EVALUER LES IMPACTS ENVIRONNEMENTAUX DE SYSTEMES DE CULTURE POUR LA BIOECONOMIE AVEC L'ANALYSE DE CYCLE DE VIE

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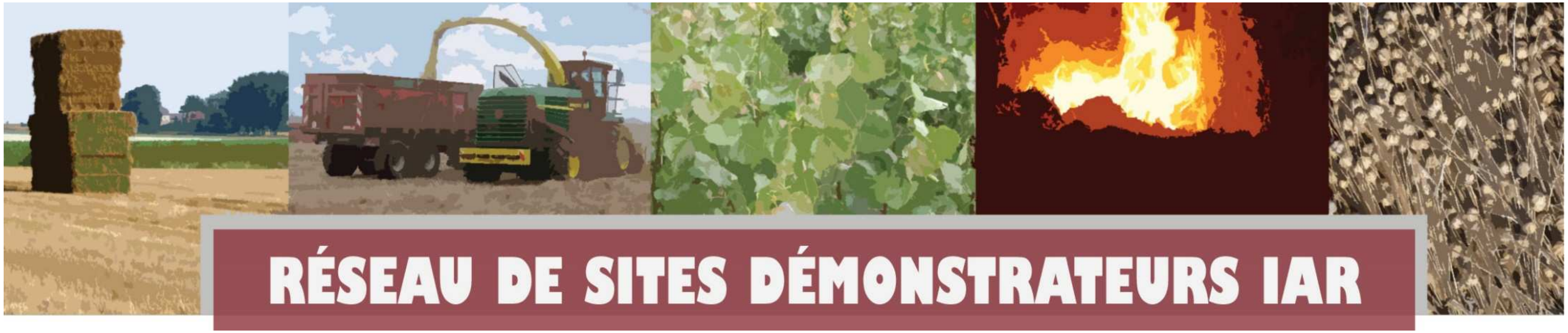
Résumé

La bioéconomie est basée sur l'utilisation de ressources biologiques renouvelables. Son développement dans le Nord de la France pourrait être contraint par le manque de connaissances à produire simultanément des cultures alimentaires et non-alimentaires variées pour alimenter ces filières, telles que le chanvre, la cameline ou les cultures dérobées. Ainsi, un des objectifs du projet "Réseau de sites démonstrateurs IAR" est de pouvoir donner aux agriculteurs et à leurs conseillers des clés pour modifier leurs systèmes de culture actuels, pour produire à la fois des cultures alimentaires et non-alimentaires, et ce de façon durable. Pour s'assurer de la durabilité de ces systèmes de culture innovants, leurs impacts environnementaux sont étudiés (émissions de gaz à effet de serre et consommations d'énergie) avec l'analyse de cycle de vie (ACV).

Dans cette étude, les systèmes de culture les plus courants du Nord de la France ont été sélectionnés (systèmes à base de pomme de terre, de betteraves et à base de céréales et oléo-protéagineux). Ils ont été déclinés en différents scenarios "bioéconomie" de façon à maximiser la production de biomasse et également la diversité de ces biomasses. La faisabilité de chaque scenario est testée sur des parcelles expérimentales, de façon à identifier les itinéraires techniques les plus adaptées. Plusieurs mesures expérimentales au champ sont réalisées pour collecter les données nécessaires au paramétrage et à la validation des modèles. Le changement climatique (méthode ILCD) et la consommation en énergie (méthode Cumulative Energy Demand) sont étudiés. Les impacts environnementaux de chaque scénario « bioéconomie » seront ensuite comparés à ceux des systèmes de culture actuels.

La limite du système est le champ sur lequel est cultivée la succession culturale sur plusieurs années. Concernant l'inventaire de cycle de vie, les émissions directes liées aux opérations culturales de chaque culture sont calculées avec le modèle de culture STICS. Les émissions et consommations d'énergie associées à la production des intrants sont collectées via la base de données Ecoinvent v3.3 et les émissions et besoins en énergie associés à la production des machines sont issues de la base de données Agribalyse. Le modèle AMG est utilisé pour simuler l'évolution de la quantité de carbone organique dans le sol sur la durée de la rotation, et sera déduit des émissions de carbone finales.

Evaluer les systèmes de culture avec l'ACV offre la possibilité d'identifier quelle opération culturale des scenarios « bioéconomie » est la plus émettrice en gaz à effet de serre et la plus consommatrice en énergie, comparativement aux systèmes de culture actuels. Il est ensuite possible d'optimiser les systèmes innovants proposés, de façon à ce qu'ils puissent être le plus productif tout en ayant des impacts environnementaux moindres.



Assessing environmental impacts of "Bioeconomy-oriented" cropping systems using Life Cycle Assessment (LCA) approach

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congrès [avniR]
Le Management en Cycle de Vie, la solution pour l'écotransition

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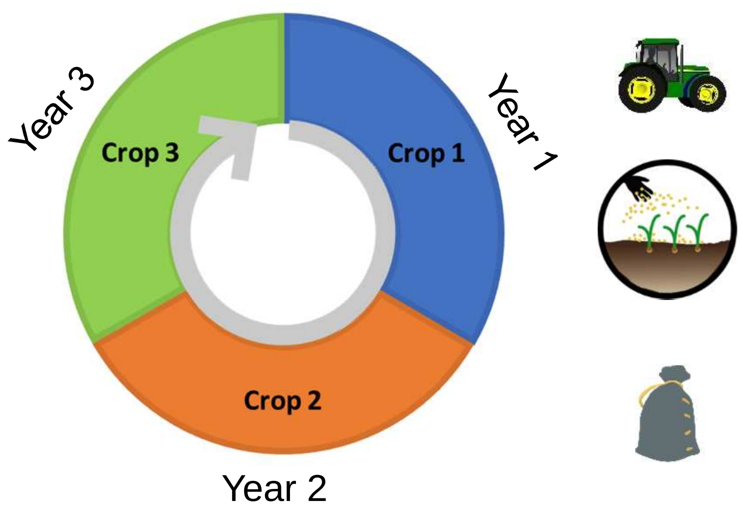
« Bioeconomy-oriented » cropping systems in Northern France

Cropping system



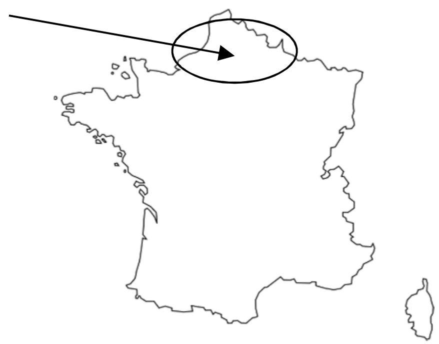
\+ **Bioeconomy**

each economical activity based on bio-resources (food AND non-food)

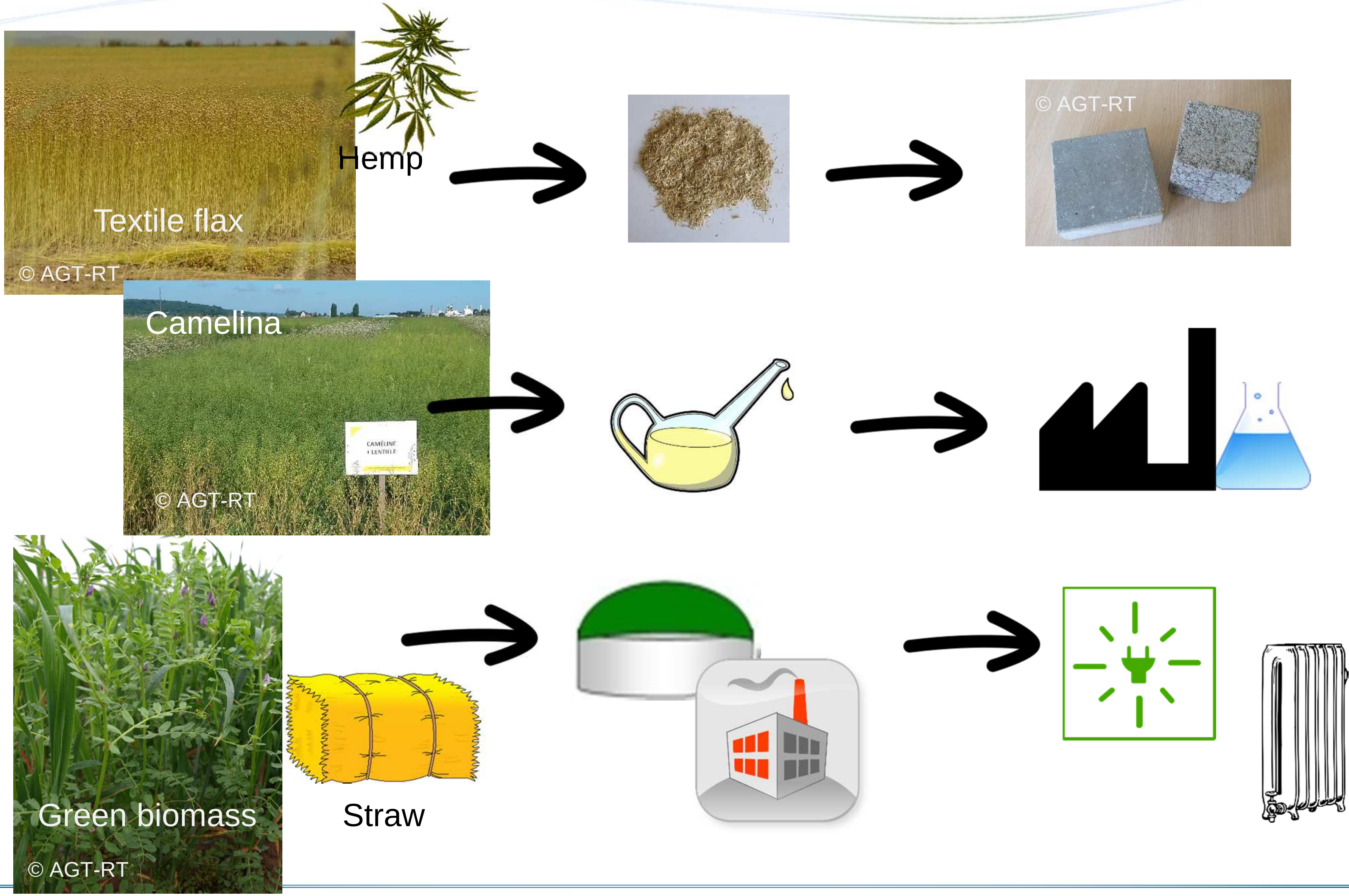
= « Bioeconomy-oriented » cropping systems

cropping systems that produce resources for the bioeconomy sectors

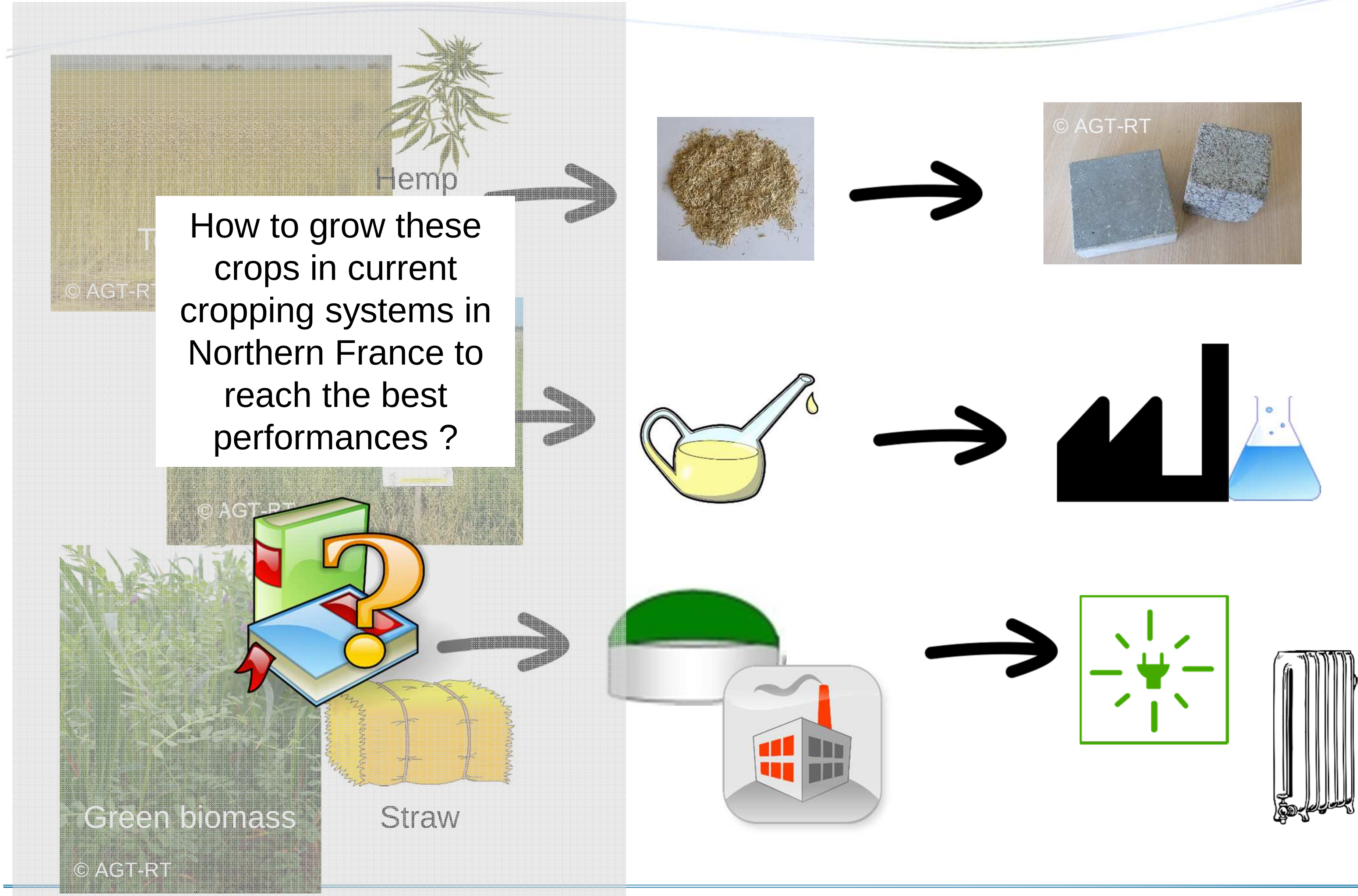
→ Great potential for bioeconomy development in Northern France



« Bioeconomy-oriented » cropping systems in Northern France



« Bioeconomy-oriented » cropping systems in Northern France



« Demonstrating sites network » project

2015-2020

Study and show the feasibility + performances + sustainability of "bioeconomy-oriented" cropping systems

Experimental site network

Environmental impacts of "bioeconomy-oriented" cropping systems compared to the current grown ones in the region

Agronomical keys to enhance the implementing of "bioeconomy oriented" cropping systems

Question and LCA methodology

What is the climate change impact of the “bioeconomy-oriented” cropping systems compared to the current grown ones in Northern France ?

❑ Studied indicators :

- Climate change impact using the ILCD method, Europe, JRC, 2012

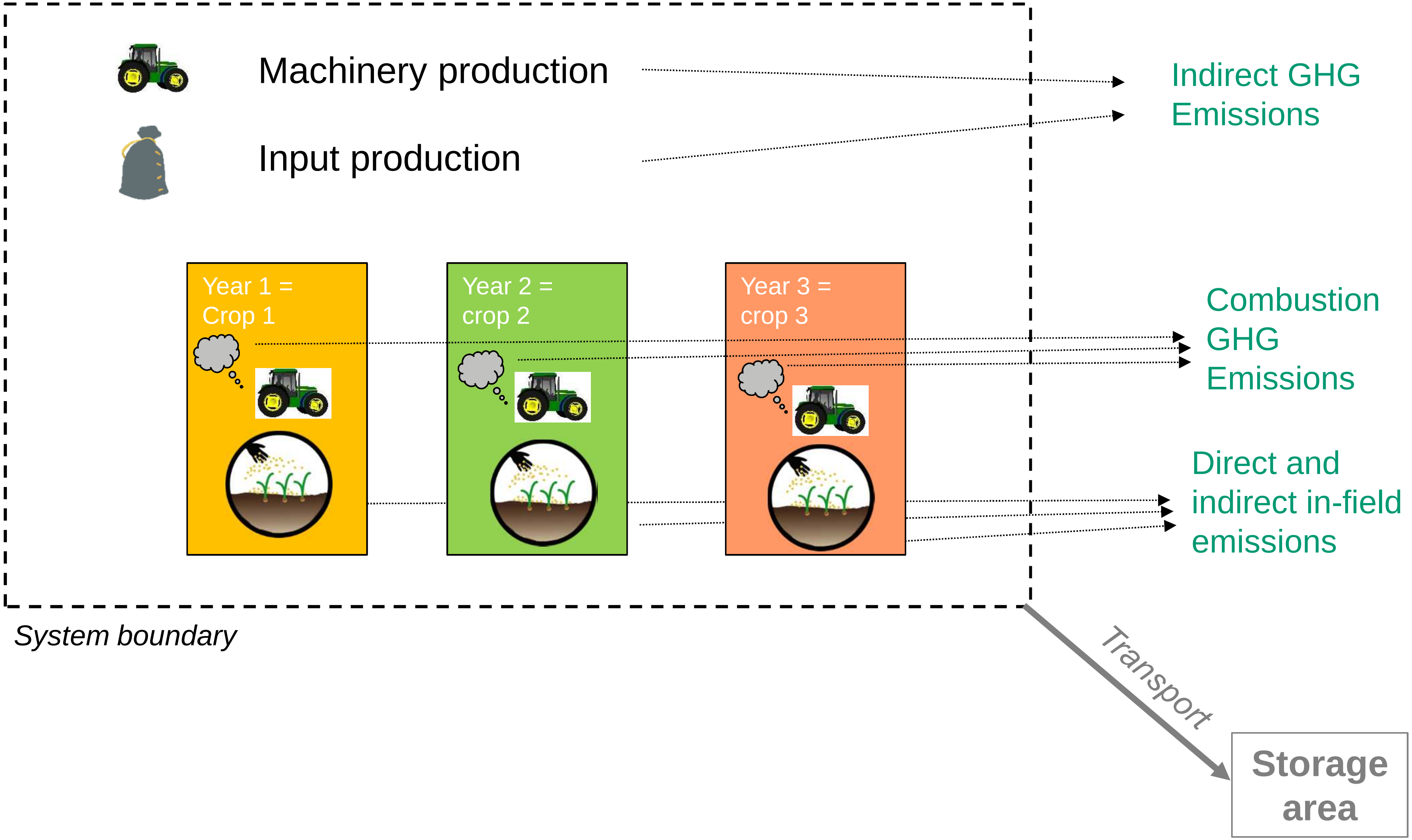
❑ Functional units :

- Production function : 1 ton of produced dry matter
- Land management function : 1 hectare of field used to grow the cropping system

❑ Life cycle inventory :

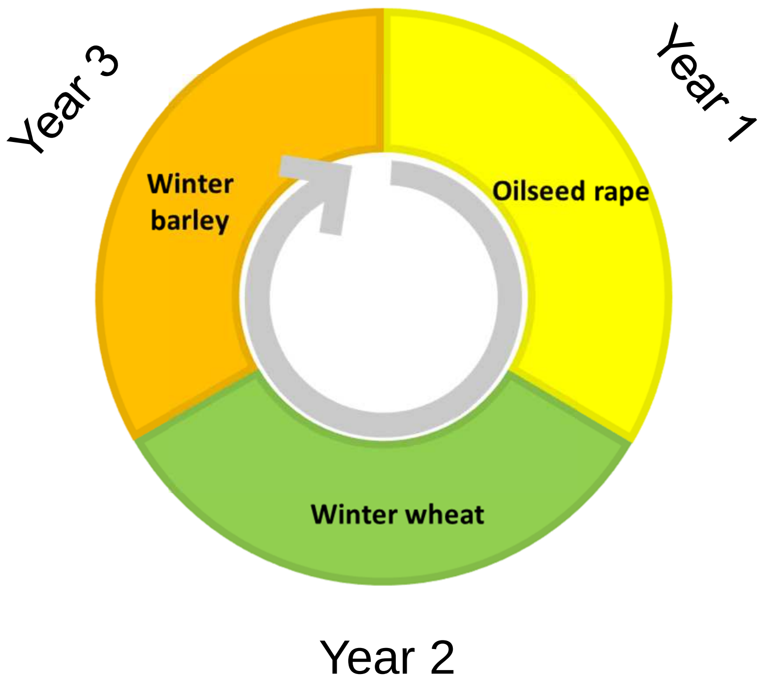
- Input and machinery production + fuel combustion : Ecoinvent v3.3 + Agribalyse databases
- Direct and indirect N_2O in-field emissions : IPCC tier 1, 2006 ; using data collecting on field experiments

Studied system for the LCA



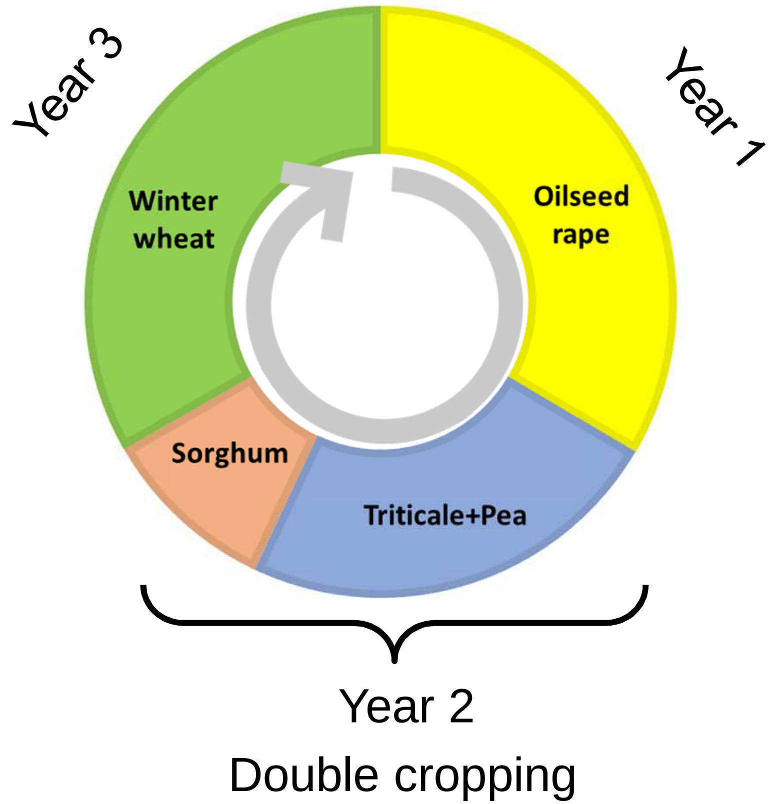
Compared systems

Current cropping system
= Reference
100 % food



vs.

« Bioeconomy-oriented » cropping system
2/3 food + 1/3 non-food

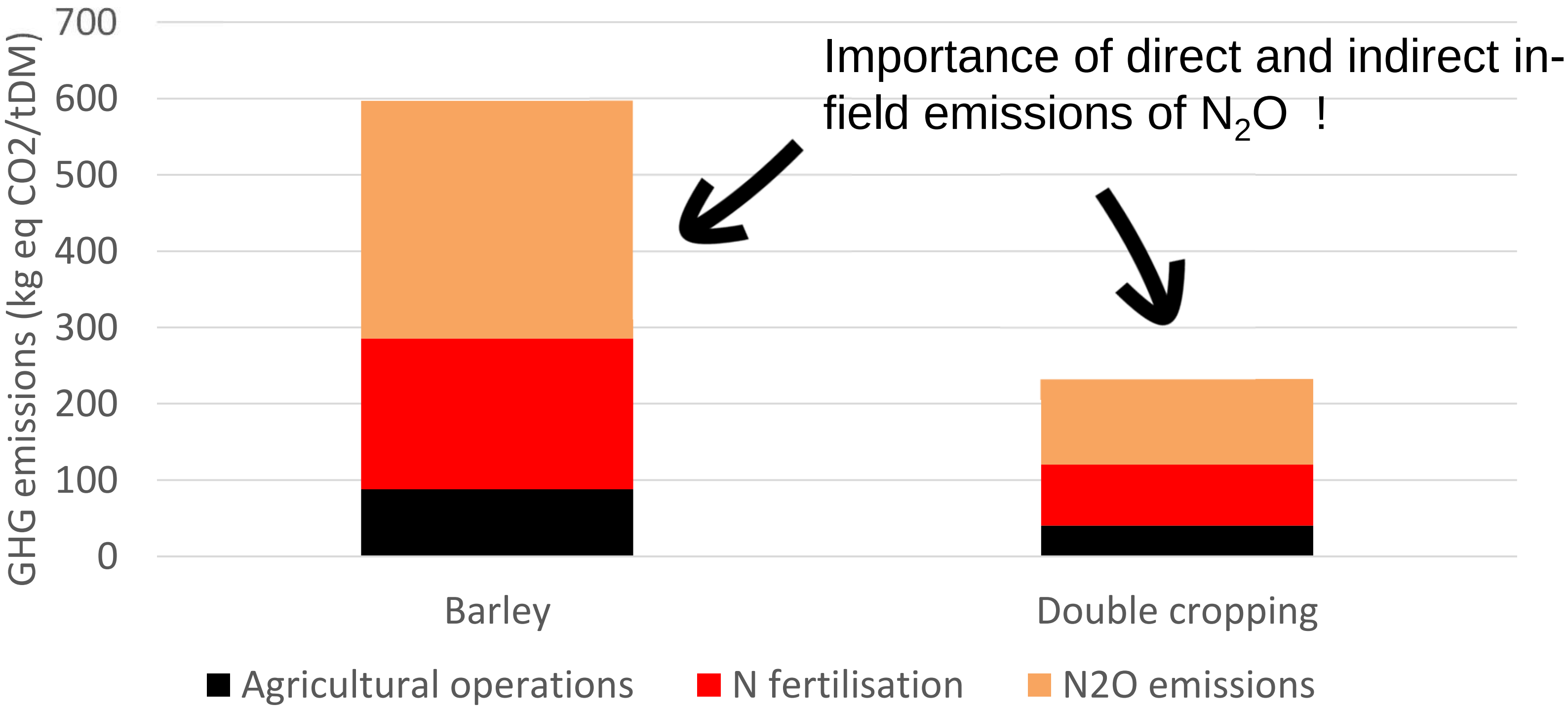


Barley vs. Double cropping

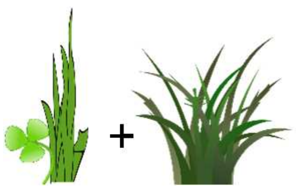
1 tDM

Barley vs. **Double cropping :**

597 > **233** kg eq CO2 / tDM



3,8 tDM/ha (grain)



10,3 + 5,5 = 15,8 tDM/ha

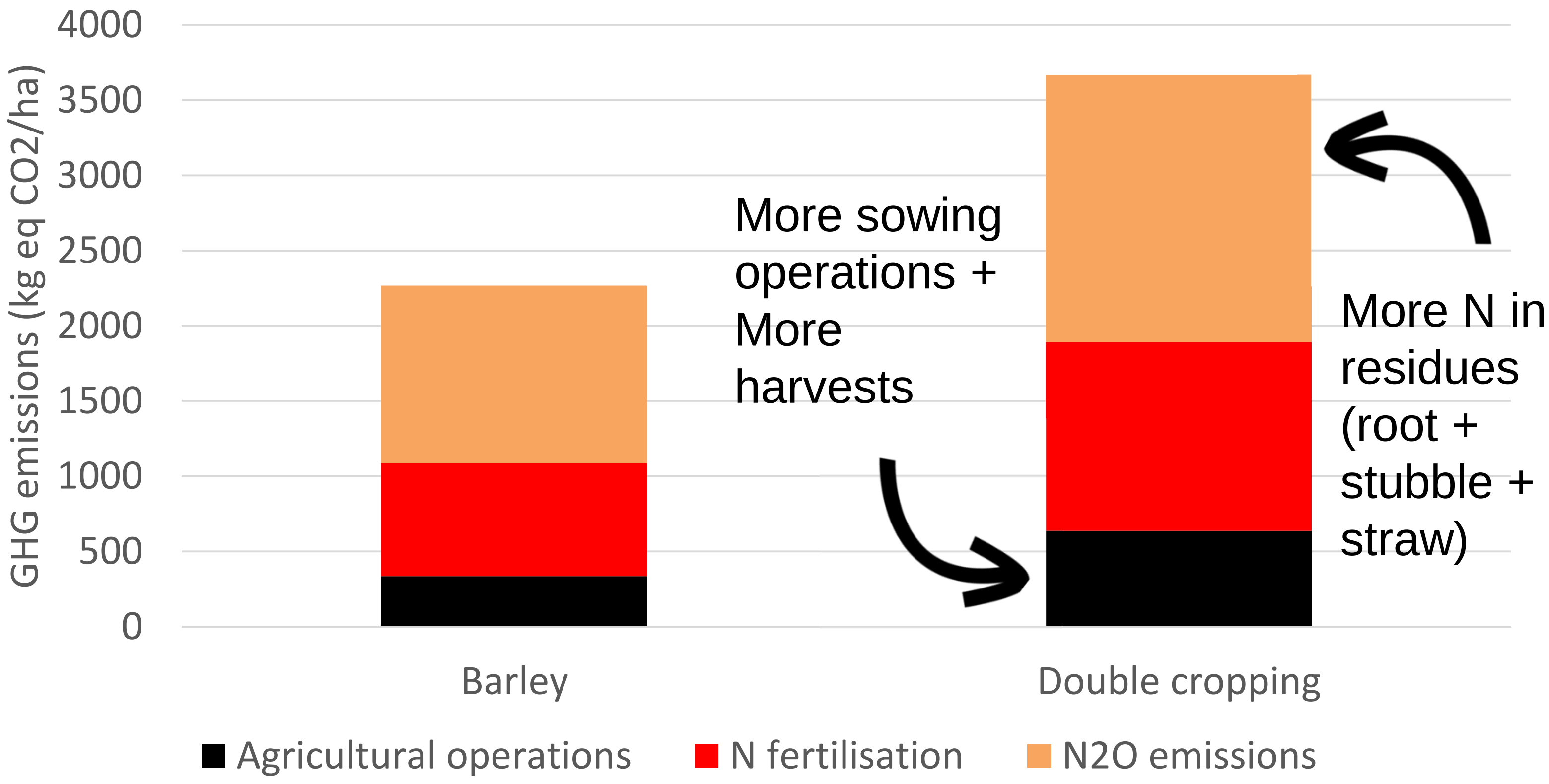
Barley vs. Double cropping

GHG/ha

1 ha

Barley vs. **Double cropping** :

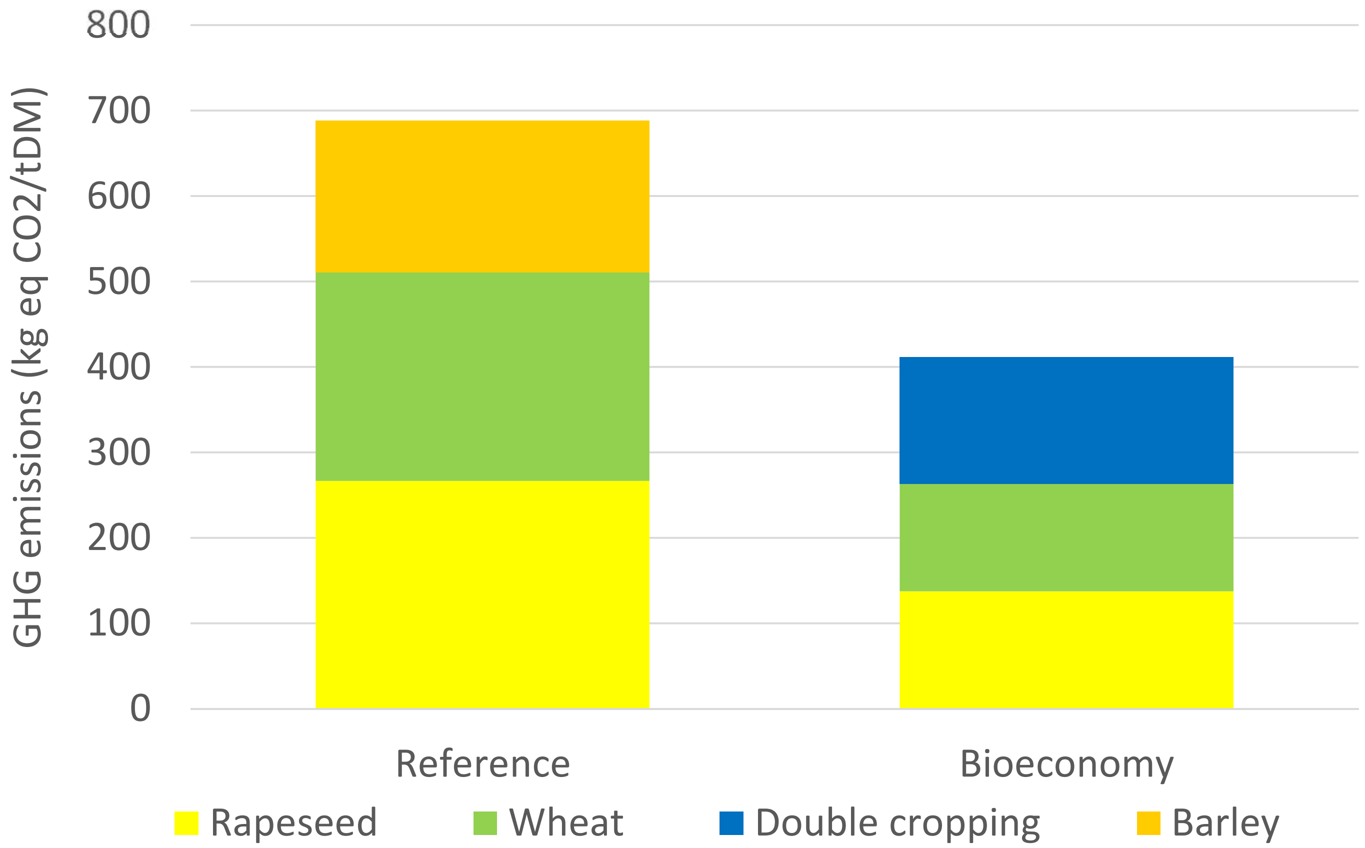
2267 < **3665** kg eq CO2 / ha



Cropping systems comparison

1 tDM

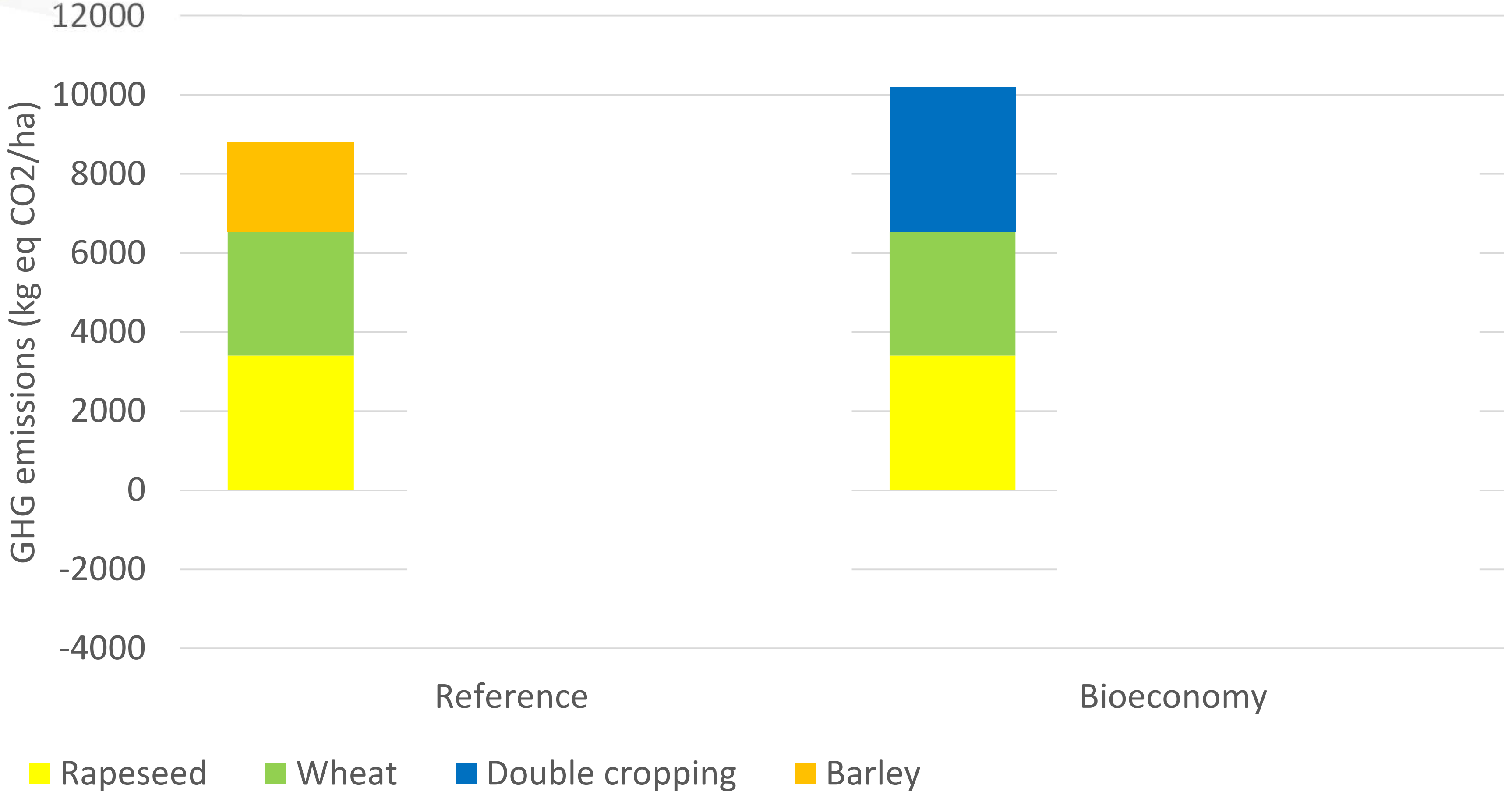
For 1 tDM of each system



Cropping systems comparison

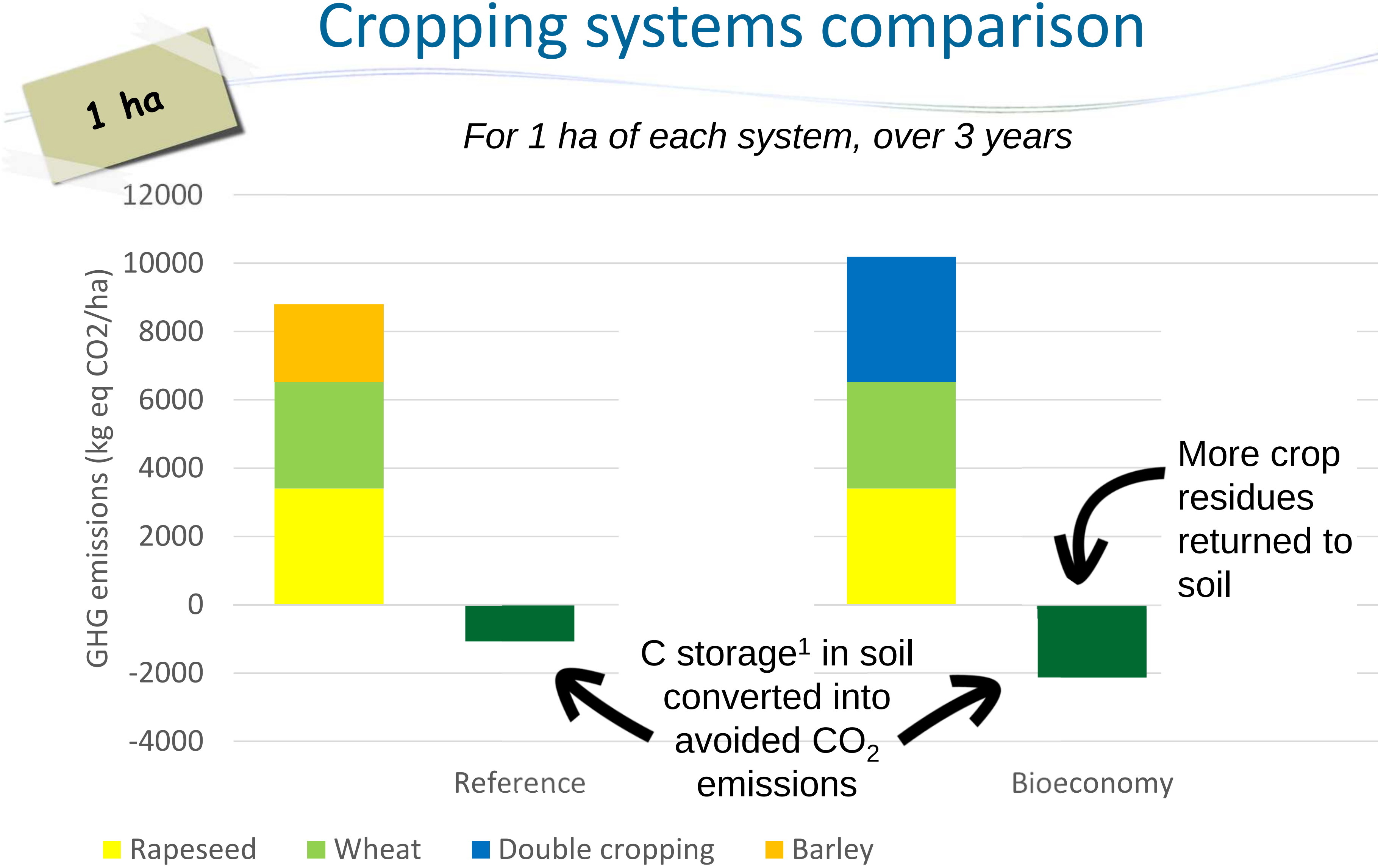
1 ha

For 1 ha of each system, over 3 years



Cropping systems comparison

For 1 ha of each system, over 3 years

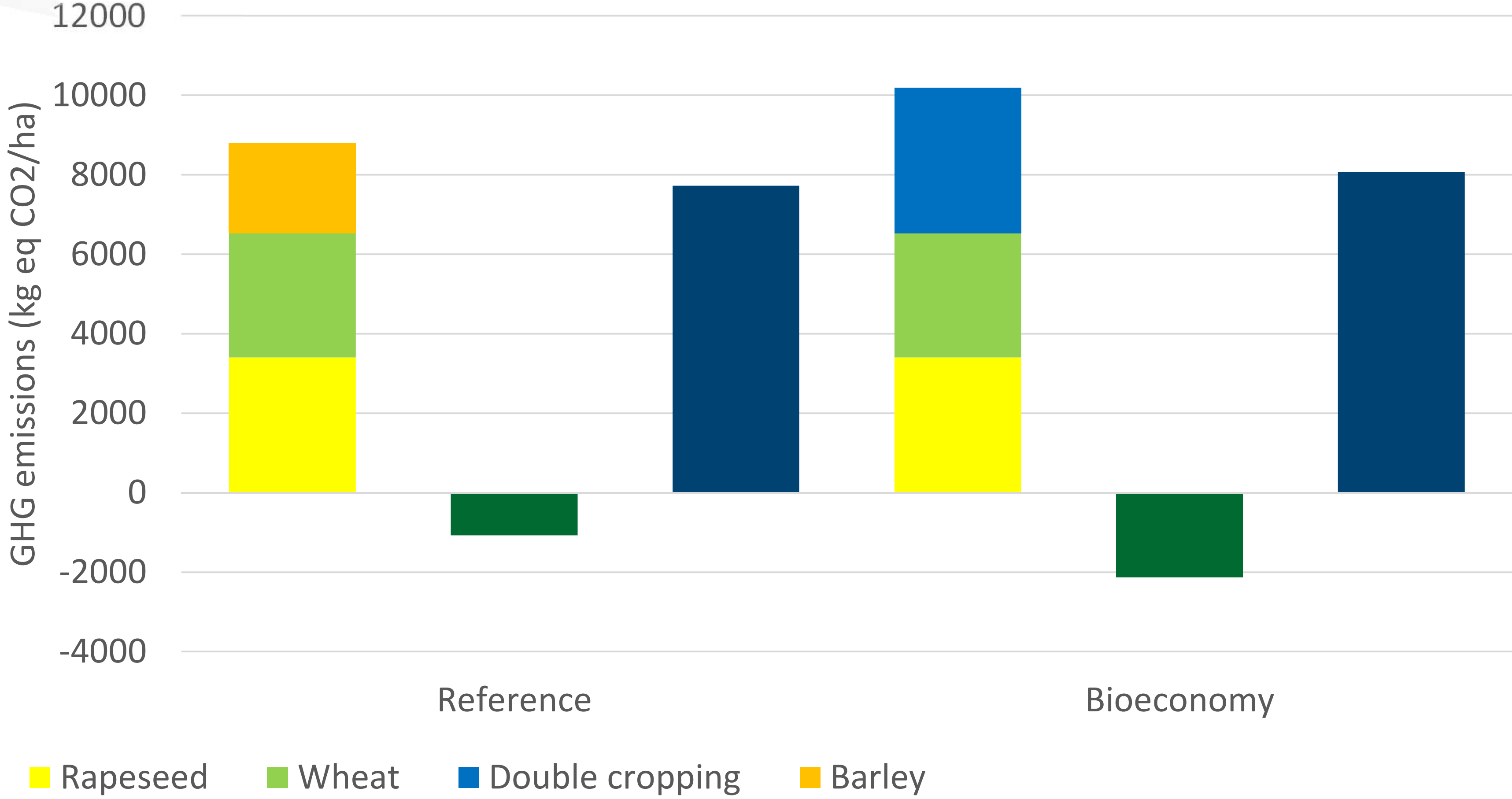


[1] Calculated with AMG model (Saffih-Hdadi & Mary, 2008)

Cropping systems comparison

1 ha

For 1 ha of each system, over 3 years



Conclusions and perspectives

- ✓ Different results obtained depending on the functional unit considered

- ✓ Nitrogen fertilization and N_2O emissions contribute a lot to GHG emissions

- ✓ These results can contribute to optimize environmental performances of the bioeconomy oriented systems

Thank you for your attention…

… and the whole project team !

ASSESSING ENVIRONMENTAL IMPACTS OF BIOECONOMY-ORIENTED CROPPING SYSTEMS USING LIFE CYCLE ASSESSMENT APPROACH

Abstract

Bioeconomy is based on the use of renewable biological resources. One restraint for its development in Northern France could be the lack of knowledge on simultaneously producing various food and non-food crops in current regional cropping systems to supply bioeconomy sectors, such as hemp, camelina or catch crops. One of the purposes of the project "Demonstrating Sites Network" ("Réseau de sites démonstrateurs IAR" in French) is thus to give to farmers and their advisers some agronomical keys to modify their current cropping systems to grow both food and a diversity of non-food crops in a sustainable way. In order to ensure sustainability of these innovative cropping systems, their environmental impacts (greenhouse gases emissions and energy consumptions) are studied using the life cycle assessment (LCA) method.

In this study, the most currently cultivated cropping systems in Northern France were selected (potato-, sugar beet- and cereal/oilseed-oriented systems). They were modified in several "bioeconomy" scenarios, in order to maximize biomass production, as well as the diversity of produced biomasses. The feasibility of each scenario is tested on experimental fields in order to find out the most adapted crop management of each crop in each system. Several field measurements are carried out in order to collect yield data as well as the necessary data for model parametrization and validation. Both climate change impact (using the ILCD method) and energy consumption (using the Cumulative Energy Demand method) are assessed in this study. The environmental impacts of each "bioeconomy" scenario will be compared to the ones of the current cropping systems.

The system boundary is the field on which the crop rotation is implemented over several years, but is does not entail the transport to the storage area. Concerning the life cycle inventory, the direct field emissions of each crop linked to crop management are calculated using the crop model STICS. The emissions and energy consumptions which are associated to the input production are collected from the Ecoinvent Database v3.3 and the emissions and energy need associated to machinery production are obtained from the Agribalyse Database. The AMG model is used to predict the amount of organic carbon stored during a crop rotation, which will be then deducted from the final carbon dioxide emissions.

To assess the cropping systems with the LCA method offers the possibility to identify which crop management operation in the "bioeconomy" scenario is the most greenhouse gases emitting and energy demanding one, compared to the current grown cropping systems. It is then possible to optimize the proposed innovative systems so that they can reach the highest biomass production with the lowest environmental impact.

Keywords

Bioeconomy, cropping system, greenhouse gas emissions, energy consumption, Northern France

INTRODUCTION

European commission defines bioeconomy as “the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy” [1]. These resources can have several origins: forestry, aquaculture, organic wastes from industry and agriculture. In this study, the focus is laid on following bioeconomy sectors: biogas production, bio-sourced materials, oil and sugar chemical industry. Food and non-food crops cultivated on the arable lands of Northern France could supply these sectors. However, one restraint for the development of the bioeconomy sectors in this region could be precisely the lack of knowledge on simultaneously producing various food and non-food crops in current regional cropping systems, such as for instance hemp, camelina, sorghum, as well as legumes and cereals associated catch crops.

One of the purposes of the project “Demonstrating sites network” (« Réseau de sites démonstrateurs IAR » in French) is thus to study and show the feasibility of the introduction of these crops in current crop rotations of the region. To do so, these systems are tested on experimental fields. The achieved results should give to farmers and their advisers more agronomical keys to enhance the implementing of “bioeconomy-oriented” cropping systems. These proposed cropping systems should not only be highly productive but also sustainable. Thus, their environmental impacts (especially greenhouse gas emissions and energy consumption) are studied using a life cycle assessment (LCA) approach and compared to the current grown ones in the region.

The project is carried out from 2015 to 2020. The current phase consists in defining methods and collecting data. This paper aims at presenting the methodology which is going to be implemented to assess the environmental impacts of the cropping systems, as well as the expected results.

METHODS

Studied cropping systems

A cropping system is defined as the combination of a crop succession and the crop management associated to it. In this study, the most currently cultivated cropping systems in the North of France were selected (potato-, sugar beet- and cereal/oilseed-oriented systems). They were modified in several scenarios, in order to maximize biomass production, as well as the diversity of produced biomasses. Moreover, the proposed systems should still produce food crops. Several “bioeconomy” scenarios with an increasing gradient of biomass production were designed for each current cropping system according to these specifications.

The used levers to increase biomass production were:

- the **exportation of straw** from oilseed rape and cereal crops,
- the introduction of **dedicated non-food crops** (hemp, camelina, …)
- the introduction of harvested **catch crops**.

Figure 1 shows an example of the possible modifications to create “bioeconomy oriented” cropping systems from the current grown cropping system (control system).

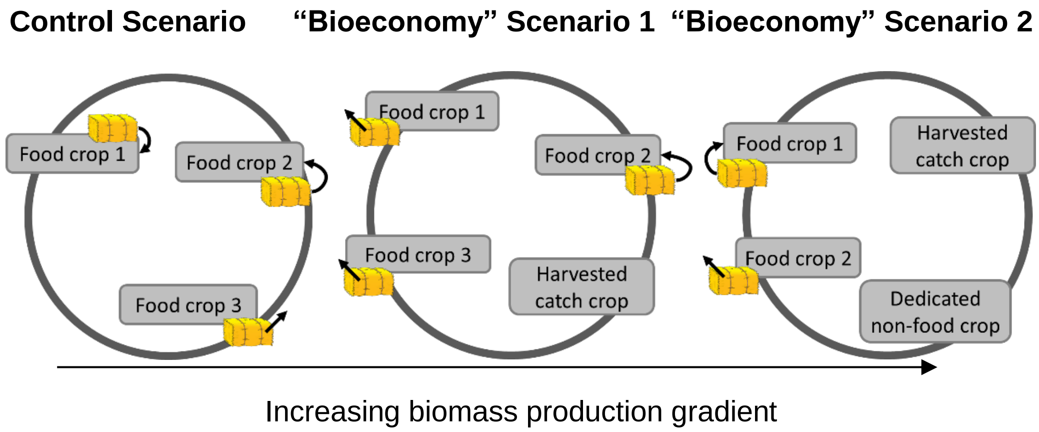


Figure 1: Example of the modification of the control scenario for the creation of the “bioeconomy” scenarios cropping systems (the small arrows symbolize the exportation or restitution or straw)

Experimental fields were laid out in different pedo-climatic contexts in order to test the feasibility of each proposed scenario and to find out the most adapted crop management of each cop in each system. Several field measurements are carried out during the cropping seasons in order to collect yield data, as well as the necessary data for model parametrization (soil parameters such as clay content or soil depth) and validation (e.g. biomass production, soil water and nitrogen content).

LCA methodology

In this study, the main function of the system is biomass production. Thus, the corresponding functional unit is the dry matter weight produced by one hectare of the cropping system. However, to consider only this unit would not be representative of all the potential functions of an agricultural field. Nemecek et al. [2] suggested also to include the “land management” and the “financial” functions. Thus, the environmental impacts of each cropping system are studied with the three corresponding functional units: the ton of produced dry matter, the hectare.year, and the gross margin of one hectare.

An allocation is necessary for cereal and oilseed rape straws in systems where the co-product is harvested. In these cases, two types of allocation will be carried out: an economic allocation and an allocation using the construction cost of plant compounds, which takes account for the different amount of energy needed by the plant to produce different kind of biomass, as proposed by van der Werf et. al [3].

The system boundary is the field and the crop rotation of one cropping system. It entails all crop management operations as well as the production of machinery equipment and inputs (fertilizers, phytosanitary products, seeds) required to achieve the crop production. However, the transport of the product to the storage area is not considered (see figure 2).

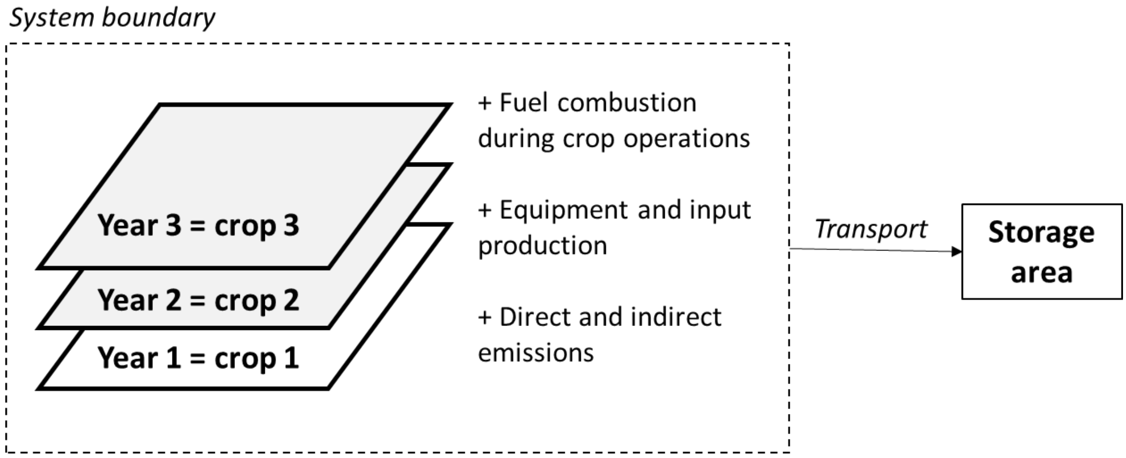


Figure 2: System boundary for the LCA of the cropping systems

Both climate change impact (using the ILCD method [4]) and energy consumption (using the Cumulative Energy Demand method [5]) are assessed in this study. Indeed, nitrogen management is expected to be one of the most important GHG emission contributor, and energy consuming factor in cropping systems [6], caused among others by nitrous oxide emissions during this operation. It was then assumed that these two indicators would be the most interesting in order to propose improvement of nitrogen management of cropping systems to farmers and their advisers.

Life cycle Inventories

The direct nitrogen-based field losses and emissions (ammonia and nitrous oxide gaseous emissions and nitrate leaching) of each crop are calculated using the crop model STICS [7], which simulates crop growth and associated water and nitrogen balances. The model simulations are validated with data collected on field experimentations. The effect of the preceding crops and of the catch crops is taken into account in the model simulations. The AMG model [8] is used to predict the amount of soil organic carbon stored during a crop rotation. The stored organic carbon will be then deducted from the final carbon dioxide emissions.

The emissions and energy consumptions which are associated to the input production are collected from the Ecoinvent Database v3.3 [9] and the emissions and energy need associated to machinery production are obtained from the Agribalyse Database [10]. The fuel consumption of each agricultural operation is calculated using the GES'TIM method [11].

EXPECTED RESULTS AND CONCLUSIONS

The environmental impacts of the "bioeconomy" systems will be compared to the ones of the "control" systems, currently grown in Northern France. As the LCA is an integrative method for the assessment of environmental impacts of cropping systems, it offers the possibility to identify which crop management operation is the most greenhouse gas emitting and energy demanding one, and thus to optimize the proposed innovative systems so that they can reach the highest biomass production with the lowest environmental impact. These conclusions will give farmers and their advisers some agronomical keys to modify their current cropping systems to grow both food and a diversity of non-food crops in a sustainable way, to supply bioeconomy sectors. Some results expectations can already be presented.

As the main objective of the tested cropping systems is to maximize the total biomass production of grain, straw, fresh matter, roots and tubers, no restriction is made on fertilization, which is conventionally managed. Thus, it is expected that nitrogen fertilization will be an important factor of greenhouse gases emissions, as already found in the study of Nemecek et al. [6].

Moreover, as already observed by Deytieux et al. [12] by studying the environmental impacts of differently managed cropping systems, different results are expected when the results are expressed with the different functional units. In the "bioeconomy" scenarios, the greenhouse gases emissions and energy consumptions will probably be lower per unit of produced dry matter than per unit of cultivated hectare, as we expect a higher dry matter production in the proposed systems. If those results are confirmed, it could be interesting to consider the potential number of hectares that would be concerned by these "bioeconomy" cropping systems, in order to see at the regional scale whether an increase of environmental impacts would be acceptable.

ACKNOWLEDGEMENTS

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