional biomass could only be calculated for those last 2 years, as the CIVE yield was not known by the farmer for 2018/19 and 2019/20.

Method 2: calculating the additional biomass using absolute change in main crop yield for compensation

Using absolute change rather than percentage change in main crop yields to calculate the amount of additional biomass results in higher quantities being eligible for low ILUC, as can be seen in Table 10. This is because the absolute yields are generally higher for the summer

CIVE (9.0 t/ha on average) than for the barley (5.4 t/ha on average) and the wheat (7.0 t/ha) throughout the sequential cropping period (2018-2022).

Method 3: calculating the additional biomass using absolute change in main crop yield in *energy* units for compensation

Comparing the main crop and sequential crop yields on an energy basis requires data for the energy content of all the crops in the rotation. Annex IX of Implementation Regulation 2022/996 includes energy content values for the main biofuel crops. The energy content of wheat and barley (grains) are therefore included. However, energy content standard values for the summer CIVE crops are not included. Annex IX does not currently include data for *whole* crops typically used in anaerobic digestion (with the exception of maize silage). Furthermore, for this pilot, the CIVE crop is sown as 65% sunflower and 35% sorghum, and the farmer also does not have data for the harvested share of the two feedstocks as they are harvested together. Therefore, the proportions of feedstock as sown had to be used as the best available estimate for yield as harvested.

As the energy content for sunflower and sorghum are not included in Annex IX of Implementation Regulation 2022/996, the energy content and dry matter values were obtained from an alternative French data source, INRAE-CIRAD-AFZ[6]. Finding data for sunflower whole crop was more challenging, as most databases only provide data for sunflower seeds, as this is the more common product. The energy content for sunflower whole crop was calculated based on findings from Kallivroussis et al, (2002)[7]. The values used are summarised in the table below.

Table 9 Data used for Site 1 additional biomass calculation based on energy content

Crop	Energy content	Dry matter
Barley	18.3 MJ/kg dry matter	87.2%
Wheat	18.5 MJ/kg dry matter	87.8%
Sunflower	18.3 MJ/kg fresh matter	-
Sorghum	18.7 MJ/kg dry matter	87.8%

These values were used to calculate the additional biomass on an energy basis. The values were used to convert all the yields in Table 6 from t/ha to MJ/ha. The energy yields were then plotted as shown in Figure 12.

To calculate the sequential crop energy yield, it was assumed that the summer CIVE yield is split between the sunflower and sorghum according to the sowing proportions of 65% and 35% respectively. This assumption may not be an accurate reflection of the reality as the sorghum is mainly added as a support for the sunflower and may therefore have a lower share of the yield. Generally, this shows that in situations where the sequential crop is a mixed variety, it may be difficult to accurately calculate the energy yield. In addition, the energy content values are for fully mature crops, however sequential crops may be harvested when they are still green to fit into a shorter growing period. This would affect the energy content and is another potential source of error in the calculation. This could be remediated by using data for green crops (if available) in such cases. This should be left to the auditor's judgement.

[6] https://feedtables.com/fr

[7] L. Kallivroussis, A. Natsis, G. Papadakis, Rural Development: The Energy Balance of Sunflower Production for Biodiesel in Greece, Biosystems Engineering, Volume 81, Issue 3, 2002, pages 347-354,

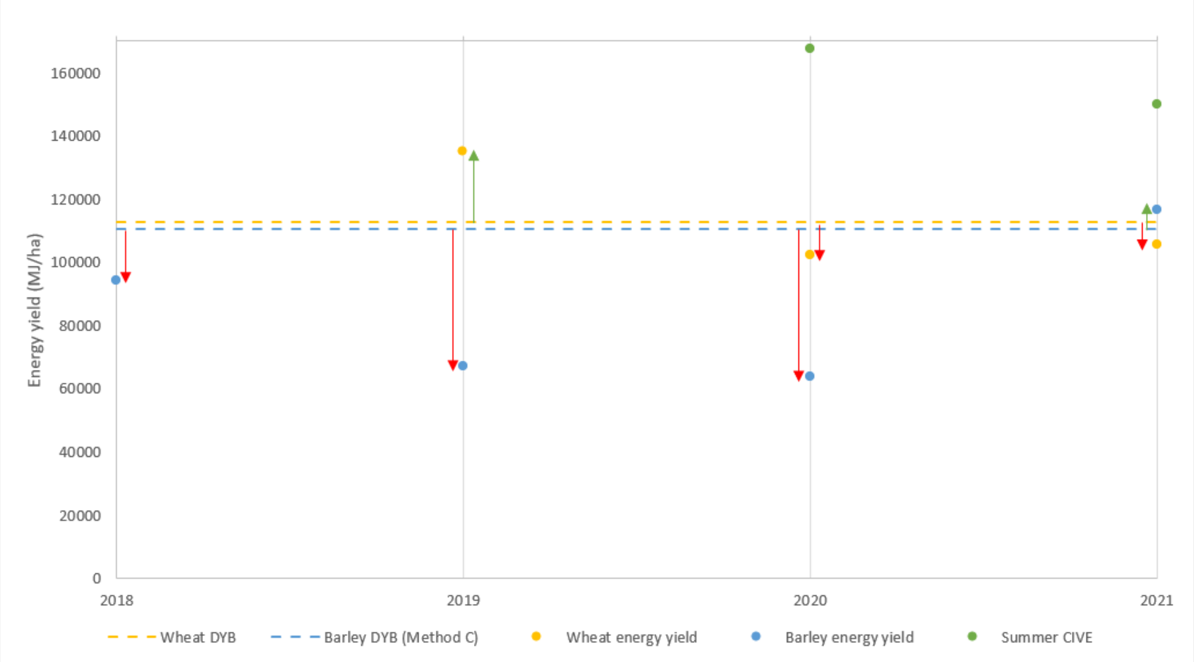

Figure 12 Site 1 energy yields and dynamic yield baselines for additional biomass calc.

Sequential crop yield data was only available for 2020 and 2021, so the additional biomass calculation could only be made for those years. In 2020, it can be seen that there was a decrease in the energy yield of both the main crops grown before the summer CIVE, particularly the barley. This represents a reduction in energy yield of 57,096 MJ/ha for that year, as shown in Table 10. In 2021, overall main crop energy yield reduced by just 1,188 MJ/ha.

The additional energy yield was then calculated as the sequential crop energy yield, minus the main crop energy yield reduction. This is then converted back to t/ha, resulting in additional biomass yield of 6.3 and 8.5 t/ha in 2020 and 2021 respectively, as shown in Table 10. Compared to doing the calculation on a mass basis, these results are similar, but slightly higher, as sunflower and sorghum have slightly greater energy contents than wheat and barley, as seen in Table 9.

Using the mass approach removes the challenge of certain assumptions on energy content, crop maturity and mixed crop yields, but it is more simplistic and does not make sense when crops in a rotation have significantly different energy contents.

Table 10 Additional biomass based on percentage and absolute compensation (Site 1)

		2018/19	**2019/20**	**2020/21**	**2021/22**
	CIVE yield [t/ha]	*unknown*	*unknown*	9.5	8.5
Method 1 - percentage	*Yield impact [%]*	-15%	-19%	-51%	-1%
	Additional biomass [t/ha]	N/A	N/A	**4.7**	**8.4**
Method 2 - absolute	*Yield impact [t/ha]*	-1.0	-1.3	-3.5	0
	Additional biomass [t/ha]	*N/A*	*N/A*	**6.0**	**8.5**
Method 3 - energy	*Yield impact [MJ/ha]*	-16,490	-21,419	-57,096	-1,188
	Additional biomass [MJ/ha]	*N/A*	*N/A*	110,666	148,916
	Additional biomass [t/ha]	*N/A*	*N/A*	**6.3**	**8.5**

3.5 Sustainability of the additionality measure

Introducing sequential cropping can be advantageous for farmers in several ways. It can allow them to grow an additional crop and hence provide an additional revenue source. The farmer at Site 2 explained that they used to produce food, including melons, but the income was unreliable. Producing for local markets was slightly better but highly labour intensive. They therefore decided to switch to arable crops for biomethane production with sequential cropping as this is much more reliable.

Sequential cropping also allows farmers to keep their soil covered for a longer period which reduces soil erosion. At Site 2, the farmer explained that once sequential cropping is introduced, the ground is covered for 90% of the year, with minimal fallow periods. Finally, it can decrease the need for synthetic nutrient fertiliser if the cover crop is ploughed into the soil or used to produce biogas, which co-produces digestate, which is then used as an organic fertiliser.

However, this also comes with additional sustainability and farm risks. Because the sequential crop is generally grown during the worst period of the year, there is a higher risk of crop failure. This can have a negative impact on the farmer's revenue and sustainability especially if they have invested in fertiliser and other inputs to grow the sequential crop and the crop then fails. An example of crop failure was observed at Site 1, where one of the fields with a sunflower summer sequential crop had not reached maturity due to insufficient water supply. If the crop fails (very low yield achieved), it is often ploughed back into the land rather than harvested. This means the farmer has still achieved several of the benefits, including soil cover and returning some nutrients to the land, but they have not provided the desired feedstock for the anaerobic digester.

Sequential crops could be grown without additional inputs such as fertiliser, herbicide, irrigation etc., however, that can increase the risk of crop failure. Any additional inputs farmers do use to grow the sequential crop add to the GHG intensity and have the potential for negative environmental impacts. For example, additional synthetic fertiliser has an impact on GHG emissions, as well as carrying an acidification and eutrophication risk. Farmers sometimes use herbicide to ensure a clean soil after the sequential crop and before sowing the main crop, and this can have a negative impact on biodiversity. If sequential crops require irrigation, this can pose a risk to water resources and exacerbate any water scarcity issues in a region.

Neither of the pilot sites were certified to an EC-recognised voluntary scheme, however in the auditor's opinion, this is likely something they could obtain if desired. Potential barriers would be the open storage of digestate, which was used at both sites. This can impact the GHG performance of the anaerobic digester and the biogas it produces. At Site 2, this risk was reduced by having a long digestion time of 120 days, which greatly reduces the residual methane emissions of the digestate in storage. At Site 1, the digestion time was 1 month so there is a higher risk of negative fugitive emissions from the open storage.

Site 1 had fully switched to using liquid digestate as a fertiliser which will have a positive impact on GHG performance compared to using synthetic fertilisers. However, the farmer highlighted that soil compaction could become an issue because liquid digestate is much heavier than synthetic fertiliser. At Site 2, the farmer began spreading digestate in 2021 only, and has so far been able to displace 30% of synthetic fertiliser. Site 2 also had an interesting method for transporting digestate around the farm, by means of a pump-operated 6 km trench connected to different lagoons and spreading systems. Both sites expect to see an increase in soil organic matter over time thanks to the use of digestate.

4. Conclusions and recommendations for low ILUC-risk methodology

4.1 Key conclusions from this pilot

The key findings from the pilot on the two farms are:

- **Yield data was (mostly) available but sometimes at the farm level and not always at the field level**. One of the farmers only had farm level yield data, while the other also had field level yield data available, but only for some years, crops and fields. This presents a challenge to isolate the yield impact of sequential cropping, as it was not implemented across the whole farm. For example, Site 1 had implemented sequential cropping on roughly 10% of the total land area only. This means that it is likely that the main crop yield decrease observed in the farm level data could not be attributed directly to the introduction of sequential cropping, but also due to other factors. Sequential crop yield was less consistently recorded than main crop yields.

- **Yield was not a good indicator for the Option 1 farm. There was significant variation in main crop yields due to other factors.** The Site 1 pilot showed that the methodology defined in the guidance for “Option 1” (no impact on main crop yield) may not lead to the right conclusions. There was no impact on the duration of the main crop growing periods, and yet a decrease of up to 45% was observed in the main crop yield. On the other hand, main crop yield also increased compared to the baseline in certain years, demonstrating a significant variation in yields of the main crops in general. As sequential cropping was only applied to a small proportion of the farm, and the calculation was based on farm average yields, the variation cannot be directly attributed only to sequential cropping. Such variations could occur due to other factors than sequential cropping, such as weather or changing crop rotations over several years, and so it may be difficult for farmers to demonstrate that they fit Option 1 (no main crop yield impact) just by using yield as an indicator. If this is required, it could lead to significant risk due to natural variation in yields.

- **When yield data is missing, it was too complicated to use corrected regional values.** Calculating crop-specific baselines was possible, but led to challenges when there was insufficient historical data available. Trying to set the baseline by combining available farm data with regional averages *which were corrected to align with farm performance* was complex and did not necessarily add accuracy to the calculation. Simply taking the average of the last 3 years of regional data gave similar results and was much more straightforward.

- **Site 2 highlighted the challenge of calculating additional biomass when the crop *after* the sequential crop is impacted.** As the sequential crop changed the growing period of subsequent main crop, the impact on the main cannot be known until the season after the sequential crop is harvested and sold or used. Therefore, guidance is needed on how to account for this. This was further reinforced by analysis of Site 1, where both the crop before *and* after the sequential crop could have been impacted.

- **Percentage yield impact was the easiest to apply.** For calculating the amount of additional biomass which can be claimed, using the percentage rather than absolute yield impacts avoids issues in cases where the typical yield of the main crop and sequential crop are very different. In that scenario, using absolute figures risks resulting in extremely low (even negative) results. **However, absolute yield impact was more logical in cases where crops in the rotation have significantly different energy**

contents. The energy content approach is considered to most fairly represent the actual change in land productivity in terms of amount of biomass produced (either for food, feed or fuel. The energy content approach should be applied when calculating additional biomass. While using percentage impact is also possible, this may not best represent the actual change in land productivity.

- **The sustainability of sequential cropping as an additionality measure depends strongly on the use of external inputs, which should be monitored.** The use of synthetic fertiliser, herbicide and irrigation for sequential crops can result in a negative impact on greenhouse gas emissions, biodiversity, and water resources. This should be checked as part of the audit to ensure sequential cropping is deployed sustainably.

4.2 Improvements to the certification guidance

For Option 1 cases, due to the complexity and naturally large variations in yields, it is recommended to simplify as much as possible the approach for situations where the sequential crop is grown during periods when the land would be bare and hence does not impact the growing period of the main crops.

This should be done in a way that encourages good agricultural practices and minimises the risk of soil health being compromised. **Therefore, to prove that main crop yields are not affected by sequential cropping (Option 1) and that this is done in a sustainable way, we recommend the farmer should demonstrate that:**

- **The main crop growing period remains the same before and after the introduction of sequential cropping.**
- **The total field inputs do not increase.**

For Options 2a and 2b, we tested using the percentage change in yield but found this did not allow for differences in crop properties, especially when some sequential crops are sown as a mixture (e.g., sunflower and sorghum for Site 1). **Using the absolute change in total energy produced to calculate additional biomass is recommended, especially in cases where the crops involved have significantly different energy contents**. The energy content approach is considered to most fairly represent the actual change in land productivity. Energy content values from Annex IX of the Implementation Regulation 2022/996 should be used where available and appropriate to the crop harvested and used (i.e. whole crop energy values should be used if the whole crop is put into an anaerobic digester). **To enable this method to be used in more scenarios, it is recommended the Commission adds more whole crop energy values to Annex IX.** Otherwise, a reputable country-specific source could be used. If it is not possible to find appropriate energy content values, and these are not expected to be significantly different for the crops in rotation, the percentage change in tonnes of biomass produced can be used as a simpler alternative. This should be decided by the auditor.

The Site 1 pilot also demonstrated that the guidance for calculating the baseline when insufficient farm data is available is too complex and does not necessarily add significant accuracy. Therefore, it is recommended that, where fewer than 3 historical main crop yields are available within the last 10 years, the baseline should be taken as the average of the last 3 years of regional yields for that crop. This was "Method C" in section 0, which gave very similar results to the other, more complex options tested (within 3 percentage points).

The Site 2 pilot highlighted the challenge of calculating additional biomass **when the crop *after* the sequential crop is impacted**. This is because the impact cannot be known when the sequential crop will be harvested and sold. It is therefore recommended that **no impact be applied in the first year of sequential cropping, allowing the farmer to claim the entire sequential crop as additional biomass. The impact will then be compensated for from year 2, by applying the decrease in main crop from the previous year.**

This does create some risk that the farmer would not continue sequential cropping if they saw a strong negative impact in the first year. However, this could be mitigated by including a requirement to implement the additionality measure for a certain number of years in order to obtain low ILUC certification. The risk can also be decreased by stipulating that the impact on the main crop should be carried over for a certain number of years. This will avoid the possibility of farmers “pausing” sequential cropping for one year to “reset” the main yield impact to zero. Instead, the main yield impact from the first year of implementation will be carried over to the next sequential crop harvest, regardless of how much time has passed in between.

Appendix A. Arvalis examples of typical crop rotations after introducing sequential cropping in different regions of France

Appendix B. Raw pilot data

This section includes the raw yield data for the two pilot sites, and additional calculation data for site 2.

Table 11 Site 1 yield data for crops in the sequential cropping rotation (yield t/ha)

	Before sequential cropping					After sequential cropping			
	2009/10	*2010/11*	*2011/12*	*2012/13*	*2013/14*	*2018/19*	*2019/20*	*2020/21*	*2021/22*
Wheat	7.3	6.5		6.8	7.5	8.3	6.3	6.5	
Barley	N/A		N/A	8.5		5.9	4.2	4.0	7.3
Summer CIVE						N/A	N/A	9.5	8.5

Table 12 Site 2 farm average yield data for main crops (yield t/ha)

	Before sequential cropping			After sequential cropping		
	2016	*2017*	*2018*	*2019*	*2020*	*2021*
Wheat	5.3	6.3	7.4	7.3	6.7	6.8
Maize	12.3	12.2	13.4	11.3	11.4	12.3

Table 13 Site 2 difference in yield between wheat baseline and yields after sequential cropping

	2018/19	2019/20
	Chiron Cailla	*La Fruitiere*
Absolute [t/ha]	1.1	0.7
Percentage [%]	17%	11%

Table 14 Site 2 difference in yield between maize baseline and yields after sequential cropping

	2018/19	2019/20
	Chiron Cailla	*La Fruitiere*
Absolute [t/ha]	-3.5	-0.7
Percentage [%]	-28%	-6%

Table 15 Site 2 additional biomass based on absolute energy compensation

	2018/19	2019/20	2020/21
Change in wheat yield (MJ/ha)	0.02	0.01	N/A
Change in maize yield (MJ/ha)	N/A	-0.06	-0.01
Winter CIVE yield (MJ/ha)	0.33	0.33	N/A
Additional biomass (MJ/ha)	0.33	0.27	N/A
Additional biomass (t/ha)	21.0	17.3	N/A

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