UTILISER L'ACV POUR CONCEVOIR DES FILIERES LOCALES D'APPROVISONNEMENT EN BIOMASSE : L'EXEMPLE DE L'APPROVISIONNEMENT EN PLAQUETTE BOIS DE CHAUDIERES

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Intégrer des enjeux alimentaires et environnementaux dans la conception des stratégies agricoles peut être un moyen pour y répondre. Le monde agricole doit produire une alimentation de qualité, en quantité suffisante et participer en parallèle à l'approvisionnement de filières non-alimentaires et tout en limitant ses impacts sur l'environnement. La Picardie se caractérise par un secteur agricole très développé, au sein duquel les organismes de recherche et développement sont actifs et sources d'innovations. Une réelle dynamique est présente dans cette région autour de la production et de la mobilisation de biomasse destinée à une valorisation non-alimentaire. Le projet « Réseau de sites démonstrateurs IAR » s'intègre dans cette dynamique puisque son principal objectif est de développer une démarche d'accompagnement permettant de faciliter le développement de filières biomasse à valorisation non-alimentaire. Cette approche est partiellement basée sur l'évaluation multicritères de scénarios d'approvisionnement de biomasse où les aspects environnementaux, agronomiques, économiques et organisationnels sont évalués.

La présente étude se concentre sur l'évaluation environnementale menée dans le cadre du projet et se base sur l'étude de cas d'une coopérative diversifiant ses activités via la commercialisation de plaquettes à destination de chaudières. Actuellement, la filière d'approvisionnement se compose exclusivement de produits forestiers mais la coopérative cherche à diversifier et sécuriser ses sources d'approvisionnement avec de la biomasse agricole. Des sources de biomasse agricoles ont donc été identifiés en considérant (i) les conditions pédoclimatiques du territoire, (ii) la nécessité de conserver, dans les exploitations agricoles, les cultures à haute valeur ajoutée déjà présentes, et (iii) les caractéristiques de combustion des chaudières. Trois scénarios basés sur trois cultures pérennes (miscanthus, TtCr de saules et TCR de peuplier) correspondent à ces critères.

Afin de déterminer le scénario ayant le moins d'impacts sur l'environnement, et d'aider la coopérative à concevoir son approvisionnement, une Analyse de Cycle de Vie (ACV) est réalisée. Ces scénarios sont comparés à une référence, qui correspond à un approvisionnement uniquement basé sur des produits forestiers. Les frontières du système s'étendent de la production des ressources agricoles ou forestières jusqu'aux portes des chaudières considérées. L'unité fonctionnelle est 1 MWh potentiel d'énergie produite. L'ACV permettra d'étudier des impacts environnementaux typiques (acidification, consommation d'énergie, etc.). Un focus est réalisé sur le changement climatique puisque les cultures pérennes sont caractérisées par une capacité de stockage de carbone importante, ce qui devrait permettre de compenser en partie les émissions de GES du système. De plus, les résultats de l'ACV permettront également aux acteurs de la coopérative et aux agriculteurs de pouvoir élaborer ou modifier leurs scénarios d'approvisionnement en considérant l'impact des étapes de broyage, stockage, transport et la localisation des ressources agricoles sur la zone d'approvisionnement.

Mots-clés

Bioéconomie, filières d'approvisionnement, plaquettes de bois, ACV

RÉSEAU DE SITES DÉMONSTRATEURS IAR

THE USE OF LCA TO DESIGN LOCAL AGRICULTURAL FEEDSTOCK SUPPLY CHAINS: THE EXAMPLE OF WOOD CHIP BOILERS SUPPLY

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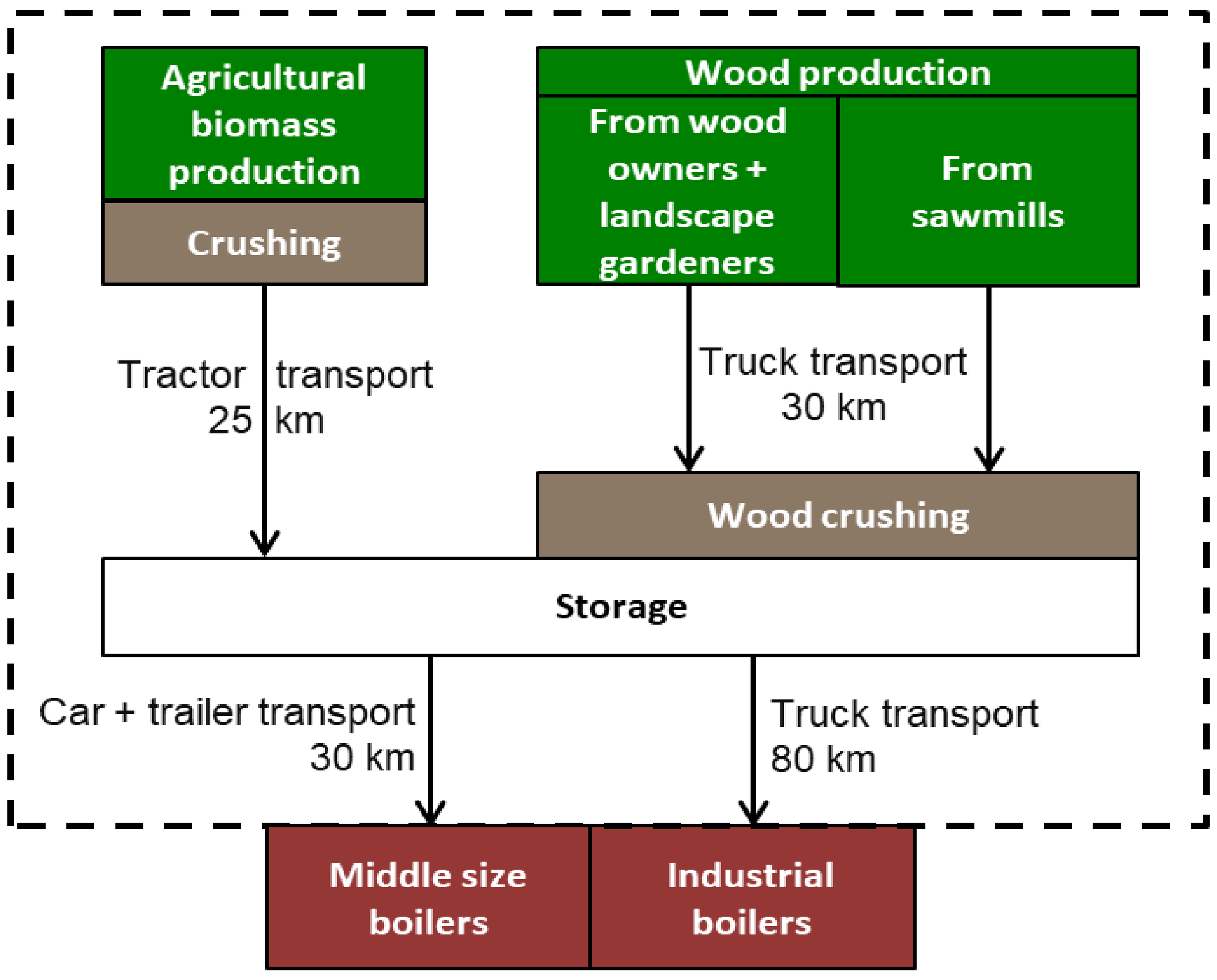
Introduction

The "Demonstrating Sites Network" aims at developing an approach to support the creation of biomass supply chains dedicated to non-food valorisations. An environmental evaluation was led on the case study of a cereal cooperative diversifying its activities into commercialization of chips for boilers. Chips are currently supplied by wood sector and the cooperative wishes to complement it by incorporating agricultural resources and has to choose between several feedstocks: miscanthus, poplar short rotation coppice (SRC) and willow SRC. They were combined with wood chips in three supply scenarios. To determine which scenario has the least environmental impacts, a LCA was achieved. Scenarios were compared to the current supply chain only based on wood chips.

Method

LCA system boundaries of the LCA



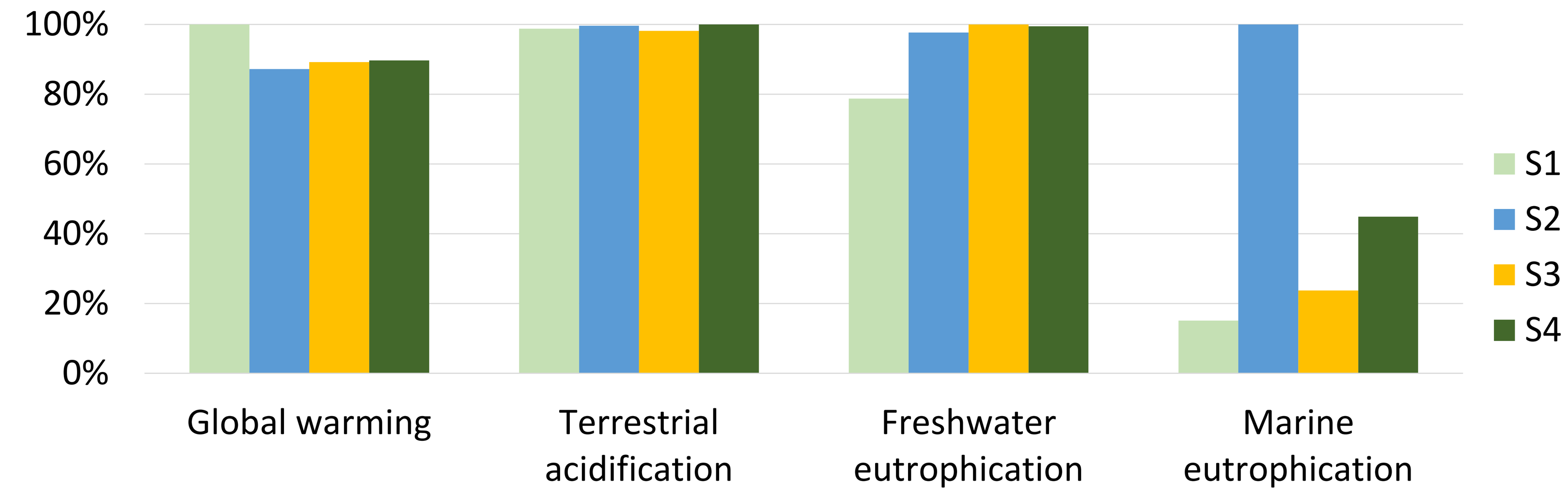
Supply scenario	% of wood chips	% of agricultural biomass
S_1	100 %	0 %
S_2	92 %	8 % Miscanthus
S_3	93 %	7 % poplar SRC
S_4	93 %	7 % willow SRC

Data sources		
Agricultural inputs	Agribalyse database, bibliography (Savouré et al., 2014)	
Other inputs	EcoInvent database (v 3.3)	
Direct emissions to air, water, soil	IPCC, 2006 (direct and indirect N_2O), Nemecek et al, 2015 (NH_3, NO_x, NO_3^-), Nemecek and Schnetzer, 2011 (P_2O_5)	
Soil carbon potential sequestration	Miscanthus Brandao et al, 2011, Clifton-Brown et al, 2007	Poplar and willow SRC Brandao et al, 2011, Hillier et al, 2009
	(main bibliography sources)	

Results

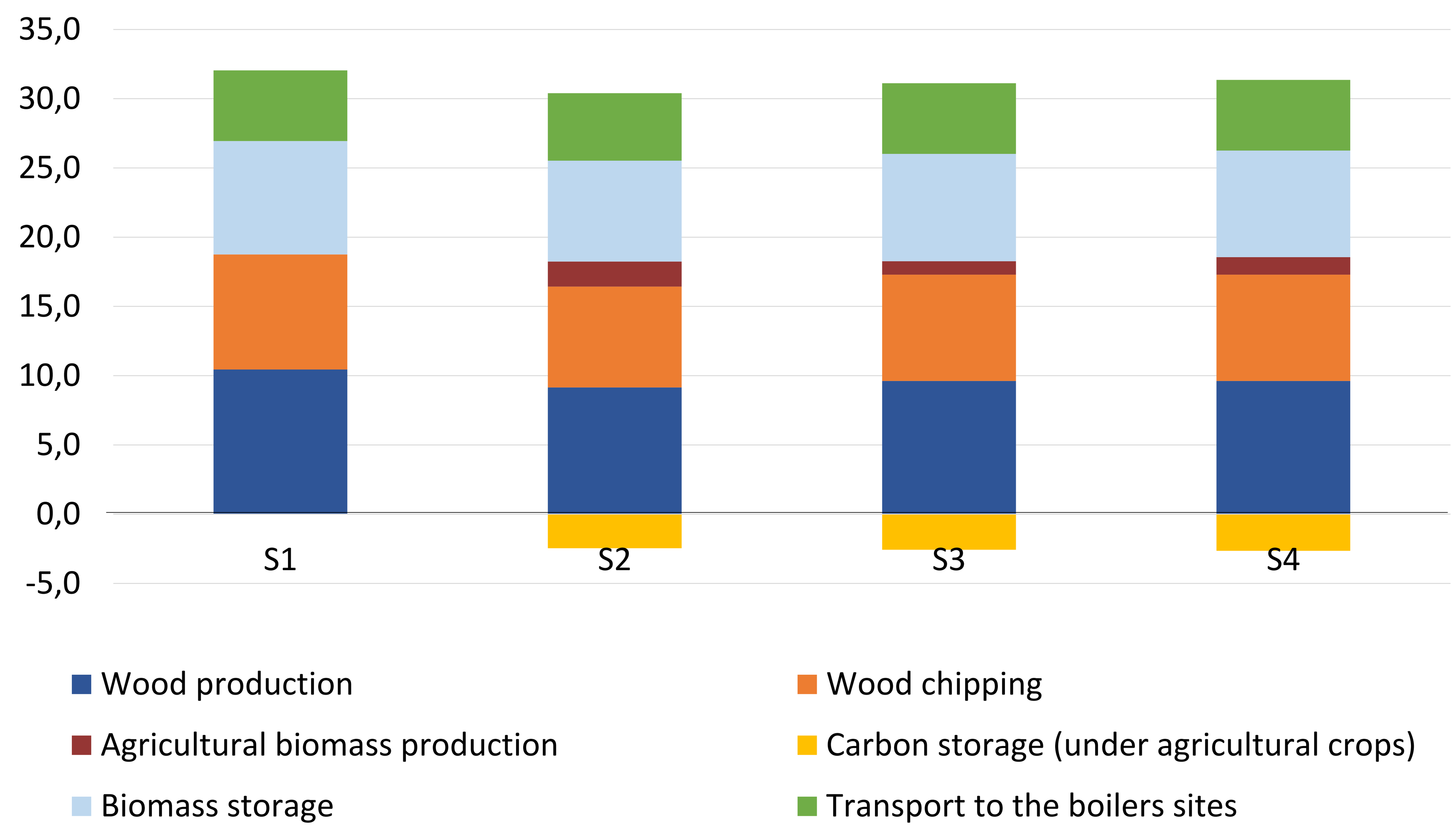
(ReCiPe Midpoint (H) 2008 V1.13)

Environmental analysis of the four supply scenarios for 1 potentially produced MWh (%)



- Terrestrial acidification is very similar in all the scenarios: wood chipping stage is the main source of acidifying molecules emissions, and wood represents more than 90 % of each supply scenario.
- Freshwater eutrophication is mainly caused by phosphorus erosion, similarly found in each scenario. Additional emissions in S2, S3 and S4 scenarios are caused by crop phosphate fertilisation.
- Marine eutrophication deeply depends on nitrogen fertilisation of agricultural crops, explaining particularly high impact level for Miscanthus.

Environmental contribution of each supply scenario to climate change indicator for 1 potentially produced MWh (kg CO_2 eq.)



- Carbon sequestration in soil under agricultural crops mitigates crop production GHG emissions.

Conclusion

LCA results show introducing agricultural biomass in supplies leads to an increase of environmental impacts except global warming indicator, as it integrates soil carbon storage. However, scenarios with willow and poplar SRC (S3 and S4) are less impacting than the one with miscanthus (S2), particularly on marine eutrophication. For a full comparison between scenarios with agricultural supply, an economic study on the return on investment of each considered agricultural crop will be led.

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It is led by Agro-Transfert Ressources et Territoires in partnership with scientists and technical actors as well as actors from the industrial sector.

THE USE OF LCA TO DESIGN LOCAL AGRICULTURAL FEEDSTOCK SUPPLY CHAINS: THE EXAMPLE OF WOOD CHIPS BOILERS SUPPLY

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Abstract
Current food and environmental global stakes have a direct impact on agricultural strategies. Thus agriculture has to produce healthy food in a sufficient way and at the same time to participate to renewable resources production (for chemistry or energy for example), both accounting for the urgent need to reduce negative environmental impacts due to those productions.

Northern France is a region where agriculture is an important sector and thus where research and agricultural innovations are productive and efficient. Recently, a dynamic was set up around the energetic biomass production and mobilization stake. The "Demonstrating Sites Network" project is completely integrated in this dynamic since one of its goals is to develop a support approach allowing facilitating the creation of biomass supply chains dedicated to non-food valorisations. A part of this approach is based on a multi-criteria evaluation of biomass supply chains where environmental, agronomic, economic and organizational characteristics are studied.

This paper focuses on the environmental evaluation led in the project and on the study case of a cereal cooperative diversifying its activities with chips commercialization to boilers. The actual chips supply chain is based on wood products. Here, agricultural resources which could complete wood supply chain were identified while considering (i) its soil and climate growth conditions, (ii) the necessity to preserve the existing high-value-added food crops and (iii) combustion boilers characteristics. Three scenarios based on three perennial crops (miscanthus, poplar and willow Short Rotation Coppice - SRC -) correspond to these criteria.

In addition, to determine which scenario has the least environmental impacts and to help the cooperative to improve the other ones, a life cycle assessment (LCA) was achieved. They will be compared to a reference one, which correspond to the current supply chain only based on wood products. System boundaries will stretch from agricultural and wood productions to the gate of the valorisation areas. Functional unit will be 1 potential MWh of produced energy.

LCA will allow the study of typical environmental impacts (acidification, energy consumption, etc.), and a focus will be made on climate change. Indeed, perennial crops are characterized by an important capacity of carbon sequestration. We attend so GHG emissions are partly compensated by soil CO2 sequestration. Moreover, the LCA results will allow the cooperative managers and the farmers to decide the best suitable combination of biomass supply by choosing and adapting the crushing, storage and transport devices, as well as biomass crop location within the supply area.

Keywords
Bio-economy, supply chains, wood chips, LCA

1. INTRODUCTION

European commission defines the 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]. This definition points out the importance of the biological resources to insure the bioeconomy productions. These resources can have different origins: forestry, aquaculture, organic waste from industry and, of course, agriculture.
In order to provide local non-food supply chains with local feedstock, equal or lower environmental impacts are expected from the supply chains to be designed. This paper focuses on the use of life cycle assessment (LCA) to design local non-food agricultural biomass supply chains. This approach was developed in our current R&D project called “Demonstrating Sites Network” (Réseau de sites démonstrateurs IAR - in French). It is conducted by Agro-Transfert Ressources et Territoires in partnership with scientists and technique actors as well as actors from the industrial sector. This project aims at developing an approach to help local actors to design and implement an agricultural supply for their local project of bioeconomy value-creation.

2. LCA TO HELP DECISION MAKING ON AGRICULTURAL FEEDSTOCK SUPPLY CHAINS

Production and mobilization (i.e. pre-processing treatments, transport and storage) of agricultural feedstock are key stakes for the local supply chain actors:

- For industrials, the challenge is to get access to enough resources in conformity with their bill of specifications.
- For farmers, the aim is to supply industrials with new resources in conformity with their specifications while keeping their income and preserving environment.
- For local public actors, the stake is to create positive conditions to setting up of supply chains on their territories in order to maintain or create local activities as well as maintaining the environment.

In order to give decision-making factor to the industrial, the first task in the conception of the supply is to identify all resources in conformity with the bill of specifications of the project promoter and which can be produced and mobilized on the area. The second step is to compare these resources amongst themselves in order to determine the most adapted supply. To do so, four kinds of indicators, estimated with an *ex-ante* evaluation, are used: they are economic, agronomic, organizational and environmental indicators.

LCA is a holistic approach that is adapted to assess environmental impacts of non-food supply chains, whether at regional [2] or local [3] scale. Indeed by analyzing each step of the supply chain, it provides the contribution of each step to each environmental indicator. By doing so, it also delivers environmental impacts that help each actors’ concern. For supply-chain managers (collecting services), the weight of storage and transport steps compared to other ones are analyzed, and which area provides the least impacting production. For farmers and their advisors, it gives the environmental burden at the field production step and the crop management practices they can improve. Indeed the environmental impacts that are assessed are complementary from usual agronomical constraints (pedo-climatic, cropping techniques).

The Demonstrating sites network project is based on three pilot areas in which agricultural resources are needed to supply industrial activities already settled or which will be established soon. As underlined by [4] for biomass crop location, the collection of detailed data on supply chains is central to improve their environmental assessment. Hence, the paper focuses on the case of wood chips boilers network that are completed by agricultural resources.

3. EXAMPLE OF WOOD CHIPS SUPPLY CHAINS

3.1. Supply chain and feedstock characteristics

Located in Northern France, the studied supply area corresponds to the one of a local cereal cooperative that diversified its activities by commercializing wood chips for feeding municipalities and particular boilers. Wood chips supplies come from different sources (wood owners, sawmills and landscape gardeners) but partly remain based on an opportunity market. This means some contracts are annuals and cannot be transferred from a campaign to the next one. On the other hand, the cooperative is bound to several customers by contracts and has to supply determined tonnage of wood chips each year. Hence, the cooperative has to achieve the security of its chips supplies with agricultural resources.

To reach this goal, candidate crops were searched among crops that are both cultivable under Northern France meteorological and soil conditions, and suitable combustible for boilers. Hence three different agricultural energetic crops were selected: miscanthus, poplar short rotation coppice (SRC) and willow SRC. In order to maintain boilers energetic performances, these agricultural resources had to be associated with wood chips to match bills of specification of the boilers considered in the project [5].

Three scenarios were set up and validated with the cooperative. They are presented in Table 1. In addition, the situation without project, i.e. if the cooperative would continue with its current wood supplies, is also studied, as the reference wood scenario.

Table 1: Feedstock supply scenarios studied

SUPPLY SCENARIO	PERCENTAGE OF WOOD CHIPS	PERCENTAGE OF COMPLEMENTARY BIOMASS
Wood	100% wood chips	0%
Miscanthus	93% wood chips	7% Miscanthus
Poplar SRC	93% wood chips	7% poplar SRC
Willow SRC	93% wood chips	7% willow SRC

3.2. LCA framework

On this supply area, analysis with LCA method allows us to compare the scenarios according to their environmental impacts.

System boundaries stretch from the agricultural production to the gate of the boiler, as presented in Figure 1.

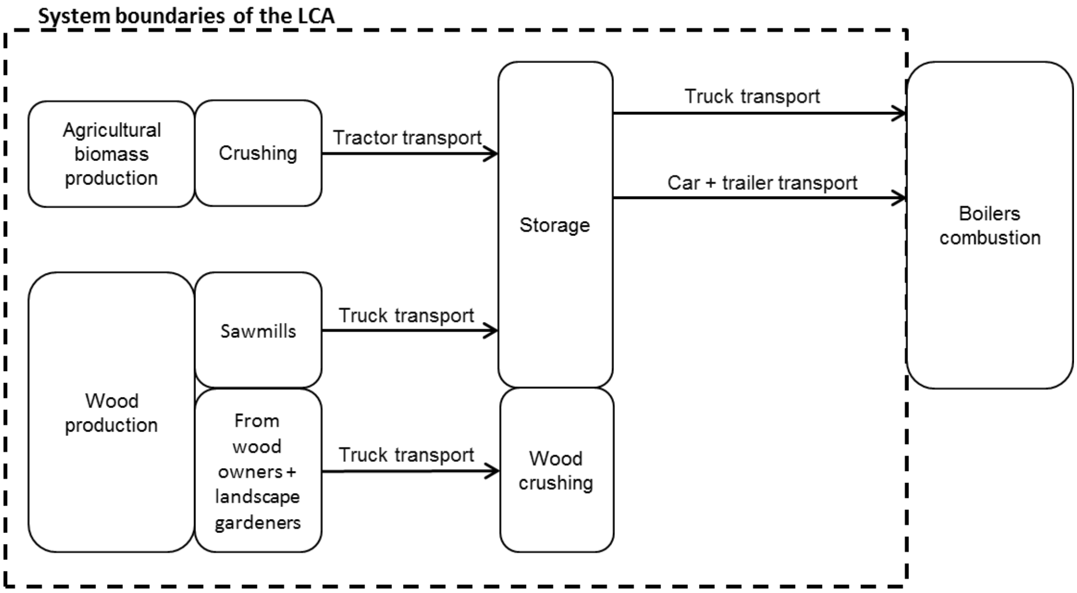

Figure 1: System boundaries of the studied supply area

Agricultural biomass was supposed produced within a radius of 25 km around boilers. It was harvested with agricultural materials allowing biomass crushing while harvesting. Agricultural chips are then transported by tractor to the storage place.

Similarly, wood biomass was produced within a radius of 30 km around boilers locations. Wood supplies were distinguished as follow: i/ from sawmills, wood chips were already crushed, ii/ from forest owners and landscape gardeners, wood trunks were available. For both cases, a truck transported wood production to the storage place. Wood trunk crushing happened then at the storage place.

Agricultural and wood chips were stored for 6 to 12 months on the platform before being transported to the boilers. In municipalities' case, chips were directly delivered by truck to the boilers, but particulars came and pick their chips up from the storage platform with their own vehicle and trailer.

For each one of these operations, inputs (energy and fuel consumptions, fertilizers, pesticides and consumables, etc.) and outputs (emissions to air, water and soil) involved in the system were quantified. Infrastructures used in the various processes were also taken into account.

The function of the system was the boilers' supply. The selected functional unit (FU) was 1 potential MWh needed to supply the boiler along one year. A potential was considered because boilers effective energetic yields were not considered in the study. This FU allowed us to compare various supply chains from different biomass sources.

Technical data to model supply scenarios were collected from the cooperative manager and farmer interviews and from literature. LCI scenarios modelling were realized thanks to two databases:

(i) Data used for inputs (energy and fuel consumptions, fertilizers, pesticides and consumables, etc.) came from the ecoinvent database (V.3.3) [6].

(ii) Concerning the agricultural operations, data came from the Agribalyse database (V.1.3), which comprises LCI of many French agricultural products and processes.

Direct emissions to air, water and soil were also evaluated with recommended methods in the Agribalyse report [7]. Soil carbon potential sequestration was also accounted for.

LCA impact calculations will be made with the SimaPro software (V 8.3). Typical environmental impacts were assessed: climate change is at stake since supply scenarios were based on wood and perennial agricultural biomasses, with high carbon sequestration potential rate [8, 9, 10]. Terrestrial acidification, eutrophication and energy demand, completed the analysis. Evaluating these impacts were recommended for agricultural LCA by ADEME [11] and [12].

3.3. Expected results

The comparison of the various agricultural biomass productions will provide detailed assessed environmental impact. By doing so, a special attention will be paid to climate change impact by farmers and cooperative managers. Indeed, carbon storage under all the studied perennial crops is expected to mitigate the other GHG emissions. More precisely, the perennial energy crops (SRC and miscanthus) seem to show higher soil C sequestration rates than forest and annual crops [13]. As those results strongly depend on the soil type, the forthcoming results will be analysed accounting for each crop location, and help to better locate the various crop location within the supply area.
By comparing the supply scenarios, transport and crushing are expected to be the most important contributors to the various studied impacts [14]. Those steps can be both modified by the cooperative to improve their environmental impacts. As an *ex ante* assessment, the LCA will so help the cooperative to settle adapted crushing device and storage location, as mentioned by [3].

4. CONCLUSION

In the « demonstrating sites network » project, LCA provides decision-making elements to industrial actors of pilot areas to design their supply from agricultural resources. Indeed, this tool enables to compare different scenarios amongst themselves and to identify the most adapted one according to specific environmental criteria.

This environmental evaluation, combined with economic, agronomic and organizational ones launched in parallel, allows the project promoter to make a multifactorial choice.
Finally, it is also important to keep in mind that assessment results given to local actors in order to help them in their decision making, have to be clear. Hence, a special attention will be paid to render the LCA results completely understandable, in such a way that they really can lean on.

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