# D4.4

# Assessment of feasibility of certification adoption in selected value chains

WR (WSER)

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## ABBREVIATIONS

| | |
|---|---|
| BCI | Better Cotton Initiative |
| BMT | BIOBASEDCERT Monitoring Tool |
| CBA | Cost-benefit analysis |
| CSLs | Certification Schemes and Labels |
| CU | Control Union |
| FSC | The Forest Stewardship Council |
| FMU | Forest Management Unit |
| GRS | Global Recycled Standard |
| HARMONITOR | Harmonisation and monitoring platform for certification schemes and labels to advance the sustainability of bio-based systems |
| LCA | Life Cycle Assessment |
| ILO | The International Labour Organization |
| PEFC | The Programme for Endorsement of Forest Certification |
| STAR4BBS | Sustainability Transition Assessment Rules for Bio-Based Systems |
| TCA | True Cost Accounting |
| WR | Wageningen Research |
| WSER | Wageningen Social and Economic Research |

# Executive Summary

The increasing demand for sustainability has accelerated the adoption of voluntary sustainability certification schemes to ensure the environmental, social, and economic sustainability of biobased products and processes. These schemes play a crucial role in improving global production systems, yet their economic feasibility requires thorough evaluation through cost-benefit analysis (CBA). While existing literature largely focuses on economic factors like fees and price premiums, it often overlooks the broader environmental and social costs and benefits of certification. This omission can lead to an incomplete understanding of certification's true impact.

This study (Deliverable 4.4, Task 4.5) aims to fill this gap by integrating environmental and social externalities into CBA, offering insights into the costs and benefits of certification schemes across three biobased value chains. Using an innovative framework that includes the internalization of externalities such as climate change, water use, and labour issues, this study applies the True Cost Accounting methodology (Logatcheva et al., 2023) to three case studies: sugar cane, cotton, and wood value chains. The deliverable builds on a literature review and the CBA framework developed in D4.1, D4.2, and data collection of Task 4.3 and Task 4.4.

Chapter 2 describes the methodology used including data collection and the value chains description. This study uses CBA to assess both internal and external costs and benefits of certification schemes. Internal costs include costs for compliance, such as training and audit fees, while internal benefits include higher sales prices and improved market position. Externalities which are positive or negative impacts not reflected in transaction prices are valued using True Cost Accounting. Social and environmental externalities were selected based on available data, drawn from longlists by Benoît Norris (2020) and the European Commission (2021). Data collection for the CBA was conducted across three biobased value chains: sugar cane, cotton and wood. Initially, audit visits were planned (in Task 4.4) to combine data collection activities, but due to reluctance from companies, questionnaires were created and translated into multiple languages to simplify data sharing. The questionnaire responses were limited and often incomplete, making them less useful for the calculations.

For sugar cane value chain, the intention was to analyse until the production of biopolyethylene with plastic bags and sacks as the final products. However, due to significant data limitations, the analysis had to be restricted to the intermediate product, which is ethanol. This choice reflects the available data and ensures a more robust and credible assessment. The data for this case study was collected through a CU entity in Brazil, while for the textile and wood case studies, a literature search was conducted due to a lack of usable company responses. Secondary data on BCI-certified farmers in India was used for the cotton case study. For wood case study certification costs were sourced from the certification scheme websites (e.g., FSC), and auditing costs were estimated by CU experts. Indirect compliance costs, such as voluntary training expenses, were also derived from FSC and CU. However, due to challenges in obtaining data from certified companies, the analysis relied primarily on qualitative information from literature.

Chapter 3 demonstrates the analyses of the CBA in three value chains. The key findings from the analyses of 3 value chains are following:

- Case Study 1 – Sugar cane in Brazil to ethanol: The results show that the increase in net benefits outweighs the rise in net costs. While internal costs have increased with adoption of sustainability certification due to training, monitoring, and equipment investments, the certification leads to savings in fertilizer and diesel use due to increased efficiency. Although there is no fixed price premium, certified companies received higher prices for ethanol. Certification also improved market position and enabled access to more clients, particularly those requiring certified bio-based polymers. When looking at environmental externalities the study also revealed that certification led to an increase in costs associated with greenhouse gas (GHG) emissions especially related to land use change, while the costs associated with the other environmental indicators either increased or decreased. The conversion of degraded pastures to sugarcane resulted in lower GHG emissions, while land conversion from forest or shrubland to sugarcane led to higher emissions. This highlights the significant spatial variation in emissions depending on prior land use. The costs associated with water availability also showed substantial variation due to regional differences in climatic conditions and land cover before conversion. The use of vinasse as a tool to reduce water consumption was noted, although its environmental impact was not assessed, which may suggest potential additional burdens. Regarding social benefits, certification has the potential to reduce labour-related externalities such as forced and child labour. However, due to data limitations, the analysis relied on the Social Hotspot Database, indicating that certification might be effective in reducing social externalities, particularly by enforcing labour standards like minimum wage and injury reduction procedures.

- Case Study 2 – Cotton in India: In the cotton sector, the economic impact of BCI certification showed mixed results for direct and indirect costs and benefits. The certification had a positive effect on producer prices and production efficiency, with some regions observing a price premium, while others did not, depending on the extent of BCI's implementation. Indirectly, BCI certification resulted in lower pesticide costs, though the impact on overall production costs was modest. Notably, BCI certification also led to a reduction in pesticide expenditures and a decrease in fertilizer costs by about 12.6%. The social benefits of BCI certification were mixed, with improvements in safety practices and raised awareness of child labour, but limited impacts on economic factors like wages and working hours. Environmental impacts were region-specific, with Better Cotton exhibiting a lower carbon footprint in certain areas compared to conventional cotton production. However, gaps in data prevented a full assessment of social and environmental costs, especially regarding the economic conditions of workers.
- Case Study 3 – Wood in Europe: The impact of FSC and PEFC certification in the wood value chain is mixed. While certification boosts the environmental image of timber, price premiums are often modest or absent in some European regions. For small-scale forest owners, group certification helps reduce audit costs. Environmental benefits include improved biodiversity, carbon sequestration, and ecosystem services. However, social benefits, such as worker safety and labour conditions, show only slight improvements. Overall, the economic and social impacts of certification are highly region dependent.

Chapter 4 presents the discussion on the results of CBA analyses of three case studies and feasibility assessment. The feasibility of certification adoption in value chains is shaped by a combination of economic, environmental, social, and policy factors. While CBA helps assess economic viability, it does not capture all motivations behind adoption. Case studies show that certification can improve efficiency, market access, and sustainability, but its impact is highly context dependent. Direct financial incentives, such as price premiums and cost savings, drive adoption. However, economic outcomes vary regionally, with some certifications yielding higher prices and cost reductions, while others show limited benefits. Certification can improve bargaining power and market access, especially in high-demand sectors. But in value chains dependent on intermediaries, like cotton, certification alone may not improve market conditions. Supporting infrastructure, such as training and market linkages, can enhance economic viability.

Environmental and social impacts also play a key role. Certification can improve biodiversity and carbon sequestration, but its effects vary by region. It can reduce harmful labour practices and improve safety, but its impact on wages and working conditions remains uncertain. Complementary policies and institutional support are necessary to maximize social benefits.

Policy can drive certification adoption, as seen in the timber sector, where public procurement policies in Europe might have affected the increase in the market share of certified timber. These regulatory frameworks might create demand for certification, though a direct causal relationship is not assessed in this study.

Data collection for assessing certification impacts remains challenging. Barriers like data sensitivity and lack of tracking systems limit the availability of reliable data, which in turn affects the accuracy of CBAs.

In conclusion (presented in Chapter 5), this study was the first attempt to assess certification schemes in three biobased value chains using a new CBA approach, incorporating externalities. While internal benefits generally outweigh costs, data limitations have hindered a complete evaluation of external costs and benefits, especially in environmental and social areas.

The lack of reliable data, particularly on externalities, complicates the accurate assessment of certification's true costs and benefits. External factors such as climate variability and soil conditions further influence sustainability outcomes. To address these gaps, policymakers and certification bodies should introduce standardized reporting on key externalities, such as greenhouse gas emissions and social impacts, and develop transparent metrics across certification schemes. The BIOBASEDCERT Monitoring Tool (BMT) is a step in this direction, helping to assess sustainability certification schemes for biobased value chains, which is described in a separate D3.3 deliverable.

Further research is needed to understand the types of support and incentives that can encourage companies to collect and monitor this data. Additionally, certification should be complemented with direct financial incentives, support infrastructure, and strategies to reduce reliance on intermediaries. Policy-driven market incentives, such as public procurement sustainability criteria, can further promote certification uptake and drive more equitable benefits across regions and sectors. Future assessments should improve data collection systems and explore policy instruments like subsidies and tax incentives to further enhance certification uptake and ensure equitable benefits across value chains.

# 1. Introduction

## 1.1 Background

The growing demand for sustainability has driven the adoption of voluntary sustainability certification schemes to ensure the environmental, social, and economic sustainability of biobased products and processes. These schemes are key to enhancing the sustainability of global production systems, but their economic feasibility requires careful evaluation through comprehensive cost-benefit analyses (CBA). Existing literature typically explores the economic aspects of certification but often overlooks environmental and social costs and benefits. Most CBAs focus on fees, price premiums, and financial returns, neglecting impacts like emissions, land-use changes, and employment shifts. This omission can lead to underestimating certification's true costs and benefits. This study highlights the importance of integrating often-overlooked environmental and social costs and benefits into CBA and aims to provide insights in the costs and benefits of schemes in three selected industrial biobased value chains. This study builds on a comprehensive literature review and innovative CBA framework developed in Deliverable 4.1 (Task 4.1), Deliverable 4.2 (Task 4.2 selection of biobased value chains) and Deliverable 4.3 (Task 4.3 Data collection template for cost benefit analysis). The developed framework integrates the internalization of environmental and social externalities. Unlike conventional CBAs, which primarily focus on direct financial costs and benefits, this framework accounts for broader impacts such as contribution to climate change, water use, acidification, forced labour, and child labour.

These externalities are monetized using the True Cost Accounting methodology. To demonstrate its applicability, the framework is applied to three biobased case studies: the sugar cane value chain, the cotton value chain, and the wood value chain.

## 1.2 Reader Guide

Section 2 explains the methodology applied to determine the costs and benefits of certification schemes. This includes a description of the theoretical framework, the cost and benefit items considered, and the data collection. Furthermore, the selected case studies are discussed, which include the biobased value chains and certification schemes included in the analysis. Note that due to privacy and data protection regulations, the name of one of the certifications is not disclosed. This is due to data gathered from private companies involved in the certification process. The assumptions and boundaries of the study are also discussed in this section. Section 3 provides the results of the cost and benefit assessment. The implications and shortcomings are discussed in Section 4. The conclusions drawn from this study are provided in Section 5.

# 2. Methodology

## 2.1 Cost Benefit Analysis including internalization of externalities

### 2.1.1 *Theoretical framework*

Figure 1 shows the steps that were followed to determine the costs and benefits associated with certification of biobased value chains. First, the costs and benefits of certification at value chain level were identified in D4.1 (Aramyan et al., 2023a). Second, three value chains were selected for a cost-benefit analysis (CBA) in D4.2 (Aramyan et al., 2023b). These included the sugar cane to biopolyethlene value chain from the chemical sector (due to data limitations explained in Section 2.2.2, this value chain was restricted to intermediate product of ethanol), the cotton value chain from the textile sector (with cotton seeds and cotton fibre production- See Section 2.2.3), and a general value chain from the wood sector in Europe (no specific wood value chain was chosen due to data limitations—See Section 2.2 for more details). Instead, the analysis for the wood sector focused on CBAs of sustainable certification systems found in the literature. Third, for each biobased value chain, a certification scheme was selected using the input of D1.2 (Vural Gursel et al., 2023), and specific criteria outlined in D4.2 (See D4.2 for further description). Due to privacy reasons regarding data collection from the certified companies, the names of certification schemes are either not disclosed or partly revealed in this report. For each cost and benefit item, data was collected using a data collection template (See D4.3[1]for further description). While for sugar cane value chain a company data on CBA cost and benefit items was collected, for cotton and wood value chain due to absence of primary data, secondary data from literature was used. To assess the economic feasibility of the certification scheme, for sugar cane value chain for which company data were obtained, the costs and benefits before certification (initial audit) were compared with those five years after certification. Due to significant data limitations across the full sugarcane to biopolyethylene value chain, the analysis had to be restricted to sugarcane to the intermediate product of ethanol. For more details, see Section 2.2.2 . The selection of companies was based on the following criteria:

- Availability of audit reports for at least three years, enabling comparison of costs before and after certification. This was important given our assumption that the impact of standards on production performance may take several years to materialize.
- Location in São Paulo, Brazil’s main production region, and representativeness in terms of firm structure (e.g., size).
- Availability of audit reports from multiple companies (minimum of three) to capture heterogeneity across firms.
- Inclusion of environmental and social performance indicators in the audit reports.

Based on these criteria, we obtained audit reports from several companies covering a five-year period, which were then included in our analysis.

[1] Online publication is still pending due to review process. D4.3’s title is “Data collection template for cost benefit analysis: Accompanying reading guide to the D4.3 Excel file”.

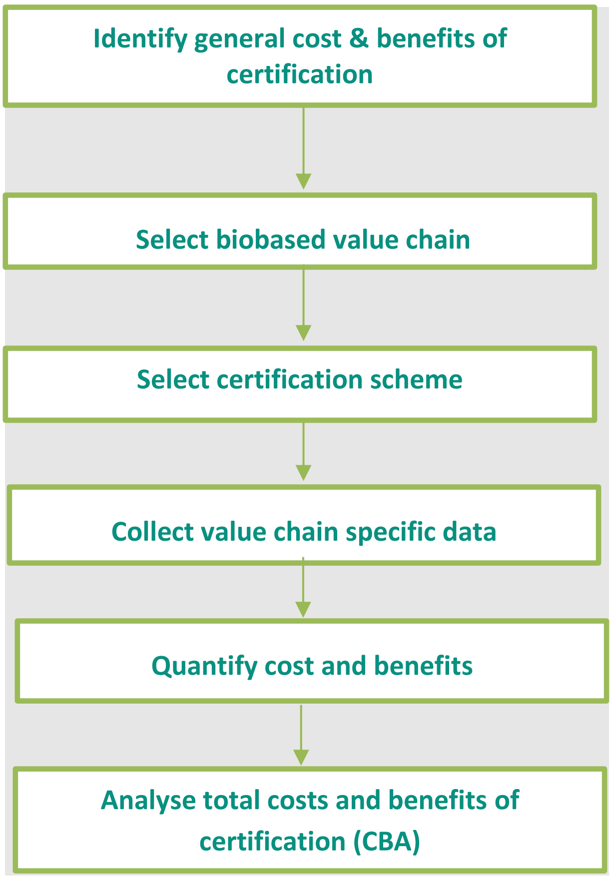


*Figure 1 Steps followed for the cost-benefit analysis*

### 2.1.2 *Cost Benefit Structure/items*

Table 1 provides an overview and description of the cost and benefit items included in the CBA based on D4.1. To be eligible for certification, companies must demonstrate their compliance with the requirements of the certification scheme. This may include an adaptation of the production and trade processes to the requirements of the certification scheme. These adaptations usually lead to higher costs due to training of staff or investing in new equipment. In a periodic audit, the compliance with the certification scheme was reviewed. The audit costs were defined as the costs that the company must pay to become or remain certified. Most certification schemes levy a membership fee for the certified company. The beforementioned costs were defined as internal costs, as they are incurred by the company to become or remain certified and are (usually) reflected in the price of the goods or services transacted.

The certification scheme may be associated with benefits for the company such as a higher sales price, efficiency improvements or an improved market position. These benefits are defined as internal benefits, as they are received by the company.

Certification schemes usually include more stringent requirements on the environment and social aspects, which affect the environmental and social externalities generated during the production process. Externalities are defined as the positive or negative consequences of an economic activity or transaction that affects the wellbeing of other parties without this being reflected in the price of the goods or services transacted (Hussain & Vause, 2018). In case of positive externalities, the actions affect the other person's wellbeing in a positive manner (benefit). Conversely, the actions affect the other person's wellbeing in a negative manner (costs) in case of negative externalities. These costs or benefits are external as they are not directly reflected in the price of the goods or services transacted. In the CBA, these externalities are monetized using True Cost Accounting. True cost accounting is a methodology to measure and value environmental and social health externalities in order to analyse the costs and benefits of business and/or policy decisions (de Adelhart Toorop et al., 2021). There are different True Cost Accounting methods, which include damage costs approach (e.g. CE Delft), prevention costs approach (e.g. Eco-cost), remediation costs approach (e.g. True price), willingness to pay approach (e.g. EPS systems), etc (Sustainability Impact Metrics, 2023a). In this study, we adopted the prevention cost approach using eco-cost values for the sugar cane and the cotton chain, as it enables the monetization of the costs for preventing environmental damage from an anticipatory perspective. Eco-costs are widely used in scientific literature and are well-suited for business decisions, as they translate environmental impacts into actionable prevention costs (Sustainability Impact Metrics, 2023a). In addition, eco-cost values are more accurate than cost factors from damage-based approach (highly uncertain) (Sustainability Impact Metrics, 2023a) or remediation-based approach (complex accounting due to rights-based reasoning) (True Price Foundation, 2025). For the sugar cane case, social costs were also quantified using the social eco-cost values. These monetization factors were taken from eco-cost values developed at the Delft University of Technology (Sustainability Impact Metrics, 2023b). A longlist of social externalities was obtained from Benoit and Mazijn (2020), and a longlist of environmental externalities was obtained from the European Commission (2021) (See D4.1). Based on this longlist of externalities, externalities were selected for each value chain based on the availability of data.

*Table 1 Overview of cost and benefit items included in the CBA*

| Item | Internal/ External | Direct /Indirect | Item | Description |
|---|---|---|---|---|
| **Costs** | Internal | Direct | Auditing costs | Costs that a company must pay for an external audit to become or remain certified |
| | | | Certification costs | Membership fee and/or quantity-dependent fee |
| | | Indirect | Administrative indirect costs | Adapting the company or farm administration to adequate traceability tools and systems and man-days to ensure the correct (and documented) implementation of the chain of custody |
| | | | Indirect costs related to sustainability compliance | Investments for adapting production and trade processes to the requirements of sustainability standards, training of workers in sustainable agriculture technologies and processes etc.. |
| | External | n.a. | Environmental (e.g. greenhouse gas emissions) | Environmental costs (e.g. from pollution) arising from the production or consumption of a good or service |
| | | n.a. | Social (e.g. underpayment) | Social costs arising from the production or consumption of a good or service (e.g. child labour) |
| **Benefits** | Internal | Direct | Efficiency and/or management improvements within company | Benefits related to reduction in the use of inputs, such as water, fertilizers and energy |
| | | | Price premium | Additional revenues obtained by selling the certified product |
| | | Indirect | Improved market position | Image and branding, meeting demands of the market |

| | | | | |
|---|---|---|---|---|
| | External | n.a. | Environmental | Environmental benefits arising from producing and/or consuming the certified product |
| | | n.a. | Social | Social benefits arising from producing and/or consuming the certified good or product |

## 2.2 Case study description and data collection challenges

This section provides an overview of the case studies, and the data collection challenges encountered. Due to these challenges, the case studies rely on different types of datasets. Section 2.2.1 outlines the data collection efforts, highlighting variations in the data obtained from each case study. Sections 2.2.2–2.2.4 present detailed descriptions of the specific case studies analysed.

### 2.2.1 *Data collection challenges*

Various data collection efforts have been made throughout the project, in order to obtain the information needed to conduct the CBA. Initially, audit visits were planned to take place for specific companies. Due to reluctance of companies to participate, guiding documents (questionnaires) were created for each of the three value chains and translated to multiple languages. The questionnaires for all three cases are provided in Appendix 1: Questionnaires.  The aim was to simplify the process, allowing companies to share information at their convenience.

For the chemical/plastic sector, only one company has provided valuable data by filling in the questionnaire. Several other companies that were approached declined to provide input due to data sensitivity concerns. Later, company data from sugar cane value chain, was obtained with the help of a CU entity in Brazil, which was anonymised and could be used for the purpose of the CBA calculations. However, the data received for the sugar cane value chain covered only a part of the chain, specifically up to the production of ethanol as an intermediate product. As a result, our analysis was necessarily limited to this stage of the value chain. See more explanation on this in the next section.

In the textile sector, with support from CU Germany, the questionnaire was distributed to over 200 GRS (Global Recycled Standard)-certified companies in Germany, resulting in responses from three companies. However, the responses were not usable as they lacked the required information related to economic costs and benefits as well as on social and environmental performance needed to perform quantitative analysis. This was primarily due to the sensitivity of the information or the absence of specific environmental or social indicators being measured by the companies, e.g. due to their size or limited resources.

To address the data gap in the textile sector, an extensive literature search was conducted, leading to the identification of secondary data on BCI-certified farmers in India. Consequently, the focus shifted from GRS-certified companies to BCI (Better Cotton Initiative)-certified farmers, and secondary data was used to partly analyse the CBA for this case study. Although contacts were made with BCI to obtain primary data—and initial progress was promising—prolonged negotiations taking several months and bureaucratic hurdles regarding data use issues prevented us from receiving the data in time for analysis. As a result, the findings presented are based solely on the literature information/data. Certain aspects, such as direct costs, could be calculated via publicly available sources (e.g. certification costs), or obtained from CU (auditing costs), however other costs, and especially social costs, were not possible to calculate.

In the wood sector, companies were approached both through face-to face and online interactions by CU auditors. Moreover, through collaboration with CU experts in Europe, FSC-certified companies in Germany, Sweden and Poland have been identified as potential candidates for data collection. Despite extensive collaboration with CU entities in these three countries and targeting companies in their native language, only one questionnaire response was achieved for the wood sector.

In a further attempt to combat these data gaps, an open call for companies involved in the selected three bio-based sectors was developed and launched. This involved creating and posting a project description geared toward bio-based companies on the project's social media accounts and developing an online form that enables representatives of companies to express their interest in the project and share their contact details. The open call was executed with the intention of utilizing all available opportunities to establish contact with relevant companies involved in the selected bio-based sectors that would be interested in participating the data collection process. Despite reaching a significant online audience, no data could be collected through this effort.

To mitigate the lack of direct data from companies, additional efforts were put into literature reviews and trend analyses. The detailed literature review and the trend analyses can be found in sections 2.2.4 and 3.4. Certain aspects, such as direct costs, could be calculated via publicly available sources (e.g. certification costs), or obtained from CU (auditing costs). However, other indicators were difficult to obtain or estimate. We additionally reached out to representatives of PEFC (for wood), with the hope that representatives of this scheme will be able to provide further information or verify existing calculations. PEFC was able to provide some information on motivations for getting certified, but no other data was shared.

### 2.2.2 *Value chain 1: Sugar cane value chain*

#### *General description of the sugar cane value chain*

The first selected value chain is sugarcane-based ethanol. It is assumed that the sugarcane is produced, milled and refined in the south-central region of Brazil. This region is selected as Brazil is the world's largest sugarcane producer, and sugarcane production is mainly located in the south-central region of the country (around 90% of total cultivated area) (Bordonal et al., 2018).

Conducting a comprehensive CBA that incorporates the internalization of externalities can be quite complex, demanding extensive datasets. However, the data required for such an analysis are often limited. For this case study, the original intention was to conduct a comprehensive CBA covering the entire value chain, from feedstock production to the final bioplastic products, specifically biopolyethylene bags and sacks. However, during the data collection phase, it became evident that reliable and consistent data were lacking for several key stages of the downstream supply chain, including the processing ethanol into polyethylene and end-product manufacturing.

Despite our efforts to engage relevant actors throughout the supply chain, many companies either did not complete the questionnaire or were reluctant to participate in the study. The reasons cited included concerns over data sensitivity, confidentiality, and the unavailability of detailed internal data.

To mitigate this challenge and ensure clarity and feasibility, we have chosen to simplify our scope. In this case study, the system boundary was from cradle to factory gate. This included agriculture, transportation and milling (processing sugarcane into sugar and ethanol, the intermediate product in the biopolyethylene production process). Further processing of the ethanol to ethylene and then to polyethylene was not assessed. The functional unit for this case study was 100 litres of ethanol.

Figure 2 shows the production process for biopolyethylene, which consists of the following main steps:

1. Sugarcane cultivation and harvest: the supply chain starts with the cultivation and harvest of sugarcane, which is the raw material for ethanol production.
2. Distillation to ethanol: sugarcane is processed in the mills to extract the juice, which contains sugars. This juice is fermented and distilled to produce ethanol.
3. Dehydration of ethanol to ethene: the ethanol undergoes a dehydration process to produce ethylene. This ethylene is the main component needed to manufacture polyethylene.
4. Processing to green Polyethylene (PE): renewable ethylene, obtained from sugarcane-based ethanol, is used as a raw material along with other chemical substances and additives in the production of green polyethylene.
5. Processing and manufacturing: green polyethylene is processed and transformed into thermoplastic resins, which can be used in different industries, such as packaging, as well as automotive, construction, among others.
6. Recycling: multiply by-products like fibrous residue and residual syrup are recycled to improve sustainability.

Our analyses cover step 1 and 2 as it is shown in

Figure 2 below.

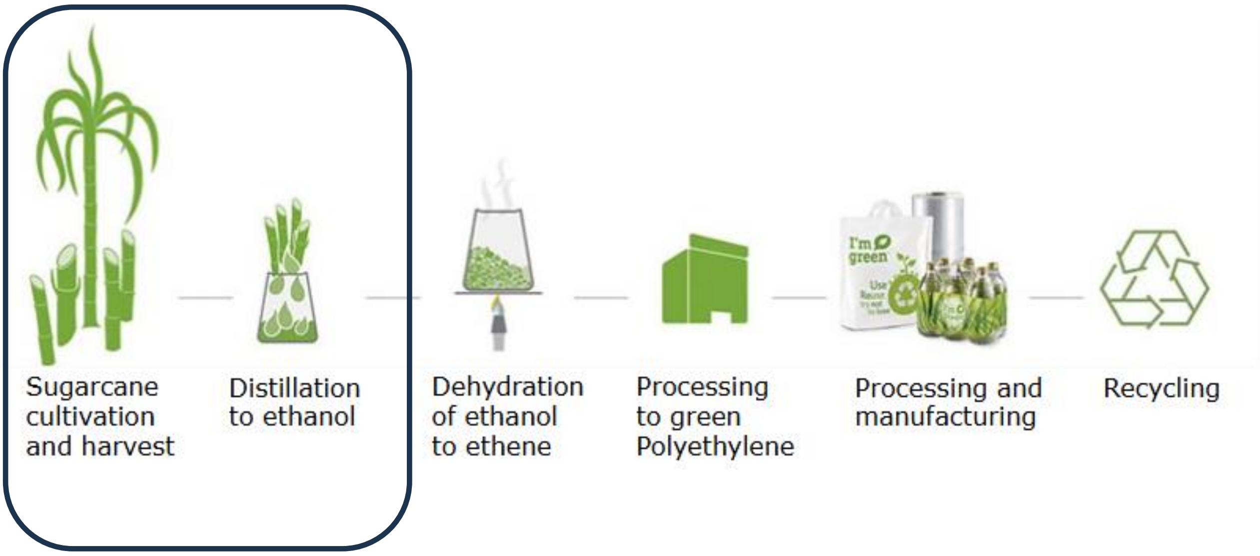


*Figure 2 Overview of biopolyethylene production process.*

## *Included externalities in case study 1*

Table 2 provides an overview of the externalities included in the case study and their corresponding unit.

<u>Environmental externalities</u>

Based on available data, four environmental externalities were included, namely contribution to climate change, acidification, non-renewable resource depletion and water stress.

The contribution to climate change was measured by the emission of greenhouse gasses (GHG). GHG emissions were expressed in kilogram of $CO_2$ equivalent. When measuring a product's life cycle emissions, different scopes (1, 2 and 3) can be used (Ranganathan et al., 2015). GHG emissions from scope 1, 2, and 3 were included in this analysis[1]. Scope 1 emissions occur from sources that the company owns or directly controls, such as emissions from burning of fuel in factories and vehicles. Scope 2 accounts for indirect emissions that come from the energy purchased. Scope 3 entails all other indirect emissions that are linked to the value chain of the company. This includes a range of upstream and downstream activities in the value chain, such as land use change, agrochemical production and transportation and export of bagasse. Land use change can be distinguished into direct and indirect land use change. Direct land use change is defined as the change from one land use type (e.g. forest) to another (e.g. cropland) and its environmental impact can be attributed to the products derived from it (Plassmann, 2017). Indirect land use is land use change that occurs outside of the system that is being assessed (Plassman, 2017). It is a result of change in the demand for land use elsewhere. GHG emissions from direct land use change were included in the analysis, but GHG emissions from indirect land use change were excluded due to unavailability of data. Similarly, GHG emissions from transportation of workers and aerial spraying were also excluded.

Acidification refers to the process of increased acid in nature, that reduces the concentrations of valuable minerals in soil and water (Doney et al., 2009). The atmospheric acidification burden is expressed in kg sulphur dioxide ($SO_2$) equivalents emitted to air. Sulphur dioxide, nitrogen dioxide and ammonia are the primary pollutants contributing to acidification (European Environment Agency, 2020). Sulphur dioxide is emitted when bagasse, which contains sulphur, is burned. Sulphur dioxide is a pollutant that contributes to acid deposition, which, in turn, can lead to potential changes in soil and water quality (European Environment Agency, 2020).

Water stress includes the extraction of water from nature. Water stress is determined by calculating the water applied in agriculture (e.g. irrigation) and water used in the milling process. The volume of water consumed at the mill equals the volume of water used less the volume of water returned to the environment (effluents exported to the fields for irrigation).

Fossil resource scarcity encompasses the reduction in future availability of fossil resources caused by the extraction of fossil fuels linked to fuel use and energy use. Extraction of crude oil, hard coal, and natural gas bears external costs because the stock of these materials is reduced for present and future generations (Huijbregts et al., 2016). In this case study, fossil fuel used for the production of ethanol is considered in the analysis.

*Table 2 Externalities considered in case study on biobased plastics and their corresponding units*

| Externalities | Item | Unit |
|---|---|---|
| Environmental | Contribution to climate change | kg $CO_2$ eq. |
| | Acidification | kg $SO_2$ eq |
| | Fossil resource scarcity | Megajoule |
| | Water use | $m^3$ water |

[1] The following activities were considered for calculating GHG emissions. Farm: agrochemicals applied, fuel usage, sugarcane burnt, decay, transportation of cane (scope 1), electricity used including for irrigation (scope 2), agrochemical production and transportation, land-use-change (scope 3). Mill: bagasse combustion, fuel usage, process water and effluent treatment, chemical usage (scope 1), electricity imported (scope 2), import of bagasse and chemical production and transportation (scope 3).

| | | |
|---|---|---|
| **Social** | Forced labour | Hours/USD |
| | Child labour | Hours/USD |
| | Living wage | Hours/USD |
| | Occupational health and safety (Workplace injuries) | Hours/USD |

Social externalities

For social externalities the following approach has been followed. Using eco-cost true cost accounting (Eco costs value, n.d.-a), four categories of social externalities were identified: forced labour, child labour, living wage (income) and occupational health and safety. While the range of social externalities can be broader, we believe that these four categories are among the most prominent ones, as all four are mentioned explicitly in the declaration of human rights (United Nations General Assembly, 1948).

According to International Labor Organization (ILO), forced labour refers to “work or service which is exacted from any person under the menace of any penalty and for which the said person has not offered himself voluntarily”. Forced labour is in contrast with Article 4 and Article 23 of declaration of human rights (United Nations General Assembly, 1948). According to ‘Walk Free’ (2022), there were more than 27.6 million people in forced labour in 2021 around the world. Eco-cost does not define, and price forced labour directly. Instead, it has a category called excessive involuntary working hours. We took this category as a proxy for forced labour.

Child labour is mentioned in Article 26 of declaration of human rights (United Nations General Assembly, 1948). Definition of Child labour is more nuanced. ILO defines child labour as “work that deprives children of their childhood, their potential and their dignity, and that is harmful to physical and mental development”. The definition then implies that not all cases of child employment is considered as child labour. More especially, if a child is employed but is not deprived of childhood and his/her development is not compromised from the employment, then it might not be considered as child labour. Eco-cost defines child labour as work that involves a child working for more than 2 hours per day (Eco costs value, n.d.-b).

Living wage, along with other working conditions, are mentioned in Article 23, 24 and 25 of declaration of human rights (United Nations General Assembly, 1948). Living wage is defined by ILO as “the remuneration received for a standard workweek by a worker in a particular place sufficient to afford a decent standard of living for the worker and her or his family” (International Labour Organization, 2024). This definition is still not operational as decent standard of living does not have a unified definition. There are different methods for estimating living wage. However, most of these methods estimate the living wage by adding cost of food, housing, clothing, education and other necessary costs. Eco-cost uses minimum acceptable wage as the proxy for living wage as it is the short-term decent living wage (Eco costs value, n.d.-b).

Finally, occupational health and safety is also mentioned in Article 23 of declaration of human rights (United Nations General Assembly, 1948). Work-related incidents are sometimes classified as fatal injuries and non-fatal injuries. Occupational health and safety are serious issues especially in the developing countries and in the agriculture sector. ILO estimates that in 2015 there were more than 6400 work-related death per day across the globe. Eco-cost differentiates injuries from mortality and prices working hours under incidence of injury and mortality (Eco costs value, n.d.-b).

For the social externalities, information regarding the incidence of these externalities before and after being certified was not available. This point is further explained below. Before certification, companies are not required to report the incidence or severity of social externalities to auditors. After being certified, companies only need to comply with certification requirements which almost always means abandoning business practices that are considered to create social externality such as child labour, safety standards and the like. As a result, there is no direct way to calculate the effect of a certificate on the incidence of social externalities. To overcome this hurdle, we use the data from Social Hotspot Database (SHDB) (Social Hotspot Database, n.d.) that report the average incidence of social externalities per industry groups and countries to represent the performance before the certificate as a proxy. These four selected indicators for social externalities are all in the units of work hours per USD output of products in the SHDB (Table 2). Next, assuming that being certified requires abandoning practices that are considered to cause social externalities, we took elimination of the average incidence of externalities from the database as the effect of the certification. To get to the total risk hours, we use the indicators from SHDB with the total revenues in USD from the company audit report. Indicators in the SHDB are based on risk levels. Because definitions of risk levels differ per indicator (e.g. forced labour, child labour and etc), we have calculated the total risk hours for four risk levels separately first (e.g. low, medium, high and very high). Then, these risk hours were priced using the average social-eco-cost values (euro/hour) to estimate total costs per risk level (see Appendix 2: Eco-cost values). Finally, the simple average value across all risk levels was used to indicate the benefit of certification on social externalities. For example, before certification, the hidden costs of forced labour are calculated by multiplying the total risk hours of forced labour at each risk level with the average s-eco-costs (across all endpoints related to excessive involuntary working hours), and then a simple average of these sums across all risk levels was calculated for the final result of hidden costs for forced labour. The risk hours per risk levels are taken from the SHDB, and these four values were multiplied with the total revenue of the reporting company to calculate the total hours worked per risk level.

Data sources

For the data collection, primary data was used when available, and secondary data when primary data was not available. Auditing costs were obtained from certified companies using a questionnaire. Certification costs were obtained from the website of the certification scheme. The price premium for certified ethanol was derived from the ethanol price received by certified companies and the average price in Sao Paulo in the same year. The price received by the certified companies was obtained from the calculator tools and the average ethanol price in Sao Paulo from USDA (2023).

No data on administrative costs and costs (e.g. training) related to compliance with the sustainability requirements of the certification scheme was found. Therefore, a survey was developed and distributed to certified companies (See Appendix 1: Questionnaires). This questionnaire included questions about these cost items. Furthermore, questions about their motivation to become certified and their main markets were included, to get a better understanding of the reasons for the company to become certified. These questions were filled out by a certified company that produces bio-based polymers.

Regarding benefits, the price premium was derived from the price received for product from certified companies. Efficiency improvements included savings on resources such as fertilizer use and energy use.

For the environmental externalities, data about the environmental impact of ethanol production was obtained from the certification organization. The data was based on the actual production data of certified companies, and emission factors from production processes from Eco Invent 3.8.

The externality non-renewable resource depletion includes the use of fossil resources, such as diesel or gas, considered in one of the processes this study (agriculture/transportation/milling). All energy sources were converted to megajoules based on conversion factors from literature.

For social externalities, data limitation was more serious compared to the environmental externalities. Sustainability certification schemes typically have strict requirements banning forced labour, child labour and paying below the minimum wage. Therefore, companies that are certified, and therefore comply with the requirements, often have no cases of those externalities. Thus, the effect of certifications on these externalities cannot be identified from the auditing reports or the certification calculator. In addition, certified companies are not individually monitored or audited to check for these three types of social externalities before certification. As a result, there is no credible data source that can be used to assess the effect of sustainability certificates on forced labour, child labour, and paying less than minimum wage. The same limitation applies to occupational health and safety to a lesser extent. The difference is that in this case, most certificates require companies to register work related injuries and mortalities. However, not all types of injuries are required to be registered. For example, a certification scheme requires registering injuries only when it results in a loss of working time. In addition, data regarding the injuries and mortality before certification are also not available.

Data limitations for social externalities left no option but to resort to using social databases. There are two available database that report social indicators such as those introduced above. These are Psilca and Social hotspot database (GreenDelta, n.d.). These databases report incidence of social externalities, such as child labour, forced labour, et cetera, per industry groups and countries. Importantly, the incidences are reported as hours per dollar of final product. That is, for an indicator such as child labour in a specific sector and country, an indicator shows how much child labour is going into producing one dollar of output, on average. Therefore, once we know the price of the product, we can estimate the externalities in that specific industry and country. We used Social Hotspot Database as our data source for social externalities. This database has the advantage that it covers more industries compared to Psilca.

Eco-cost values were used to monetize the externalities (Sustainability Impact Metrics, 2023b). Appendix 2: Eco-cost values provides an overview of the eco-cost values used for the analysis. Eco-cost values are based on marginal prevention costs, i.e. preventive cost of the environmental or social burden. A norm for sustainability is used to determine the eco-cost values (e.g., norms with respect to minimum wage, child labour, poverty and working hours). The eco-cost values were derived from market prices as much as possible. If prices were completely missing, production cost data was used.

For most externalities, the costs and benefits are not directly related to a product, but to a production process (e.g. greenhouse gas emissions from cultivation of sugarcane). Allocation factors were used to partition these costs or benefits to the product under study. The allocation factors were on energy basis and are 51.5% for ethanol and 48.5% sugar (based on calculation by certification scheme).

Model for calculating CBA

A spreadsheet model was developed for the CBA. All calculations were done in Microsoft Excel. Due to data privacy concerns and restrictions related to the right of data use, the information on primary data used for the CBA calculation is not enclosed in this report. The currency rate at the year of the initial audit (2012 or 2019 depending on the company) was used to convert the local currency (Brazilian Real) to euros. For all cost and benefit items, three values were calculated, i.e. a minimum value, average value and a maximum value. The minimum value was based on the company which reported the lowest value, while the maximum value was based on the company which reported the highest value. The average value was calculated based on the three companies that we had data from.

### 2.2.3 *Value chain 2: Cotton value chain*

#### *General description of the cotton value chain*

The second selected value chain is a textile value chain, with a focus on cotton production. As a producing country, India was selected as it is one of the largest cotton producers in the world and one of the largest exporters of cotton to the European Union (Dutch Centre for the Promotion of Imports from developing countries, 2020; USDA, n.d.). Better Cotton was selected as the certification scheme, as it is the largest cotton sustainability program in the world. In the 2022-2023 cotton season, 5.5 million megatons of Better Cotton were produced (Better Cotton, 2024a). India was one the first countries implementing the Better Cotton Standard, and various studies have analysed the environmental, social and economic impact of this standard.

The cotton value chain consists of the following key stages as shown in Figure 3. In the farming stage, cotton is grown and harvested. The cotton is transported to ginners, where cotton fibres are separated from the cotton seed. Usually, ginners receive cotton from multiple growers. After ginning, the cotton fibres are traded to spinners, who mix the various cotton fibres into one large fabric. Consequently, the cotton is processed, which may include weaving and dyeing. The manufacturers cut, make and trim the fabric into final products, like textile and apparel.

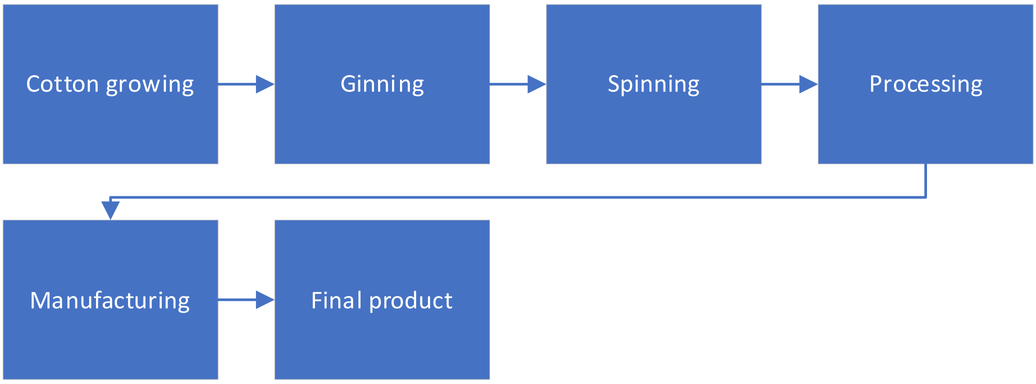


*Figure 3 Key stages of cotton value chain*

Assumptions and boundaries

The system boundary of this case study was cradle-to-farm gate (See Figure 4). This means that only activities for cotton growing are considered. This boundary is considered as most certification schemes impose sustainability requirements on farm level. Cotton growing includes four main tasks: field preparation, planting, field operations (such as irrigation) and harvesting. The functional unit for this case study was 1 ton of seed cotton at the farm gate. During cotton production, two co-products are produced, namely cotton fibres and cotton seed. The emissions included not only emissions from fertilizer and pesticides but also field emissions, electricity for pumps and all transports (such as transportation of fertilizer to the field).  Effects of land-use-change on emissions are not taken into account, due to absence of data.

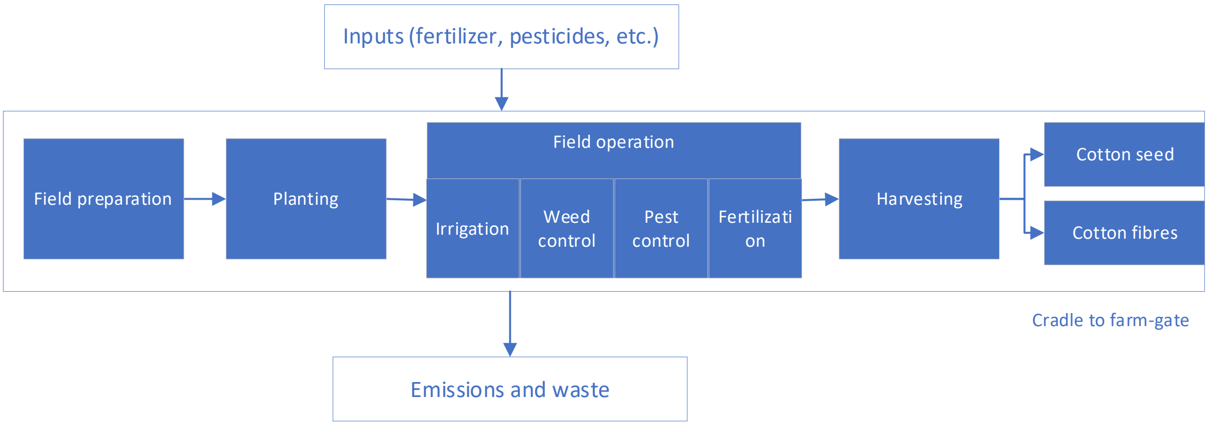


*Figure 4 System boundary and key activities in cotton growing*

## *Included externalities in case study 2*

Table 3 provides an overview of the externalities included in this case study. The same group of externalities included in case study 1 is also considered here (See 2.2.2 for the description of externalities). In addition, eutrophication expressed in kilograms of phosphate equivalents (kg P-eq), has been included in the analyses. Eutrophication refers to the excessive enrichment of water bodies with nutrients, primarily nitrogen (N) and phosphorus (P), which leads to overgrowth of algae and aquatic plants (Bonsdorff, 2021). In cotton production, eutrophication is a key environmental impact indicator, particularly due to the heavy use of fertilizers and agrochemicals. In the case study, all materials and energy use, and associated waste and emissions, were taken into account in the cotton growing phase. While in bioplastic value chains GHG emissions from scope 1, 2, and 3 were included, for the cotton case, only scope 1 was considered (this is due to fact that the authors (Shath et al., 2018) that carried out the environmental impact analysis did not mention why they did not include scope 2 and 3).

*Table 3 provides an overview of the externalities included in the case study for cotton.*

| Externalities | Item | Unit |
|---|---|---|
| Environmental | Contribution to climate change | kg $CO_2$ eq. |
| | Acidification | kg $SO_2$ eq |
| | Eutrophication | kg P eq |
| | Fossil resource scarcity | Megajoule |
| | Water use | $m^3$ water |
| Social | Forced labour | (Qualitative secondary information) |
| | Child labour | (Qualitative secondary information) |
| | Living wage | (Qualitative secondary information) |
| | Occupational health and safety (Workplace injuries) | (Qualitative secondary information) |

For most externalities, the costs and benefits are not directly related to a product, but to a production process. Seed cotton consists of around 55% of seeds, 40% of fibre and 5% of trash (Möller &

Popescu, 2012). Mass allocation was used to allocate the environmental externalities to these products, which means that the externalities are partitioned based on the mass of the products.

Social externality indicators used in Better Cotton evaluation studies include forced labour, child labour, living wage as well as occupational health and safety (Ghori et al., 2022; Kumar et al., 2019; Pamuk et al., 2022).

Data sources

Certification costs were obtained from the website of the certification scheme (Better Cotton, 2024b). The auditing costs were estimated by the experts from Control Union in India. Information about the direct costs and benefits (price received and efficiency gains) of the certifications scheme for cotton farmers was obtained from Pamuk et al. (2022). In line with Pamuk et al. (2022), the internal costs and benefits associated with certification were based on the difference in costs and benefits between the 2018-19 and 2021-22 seasons. The impact of cotton production on environmental externalities was obtained from Shah et al. (2018). Shah et al. (2018) compared the environmental impacts of Better Cotton with conventional cotton seed production, using a Life Cycle Assessment (LCA) approach. The assessment was based on the average data from ten representative farming sites in the state of Maharashtra, India. The authors did not specify in which year the data was collected, but the study was published in 2018. For social externalities, data is based on literature information of existing BCI evaluation studies in India (Ghori et al., 2022; Kumar et al., 2019; Pamuk et al., 2022).

Model for calculating CBA

A spreadsheet model was developed for the CBA. Since data used in this study are based on literature using secondary data, detailed explanation of this data and the model calculation on environmental externalities can be found in Appendix 3: Explanation of the environmental externalities calculation for the cotton case. This model was used to convert the environmental impacts (as reported by Shah et al., 2018) into environmental costs and benefits. This was done using the monetization factors provided by eco-costs (see Appendix 2: Eco-cost values). In the study Pamuk et al. (2022), internal costs (efficiency or management improvements) and benefits (price premium) were expressed in dollars. These costs and benefits were converted to euros using the currency converter of the European Central Bank (European Central Bank, n.d.). The average currency rate of 2021-2022 was used, which is similar to the endline situation in Pamuk et al. (2022).

### 2.2.4 *Value chain 3: Wood value chain*

#### *General description of the wood value chain*

The third selected value chain is the wood value chain, with a focus on European wood production. Approximately 46% of Europe's forests are dominated by coniferous trees, while broadleaved trees account for 37%. Mixed stands make up the remaining 17% of the forest area (Forest Europe, 2020). Europe's diverse climatic regions provide its diverse forests, from boreal coniferous forests in the north to Mediterranean evergreen forests in the south. Temperate and Atlantic zones host mixed deciduous forests, while mountainous regions support alpine conifers. Transitional zones blend coniferous and broad-leaved species, with continental forests adapting to greater seasonal extremes (European Environment Agency, 2006). A total of 227 million ha of forests covers 35% of Europe's total land area, with 23.6% of the European forests in protected area for biodiversity conservation (Forest Europe, 2020). Protective forests designated for prevention of soil erosion, preservation of water resources, and maintenance of other ecosystem services represent about 32% of Europe's forests (Forest Europe, 2020).

Northern Europe has the highest forest coverage, accounting for 54% of its land area. In contrast, Central-East and Central-West Europe have the lowest forest percentages, at 27% and 28%, respectively Forest Europe, 2020). Meanwhile, forest cover in South-East and South-West Europe varies, standing at 32% and 36%, respectively. Forest area in public and private ownership is roughly balanced in Europe (53% public ones and 47% private ones), with private ones in general much smaller than public ones (Forest Europe, 2020). The wood industry is a part of the forest sector, along with forestry and the pulp and paper industry. On average, the forest sector contributes approximately 1% to Europe's Gross Domestic Product (GDP) (Eurostat, n.d.), with Northern Europe accounting for 2%, highlighting significant regional differences (Forest Europe, 2020).

The Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) are the two leading forest certification systems. Established in 1993, FSC was created by environmental NGOs, social stakeholders, and businesses following the 1992 Rio Earth Summit and operates through a tripartite governance model with equal decision-making power among environmental, social, and economic chambers (Forest Stewardship Council, n.d.-d). Whereas, PEFC, founded in 1999, endorses national certification schemes and prioritises landowner interests, with industry representatives playing a key role (Cashore et al., 2004). FSC certifies over 162 million hectares of forest, while PEFC covers more than 300 million hectares, including more smallholder-owned forests (Forest Stewardship Council, n.d.-c).

The wood value chain starts with forests cultivation and goes through several businesses that process or manufacture forest-based products before ending up at retailers and consumers (Programme for the Endorsement of Forest Certification, n.d.). Figure 5 shows three different wood chains (i.e. building material, furniture and print material) in relation to the two types of FSC certifications, which are forest management (FM) certification and chain of custody (CoC) certification. Forest management certification covers both forest management and product processing. Chain of Custody certification ensures FSC-certified products remain separate from non-certified ones throughout the supply chain, tracking them from forest to consumer (Programme for the Endorsement of Forest Certification, n.d.).

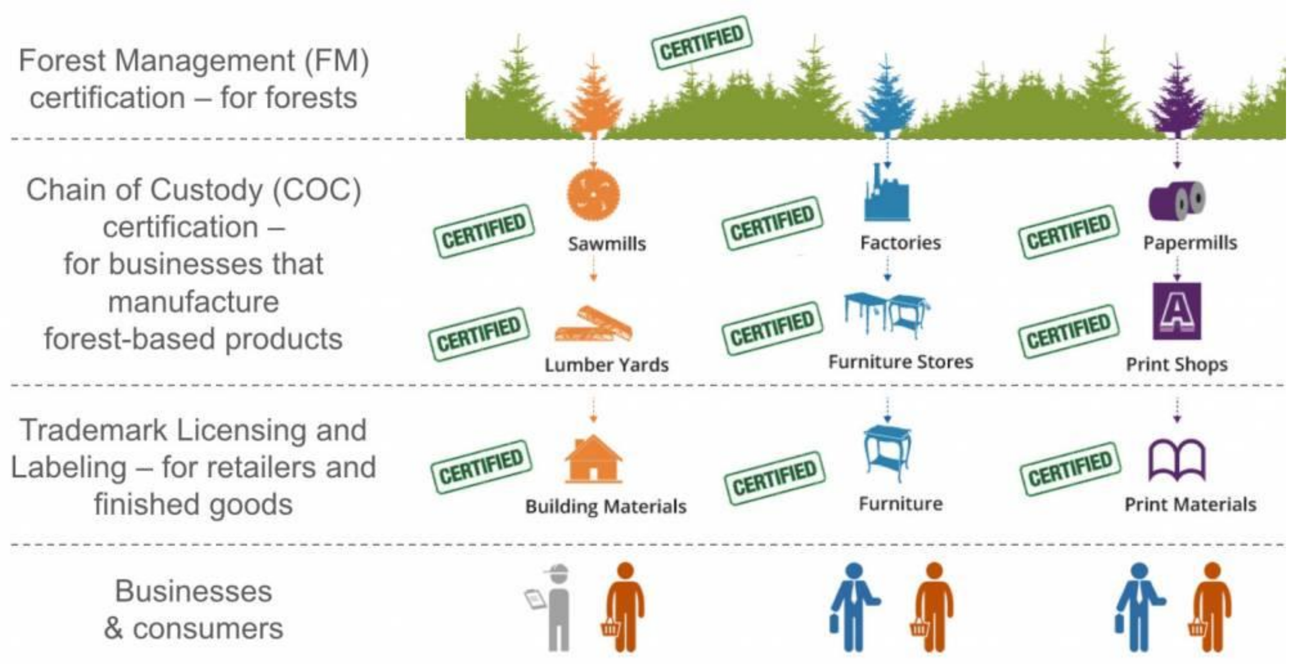


*Figure 5 Key stages of wood value chain in FSC certification (Forest Stewardship Council, n.d.-a).*

## *Impact assessment methods in literature*

Certification schemes like FSC or PEFC are private, voluntary, market-driven governance-focused intervention that ultimately aims to improve forest management (Romero et al., 2017). There have been efforts aiming to understand whether this intervention is having the expected impacts and how it might be improved (Lehtonen et al., 2021). The impact evaluation refers to the changes in the forest management unit (FMUs: the entities that get certified like concessions, communities or private lands), neighbouring communities, forest workers, and local and national stakeholders (Romero et al., 2017). Various approach exists for assessing the impact of FSC certifications, such as measuring changes in forest management (Elbakidze et al., 2011; Villalobos et al., 2018), assessing non-conformities in newly certified forests (Hirschberger, 2005), evaluating the content of the standards (Angelstam et al., 2013; Johansson et al., 2013), and comparing the contribution of FSC to biodiversity conservation in relation to national legislation as baseline (Lehtonen et al., 2021). In addition, subjective assessment towards the benefits of PEFC in terms of economic benefits, environmental protection and social performance was done using surveys such as by certification holders in Czech (Mikulková et al., 2015). Quantitative cost and benefit analysis using primary company data to evaluate the impacts of FSC/PEFC is largely missing in the current literature.

### *Included externalities in case study 3*

Due to the absence of primary data, the externalities in this study are primarily based on findings from literature. As a result, environmental externalities slightly differ from those identified in the other two case studies. This difference can be partly explained by the fact that certification schemes related to the wood case study focus on slightly different environmental impacts. According to the literature, the key environmental externalities in this case include climate change, ecosystem services, and biodiversity which are included in the analyses (See Section 3.3)

<u>Data sources</u>

Certification costs were obtained from the website of the certification scheme (FSC, 2025). The auditing costs were estimated by experts from Control Union. Information about the indirect costs related to compliance was derived from FSC websites and certification experts from Control Union but were limited to costs for voluntary trainings (Forest Stewardship Council Deutschland, n.d.-b). Due to difficulties in obtaining data from certified companies, the base of precise and actual data was insufficient, allowing only for a qualitative analysis based on literature information (See Section 2.2.1 for more explanation).

<u>Model for calculating CBA</u>

Due to the lack of primary quantitative data from FSC/PEFC certified companies, the spreadsheet model developed for the CBA was not feasible for this wood chain. Therefore, the cost and benefit analysis for the wood chain is mostly based on secondary literature information. Studies included focus on the effects of FSC/PEFC on internal costs and benefits, price premiums, and certification motivations; environmental external costs are examined only in relation to ecosystem services and biodiversity, while social external costs are limited to occupational health and safety.

# 3. Analysis of value chains

## 3.1 Results for value chain 1: Sugar cane

### 3.1.1 *Effect of certification on internal costs*

Table 4 shows the internal costs and benefits for the certification scheme in the sugar cane value chain. The costs and benefits are expressed relative to the baseline, which are the costs and benefits at the time of the initial audit (See Section 2.1.1). The results show that the increase in net benefits outweighs the increase in net costs. The internal costs have increased, which is mainly due to higher costs to comply with the more stringent requirements of the certification scheme. These costs consist of costs for training on the certification standards, monitoring of the certification requirements and investment in new equipment.

The certification is associated with more efficient use of fertilizer and diesel, resulting in costs savings on these resources. These effects can be explained by the requirements of the certification scheme, which states that the company must implement a plan that ensures optimal use of fertilizer. The certification scheme does not include a fixed price premium, but it may give companies a better bargaining position resulting in a higher price. The certified companies received a higher price than the average price that was received for ethanol in Brazil. The price difference varied between +1.23 euro to +19.34 euro per 100 Liter of ethanol. The company that filled out the questionnaire indicated that being certified did not enable them to negotiate a higher price for their products but improved their market position as it reinforces their commitment to ensure a reliable and traceable feedstock supply. Furthermore, they indicated that they were required by some customers to certify segregated bio-based polymers. Therefore, being certified allows them to access more clients. The total effect of the certification scheme on costs and benefits are +0.92 euro/100 litres of ethanol until +21.80 euro/100 litres of ethanol.

*Table 4 Overview of internal costs and benefits for certification in the sugar cane value chain*

| Costs/ benefits | Category | Item | Value in euro/100 litre of ethanol | | |
|---|---|---|---|---|---|
| | | | Minimum | Average | Maximum |

| | | | | | |
|---|---|---|---|---|---|
| **Costs** | Direct | Auditing costs | +0.01 | +0.01 | +0.01 |
| | | Certification costs | +0.08 | +0.09 | +0.09 |
| | Indirect | Administrative costs | +0.12 | +0.14 | +0.16 |
| | | Costs related to sustainability compliance | +0.11 | +0.18 | +0.27 |
| | Total | | ***+0.31*** | ***+0.42*** | ***+0.54*** |
| **Benefits** | Direct | Efficiency or management improvements | 0 | +1.10 | +3.00 |
| | | Price premium | +1.23 | +11.81 | +19.34 |
| | Indirect | Improved market position | NA | NA | NA |
| | Total | | ***+1.23*** | ***+12.10*** | ***+22.34*** |
| **Difference** | | | ***+0.92*** | ***+12.48*** | ***+21.80*** |

### 3.1.2 *Effect of certification on external environmental costs*

Table 5 shows the costs associated with the environmental and social externalities. On average, the environmental costs increased or decreased, depending on the company. The change in costs associated with greenhouse gas emission (without emissions from land-use change) vary between by -4 to +3 euro per 100 litres of ethanol.

The costs associated with water use slightly decrease or increase after certification (-0.09 until +0.06 euro/100 litre ethanol). For two companies, water use increases due to less efficient water use during the milling process. For the third company, water use decreases. The decrease is caused by a higher amount of effluents vinasse (treated wastewater) that is returned to the environment (cane fields or water streams), thereby reducing net water use in the milling process.

The external costs associated with acidification decrease or slightly increase (-0.93 euro until +0.50 euro/100 litre of ethanol). Nearly all $SO_2$ emissions occurred from energy used in the milling phase (>90%), which is mainly emitted from the burning of bagasse. Bagasse is used for energy generation by the Brazilian sugar and ethanol industry (Freitas et al., 2021). A possible explanation for the decrease in $SO_2$ emissions is that the certification scheme requires that company crushes the cane in a more efficient manner. The $SO_2$ emissions also decreases in the agricultural phase. Sugarcane residues are usually burned (Ribiero, 2008). A requirement of the certification schemes is that the company does not burn much after harvest, which prevents emissions of $SO_2$.

*Table 5 Effect of certification in the sugar cane value chain on external costs*

| Costs | Item | Value in euro/100 litre of ethanol |
|---|---|---|

| | | Minimum | Average | Maximum |
|---|---|---|---|---|
| **Environmental** | Climate change (without LUC) | -4.79 | -1.25 | +2.91 |
| | Water use | -0.09 | -0.01 | +0.06 |
| | Fossil resource scarcity | -2.07 | -0.45 | +0.83 |
| | Acidification | -0.93 | -0.14 | +0.50 |
| | Total | ***-7.89*** | ***-1.85*** | ***+4.29*** |
| **Social** | Occupational health and safety (Workplace injuries) | -0.1 | -0.07 | -0.05 |
| | Forced labour | -4.22 | -1.74 | -0.50 |
| | Child labour | *-1.73* | *-1.13* | *-0.82* |
| | Living wage | -0.27 | -0.18 | -0.13 |
| | Total | ***-6.33*** | ***-3.11*** | ***-1.50*** |

+ = increase in external costs, - = reduction in external costs. Negative costs = benefits to society

### 3.1.3 *Effect of certification on external social costs*

The social external costs are expected to decrease following certification. This is because the certificate requires business practices to be absent of child labour, forced labour, workplace injuries and provide living wages. As a result, certified companies abandoning those socially harmful practices implies a decrease in social external costs compared to before the adoption of the certificate. On average, the reduction of total social costs is 3.11 euro per 100 litres of ethanol. The absence of forced labour and child labour are the main reasons for the reduction of total social costs after the certification.

## 3.2 Results for value chain 2: Cotton

### 3.2.1 *Effect of certification on internal costs*

Table 6 provides an overview of the internal costs and benefits for BCI certification. For the certification scheme selected in this case study, membership is only required for cotton traders, yarn spinners, retailers and brands. Farmers are not required to become members and pay fees to the certification body. For suppliers and manufacturers, the membership fee depends on the turnover and for retailers on the cotton consumption, where a higher turnover or cotton consumption means a higher membership fee (Better Cotton, 2024b). Farmers are beneficiaries of the BCI programme and get training (for free) in order to apply the practices that are laid down in the certification programme (Better Cotton, 2024c).

Besides, as beneficiaries of the certification scheme farmers do not pay an audit or certification fee. The fee is only paid by suppliers, manufacturers, retailers and brands.

Farmers are trained by the certification body to apply more sustainable farming practices. The training instructs farmers on BCI's principles with regards to crop protection, water, soil, habitat fibre quality and decent work (Better Cotton, 2024a). Pamuk et al. (2022) found that BCI-certified farmers achieved lower fertilizer costs compared to conventional farmers, as the savings on chemical pesticides outweighed the increase in costs for biological pesticides. Total cost savings were 22 euro per ton of seed cotton (Pamuk et al., 2022). Savings on synthetic fertilizer was only observed in Nagpur, but not in the other study regions (Pamuk et al., 2022). Despite the savings on pesticides, total cotton farming costs were not significantly different between BCI and conventional farmers. Hence, no costs savings due to efficiency gains or management improvements were observed.

The certified cotton is traded without a fixed price premium; the price of the certified cotton is determined by the market (Better Cotton, 2015). In the study of Pamuk et al. (2022) it was reported that farmers perceived that the participation in the Better Cotton program allows them to receive better prices. On average, certified cotton farmers received a higher price than conventional cotton farmers (120 euro/ton cotton seed). In Nagpur, between 2018-19 and 2021-22 seasons, the price per 100 kg of seed cotton received by Better Cotton cohort farmers increased $US 13.5 more compared to the control farmer group (Pamuk et al., 2022). This value was used to calculate the price premium in euro per ton seed cotton. The ginner's demand for certified cotton was high and they may consider the quality of the cotton superior, which could explain the higher price received by certified farmers (Pamuk et al., 2022). Almost all farmers (>95%) perceived that resulted BCI certification resulted in higher cotton prices and a higher demand for their products (Pamuk et al., 2022), suggesting an improved market position.

*Table 6 Internal costs and benefits for BCI certification in the cotton value chain; changes relative to conventional seed cotton*

| Costs/ benefits | Category | Item | Value in euro/ton seed cotton |
|---|---|---|---|
| **Costs** | Direct | Auditing costs | 0* |
| | | Certification costs | 0* |
| | Indirect | Administrative costs | 0* |
| | | Costs related to sustainability compliance | 0* |
| | Total | | |
| **Benefits** | Direct | Efficiency or management improvements | 0 |
| | | Price premium | 120.76 |
| | Indirect | Improved market position | Yes |

| | | |
|---|---|---|
| | Total | ***120.76*** |
| **Difference** | | ***120.76*** |

* Farmers are beneficiaries of the certification scheme and do not pay an audit or certification fee. The fee is only paid by suppliers, manufacturers, retailers and brands. The audit costs are around 375-750 euro per farm.

### 3.2.2 *Effect of certification on external environmental costs*

Table 7 shows the effect of the certification on external costs in the cotton value chain. Regarding environmental externalities certified cotton has lower costs associated with reduction of greenhouse gas emissions (-39 euro/ton seed cotton), which is caused by less use of fertilizers and lower emissions from tractor operations (Shah et al., 2018). The reduction of fertilizers also leads to lower costs on eutrophication (-83 euro/ton seed cotton) and acidification (-19 euro/ton seed cotton) for certified cotton compared to conventional cotton. Water consumption is lower for certified cotton due to less irrigation water requirement, thereby resulting in lower costs related to water use (-210 euro/ton seed cotton). Certified cotton shows lower environmental costs on fossil resources than conventional cotton (-14,77 euro/ton seed cotton), which can be explained by the energy savings associated with BCI practices. BCI cotton had less use of inorganic fertilizers, less use of fuel for tractor operations and lower fuel requirements for the irrigation process (Shah et al., 2018). Detailed explanation of these results on environmental externalities can be found in Appendix 3.

*Table 7 Effect of certification in the cotton value chain on external costs; relative to conventional seed cotton*

| Costs | Item | Value in euro/ton seed cotton |
|---|---|---|
| **Environmental** | Climate change | -39,37 |
| | Water use | -210,39 |
| | Fossil resource scarcity | -14,77 |
| | Eutrophication | -83,45 |
| | Acidification | -19,20 |
| | Total | -367,18 |
| **Social** | Occupational health and safety<br>(Workplace injuries) | - Farmers reported increased use of protective equipment and more health and safety training for workers (Pamuk et al., 2022).<br>- No change observed (Kumar et al., 2019). |
| | Forced labour | - No issue of forced labour during the study field work (Kumar et al., 2019). |
| | Child labour | - The number of workers aged 6-14 decreased from 26 to 7 by midline, with no child labour reported by endline (Pamuk et al., 2022).<br>- No change observed (Kumar et al., 2019). |
| | Living wage | - BCI had no significant impact on dairy wages or working hours. Female workers in Gujarat, India, |

| | | |
|---|---|---|
| | | saw their income drop by nearly half due to fewer pesticide spraying days and lack of extra pay for clean picking (Ghori et al., 2022).<br>- No change observed (Kumar et al., 2019). |

### 3.2.3 *Effect of certification on external social costs*

Regarding social externalities BCI conducts capacity building programmes to train farmers on good agricultural practices, and the use of personal protective equipment when applying pesticides (Pamuk et al., 2022). Farmers reported increased use of protective and safety equipment, along with more health and safety training for hired workers (Pamuk et al., 2022). No change is observed on occupational health and safety by Kumar et al. (2019). In terms of forced labour, no incidence was found during the study field work by Kumar et al. (2019).

Instances of child labour have been reported on Indian cotton farms, particularly when migrant workers bring their children along to assist in the fields. However, under the BCI standards and certain relevant International Labour Organization (ILO) conventions, it is permissible for children to help on family farms during holidays, provided it does not interfere with their education or well-being (Kumar et al., 2019). Pamuk et al. (2022) find that the number of workers aged 6-14 dropped from 26 to 7 during the midline data collection, and by the endline, no child labour was reported. Kumar et al. (2019) did not find any changes on child labour use in practice, although the awareness of child labour issues seems to have increased in BCI treatment areas.

In terms of living wage, the BCI was not found to have significant positive impact on daily wages or working hours. However, female on-farm workers in Gujarat, India, report earning nearly half their previous income after BCI due to fewer pesticide spraying days and not receiving extra pay for clean picking (Ghori et al., 2022). No changes on living wages are observed in the study by Kumar et al. (2019).

## 3.3 Results for value chain 3: Wood

### 3.3.1 *Effect of certification on internal costs*

Various studies analysed the effect of FSC and PEFC certification on the internal costs and benefits of forest companies in Europe. An overview of the results is presented in Table 8. In the Nordic countries, FSC and PEFC certification did not significantly improve the internal costs and benefits of forest owners, although they gained a better environmental image of timber and wood products in the international markets (Wolff and Schweinle, 2022). This way, certification enhanced the long-term market access for timber and wood products. Group certification arrangements allowed small-scale nonindustrial forest owners to reduce audit costs (Wolff and Schweinle, 2022). Besides, some additional data estimation on the internal costs and benefits associated with FSC certification in the wood value chain (Table 8) is carried out based on the expertise from CU. The internal costs are categorized into direct and indirect expenditures. Direct costs are determined through an expert from an FSC certification body. They include auditing costs, which are priced at €1150 per day, and certification fees, which apply to initial certification, recertification, and scope extension, amounting to €300. There is also the FSC Chain of Custody Waiver fee, set at €100, applicable when an audit is postponed due to lack of sales. Reprinting a certificate incurs a cost of €50, while FSC logo approval costs €20 per trademark approval. Travel costs associated with certification audits range from €450 to €900 (Bauer, 2025). Indirect costs involve voluntary training, which can amount to between €450 and €800 (Forest Stewardship Council Deutschland, n.d.-a).

The effect of FSC or PEFC certification on price premiums in Europe is analysed in four studies (Wolff and Schweinle, 2022). In most studies, respondents indicate that they did not receive a price premium or only a small price premium. In the study of Paluš et al., (2018), a survey was distributed to 400 forest owners in Slovakia. 69% of the respondents were FSC or PEFC certified. Of this group, 92% was PEFC certified, 4% FSC and 4% were double certified with both FSC and PEFC. Nearly 74% of the forest owners replied that they received a price premium for certified wood ranging between 1 and 5% of the sales price (Paluš et al., 2018). 13% did not receive a premium (Paluš et al., 2018). A small group (4%) received a price premium of 11% or more.

*Table 8 Internal costs and benefits for FSC certification in the wood value chain*

| Costs/ benefits | Category | Item | Value in euro |
|---|---|---|---|
| Costs | Direct | Auditing costs | 1150 /Day fee |
| | | Certification fee | 300 |
| | | FSC CoC Waiver | 100 |
| | | Certificate reprint | 50 |
| | | FSC Logo Approval | 20 per trademark approval |
| | | Travel Costs | 450-900 |
| | | FSC license fees | Depends on forest product turnover |
| | Indirect | Voluntary training | 450-800 |
| Benefits | Direct | Efficiency or management improvements | Unknown |
| | | Price premium | No price premium or a small price premium (1-5%[1]) (Paluš et al., 2018; Halalisan et al., 2019; Gomez-Zamalloa, 2011) |
| | Indirect | Improved market position | Improved market access (Zubizareta et al., 2024); Obtaining new contracts (Halalisan et al., 2019). |

Regarding the benefits of FSC certification, the table indicates that price premiums are usually absent or minimal, ranging from 1% to 5%. This finding is supported by multiple studies, including those by Paluš et al. (2018), Halalisan et al. (2019), and Gomez-Zamalloa (2011). Indirect benefits include an improved market position and enhanced market access (Zubizareta et al., 2024), as well as the facilitation of obtaining new contracts (Halalisan et al., 2019).

Halalisan et al., (2019) analysed the economic impact of FSC certification in Romania. They also found that most certificate owners (63% of the respondents) did not receive a price premium or only a small price premium. Among the respondents that indicated that FSC resulted in a price premium,

[1] A 5% price premium is based on our Polish respondent for the survey, with an annual production volume of FSC-certified wood products processed and traded at 800,000 ton.

nearly 60% of the respondents indicated that the price premium was less 5% of the price of uncertified products. Most respondents (63%) indicated that FSC certification had a positive influence in obtaining new contracts (Halalisan et al., 2019). In Poland, no additional price premium was reported in association with FSC forest management certificates (Romaniuk, 2008).

In the study of Gomez-Zamalloa (2011), forest experts were asked to evaluate the effects of FSC and PEFC certification in the European Union on general aspects, ecological aspects, economic aspects and social aspects. Most experts perceived that price premiums due to certification were largely absent in the forest sector of the European Union (Gomez-Zamalloa, 2011). Most forest experts (87.5%) believed that certified wood is sold at the same price as non-certified wood, while 12.5% believed that prices increased due to certification (Gomez-Zamalloa, 2011). In very specific cases, e.g. products with a high added value, there could be a slight increase in the price of the certified product.

Various studies considered the effect of FSC or PEFC certification on profitability in Europe. Overall, the effect was negative or mixed (Wolff and Schweinle, 2022). For example, in the Czech Republic, certification costs of FSC were higher than the additional revenues (Wolff and Schweinle, 2022). The effect of the certification on sales, profits, and added value of companies was more effective over a longer timeframe (4 years to more than 10 years). In Sweden, 37% of forest owners considered certification to affect profitability positively, 28% thought it had no noticeable effect, 27% had no opinion, and 5% considered any effect to be negative (Lidestav et al., 2011). No studies were found that analysed the effect of certification on efficiency or management improvements.

Corticeiro et al. (2024) investigated the relationship between FSC and PEFC certification and economic performance. The findings show that certification has a stronger effect on output variables (e.g. yield) than on input (costs) variables. The results also showed that there was a tendency for costs to increase with the size of the certified forest area, but it tends to reach a ‘plateau’ after a certain scale is reached. This suggests that it is possible to sustain a profitable certification scheme at scale, where costs are controlled and outputs further increased (Corteiceiro et al., 2024). Zubizareta et al. (2023) analysed the effect of PEFC certification on economic performance in Spain. They did not find a treatment effect between PEFC certification and better financial performance. Instead, a positive selection effect was found; companies with better financial performance had a higher tendency to become certified.

Zubizarreta et al. (2024) analysed the motivation of companies to become certified and the perceived impact or benefits that certification may introduce. The analysis was done for a sample of Spanish companies certified by PEFC. Market motivation was listed as one of the main motivations for adopting forest certification, as it can stimulate company expansion into other markets and create a competitive advantage. Furthermore, certification, especially when it is a requirement of customers, is often an important driver for entering foreign markets. Another important driver is to gain legitimacy with direct external customers, and environmental stakeholders (Zubizaretta et al., 2024).

### 3.3.2 *Effect of certification on external environmental costs*

Regarding the environmental costs, information was found about the effect of FSC on biodiversity, carbon stocks and the provision of ecosystem services. FSC aims to promote the environmentally responsible management and conservation of forests (FSC, 2023). Conservation of biodiversity and ecosystem services are considered as essential elements in the FSC certification scheme (Forest Stewardship Council, n.d., -e). Matias et al. (2024) reviewed the effect of FSC certification on biodiversity in different continents, including Europe. The authors concluded that overall, the effect of FSC certification on biodiversity abundance, when compared to uncertified areas, was neutral in European forests (Matias et al., 2024). However, significant differences among taxa were found.

FSC-certified areas presented higher flora richness than non-certified areas. Furthermore, the abundance of mammals was higher in FSC-certified areas than non-certified areas.

The neutral effect of FSC-certification on taxa abundance could imply that FSC-certified areas and the applied management measures do not enhance the overall species abundance when compared to non-certified areas. Also in certified areas, forest loss and disturbance by humans are inevitable due to road construction, logging and logging camps (Burivalova et al., 2017). Furthermore, there is no indication of the permitted rate of forest loss for an FSC-certified concession. Therefore, it could be that the intensity, volume and area of logging are similar in certified and non-certified areas (Matias et al., 2024).

The positive effect of FSC on the abundance of flora species richness can be explained by the criteria of FSC on the management of vegetation. By complying with these criteria, managers assure that plantations aligned with FSC criteria are having a positive effect on native vascular plant communities (Matias et al., 2024). The positive effect of FSC on the abundance of mammals can also be explained by the criteria of FSC. According to the FSC certification requirements, conservation areas may need to be established based on the size of the forest area (HCV Resource Network, 2018). The goal of these conservation zones is to protect rare and threatened species and their habitats. These zones enhance tree regeneration and shrubs diversity, which are important for functional small mammal communities and threatened species (Afonso et al., 2021).

Wolff and Schweinle (2022) also reviewed the impact of FSC and PEFC on biodiversity in Europe. The authors found scattered evidence. About half of the studies reported positive impacts (53%), followed by neutral (30%) or mixed (15%) results. The effects were site-specific.

Ten studies assessed the impact of forest certification on carbon stocks, although no study focused on Europe (Wolff and Schweinle, 2022). In these studies, the impact on carbon stocks was analysed by quantifying carbon stock / density and carbon emissions from logging in certified and uncertified forests. In total, 66% of the studies reported a positive impact of forest certification on carbon stocks, followed by mixed results (22%) and no impact (11%). A positive impact on carbon stocks implied greater carbon sequestration in certified areas compared to uncertified forests (Wolff and Schweinle, 2022).

There were two studies that analysed the perceived impact of certification on the provision of forest ecosystems by certificate holders (Wolff and Schweinle, 2022). These studies were conducted in Southern Europe and reported a positive effect of certification on ecosystem services (Pezdevšek Malovrh et al., 2019; Paluš et al., 2018). For example, rarer and threatened species and water bodies were conserved through certification (Pezdevšek Malovrh et al., 2019).

### 3.3.3 *Effect of certification on external social costs*

In general, there is a lack of studies that investigate the social impacts of FSC/PEFC in the European wood sector when using Scopus database. This lack of studies on social indicators can also be observed when selecting countries in Europe using the FSC Impact dashboard (Forest Stewardship Council, n.d.-b). However, there is limited evidence of the social impacts of FSC/PEFC in the European wood sector. A recent study looked at non-conformities in the forest management practices in Lithuania using FSC auditing reports and concluded there is insufficient internal control of workers' safety and health in practice (e.g. lack of fire extinguishers, and first-aid kits at workplace; work protective equipment are not often used; lack of preparation of the forest machinery, etc), and insufficient cooperation with local communities due to the complexity of setting it up (Konstantinaviciene et al., 2024).

Earlier in 2011, there were two studies which looked into the environmental, social and economic effects of FSC in European forest management (Gómez-Zamalloa & Caparrós, 2011; Hain & Ahas, 2011). Hain and Ahas (2011) have reported the number of non-conformities for nine detailed sub-categories under the social category using auditing reports across West and East-Europe. Hain and Ahas (2011) found that non-compliance with worker safety requirements has led to a high proportion of non-conformities. In addition, most non-conformities related to social indicators stem from inadequate or lacking stakeholder communication by forest management operations (Hain & Ahas, 2011). Gómez-Zamalloa and Caparrós (2011) have evaluated the effects of 15 years of forest certification of both FSC and PEFC in the EU forest sector using Delphi method. In terms of social aspects, experts reached consensus for the positive impacts from 'integrate social criteria into traditional forest management' and the improvement of the information provided to the society on what is done in the forest and why. However, experts were mostly indifferent or in doubt for the improvement of the workers' conditions.

In short, these studies indicate that while FSC and PEFC certifications aim to integrate social criteria into forest management, there is limited evidence regarding their effectiveness in improving social conditions within the European wood sector. Some negative non-conformities have been found in relation to the 'Occupational health and safety' indicator. Evidence regarding forced labour, child labour and living wage is not found.

Table 9 below summarises our findings on external environmental and social costs. Based on existing literature, evidence of the environmental externalities of FSC/PEFC pertains only to biodiversity, with effects in the European wood value chain ranging from neutral to positive. Evidence of social externalities is limited to occupational health and safety, with effects ranging from negative to neutral.

*Table 9 Effect of FSC/PEFC in the wood value chain on external costs*

| Costs | Item | Value in euro/ha |
|---|---|---|
| Environmental | Climate change | Unknown for European forests (increase of carbon stocks found for other continents) |
| | Ecosystem services | + (perceived by certificate holders) |
| | Biodiversity | 0/+ |
| Social | Occupational health and safety (Workplace injuries) | -/0 |
| | Forced labour | Unknown |
| | Child labour | Unknown |
| | Living wage | Unknown |

+= positive impact, - = negative impact, 0 =no impact

## 3.4 Analysis on producers' motivation on adoption: example from wood sector

While CBA provides an overview of the costs and benefits of certification, it does not explicitly address what drives value chain actors to adopt certification. In literature, widely mentioned drivers are direct financial incentives like price premiums or cost savings from improved efficiency (See Deliverable 4.1), there are also motivation by economic benefits such as access to new markets and enhanced bargaining power. For instance, certifications can unlock global markets for crops with opportunities to sell their products at better prices (United Nations Environment Programme, 2020). Additionally, supportive infrastructures, including training programs and market linkages, can further enhance the economic viability of adopting certification schemes (Piñeiro et al., 2021). Next to these widely mentioned drivers in literature (See more on this in D4.1), the producers' decisions to adopt sustainability certification schemes are significantly influenced by specific policies that offer economic incentives and support for sustainable agricultural practices. Besides, when certification aligns with mandatory regulations, farmers/producers may adopt it to ensure compliance with legal requirements (Aragon-Correa et al., 2020).

To explore this question, as a complementary analyses to CBA and feasibility studies, a questionnaire was developed and distributed among biobased certified producers, but unfortunately, the response rate was low (See Section 2.2.1). As a result, additional analyses were performed by the research team based on a trend analysis for the increase in the number of certified companies in relation to specific policies, to gain further insights into the motivations behind certification adoption. The examples from three EU countries in wood sector are outlined below.

In the Netherlands, Germany and France, it is possible to observe a growing number of national public sustainability procurement policies and initiatives and an increase in numbers of certified timber in the last two decades. While the exact relationship between these trends has not been measured, the overall impact seems to be positive.

*Netherlands*

The Dutch government introduced a sustainable procurement policy that includes criteria for timber products. This policy encourages the use of FSC-certified timber in public projects. On June 24, 2004, the Dutch cabinet announced that all governmental organizations should commit to buying timber from well-managed forests whenever possible, aiming to increase this to 100% over time. Governmental organizations are required to ensure that the timber they purchase is legal. This is part of the broader effort to combat illegal logging and promote sustainable forest management. The sustainability criteria for timber procurement are informed by the National Assessment Guidelines, which were expected to be completed in 2005. These guidelines help define what qualifies as sustainable timber (Brack, 2014).

In the following, the market share of certified timber in the Netherlands increased to 65% between 2009 and 2011. In 2008, the combined market share of FSC and PEFC certified timber was only 33.5%, and just 13.3% in 2005 (Compendium voor de Leefomgeving, 2014).

*Germany*

The German government implemented a sustainable public procurement policy that includes specific criteria for timber products. Since 2007, federal institutions have been required to procure only legally and sustainably sourced timber. The policy strongly encourages the use of FSC and PEFC-certified timber in public projects to ensure compliance with sustainability goals. The 2010 amendment to Germany's Administrative Regulation on Public Procurement (VwVBU) reinforced these commitments, requiring proof of sustainability certification or equivalent documentation. As a result, the share of certified wood in Germany has grown significantly. In 2009, approximately 68% of timber used in public procurement met FSC or PEFC standards. By 2023, the proportion of forests managed under these certifications had grown, with 79.4% under PEFC and 14.6% under FSC (Umweltbundesamt, 2024).

*Belgium*

In Belgium, a significant initiative to promote sustainable timber procurement was launched in 2011. On March 1, 2011, a sector agreement was signed by various federal organizations, aiming to increase the market share of certified wood products to minimum 35% by the end of 2018. It set specific targets for the share of primary wood products originating from sustainably managed forests: e.g. at least 35% by December 31, 2018 (FPS Health, 2016). A survey for 2012 revealed that the share of wood-based products from sustainably managed forests had already reached 40.5%, surpassing the 2018 target six years ahead of schedule (Programme for the Endorsement of Forest Certification, 2014). The positive trend continued, with a 2016 market survey indicating that the share of certified timber products in the Belgian market had risen to 59.5% (FPS Health, 2016).

These examples show that policies like sustainable procurement policies and market initiatives can create a push of demand for certified goods which motivates companies to pursue certification to meet these demands.

# 4. Discussions on feasibility assessment

## 4.1 Case study 1: Sugar cane

The results indicated an increase in costs associated with GHG emissions, while the costs associated with the other environmental indicators either increased or decreased. The companies assessed are in the state of Sao Paulo. The south-central region of Brazil, which is the main production region in the country, has expanded rapidly in the past years in Brazil. In the state of Sao Paulo, sugarcane cultivation increased by 143% while the number of pasture areas decreased by 54% between 1999 and 2019 (Ogura et al., 2022).

Previous studies show that there is a strong spatial variation in the environmental performance of sugarcane expansion (Vera et al., 2020). Our results showed an increase in GHG emissions, when considering emissions from land use change. In general, the conversion of grassland and annual crops to sugarcane leads to net carbon sequestration, while the change from forest, eucalyptus and shrubland leads to land use change related CO2 emissions (Vera et al, 2020). Degraded pastures have experienced a sharp decrease in carrying capacity, productivity and biomass production (Feltran-Barbieri & Féres, 2021). Conversion of these pastures to sugarcane resulted in higher carbon sequestration and thus lower GHG emissions (Bordonal et al., 2018). The high variation in GHG emissions from land use change should be taken into account when interpreting the results.

The effects on water availability have been a significant concern for sugarcane (Vera et al., 2020). Previous studies also found a high spatial variation in the water use of sugarcane expansion (Vera et al., 2020). The variation is caused by differences in climatic conditions, particularly precipitation regimes and by the land use/cover prior to conversion.

Findings show that vinasse is used to reduce water consumption for the cultivation of crops. There are some environmental concerns about vinasse. Application of sugarcane vinasse on soil has some negative environmental impacts (Christofoletti et al., 2013). The environmental impact of vinasse application in sugarcane production is not taken into account in this study. This could imply a higher environmental burden associated with sugarcane production.

Evaluating the effect of the certificate on social externalities is very challenging due to data limitation. We had to rely on Social Hotspot Database to estimate the impact of the certificate on Brazilian companies in the sugar industry. The analysis indicates that being certified might have significant effect on reducing social externalities on average. Specifically, banning forced labour and child labour, which account for the highest external costs, can be a very effective instrument in reducing social externalities. Requiring procedures to reduce work related injuries and paying minimum wage are to a lesser extent also effective.

## 4.2 Case study 2: Cotton

Regarding direct costs and benefits, the case study results showed a positive effect of certification on producer prices and production efficiency. This finding is supported by other studies that assessed the economic impact of certification in cotton production.

The effect of BCI certification on producer prices is mixed, which can be explained by the different scope of the studies. In line with Pamuk et al. (2022), Ghori et al. (2022) found that BCI certified farmers received higher prices (+2.4%) than conventional farmers. Kumar et al. (2019) analysed the impact of better cotton on farmers in Kurnool district (India). They reported that most farmers are not in a position to select the traders upon whom they sell cotton and the corresponding price as they are indebted to them. Better Cotton certification did not change this. Pamuk et al. (2022) did also not observe a price effect in Adilabad region. This can be explained by the fact that Better Cotton is already more established in the Nagpur region, where a price effect was found. Kumar et al. (2019) suggest that producer organizations can enhance farmers' market position by facilitating price negotiations and enabling direct sales.

The effect of BCI certification on production costs is also mixed. In contrast to Pamuk et al., (2022), Kumar et al. (2019) found that certified farmers had slightly lower production costs and slightly better yields compared to those growing conventional cotton. However, the differences were small. The costs of chemical pesticides reduced due to BCI certification, and the costs of biopesticides increased. Ghori et al. (2022) also found that certification lowered total cost of production compared to conventional farms. Ghori et al. (2022) did not find a substantial difference in pesticide costs (Ghori et al., 2022), but they did find a modest decrease in fertilizer costs (-12.6%). The mixed findings can be explained by the difference in regional context of these case studies. Ghori et al. (2022) compared the impact of BCI certification in India and Pakistan. They found substantial and statistically significant reductions in pesticide expenditures and increases in cotton yields only in Pakistan. These findings highlight the potential role of local context in mediating BCI's impacts.

The evidence provided in various studies provides a mixed picture of the impacts of the BCI on the social indicators for farmers in India (Ghori et al., 2022; Kumar et al., 2019; Pamuk et al., 2022). While BCI's initiatives have led to some improvements in safety practices and raised awareness of child labour issues, the program's impact on economic conditions, particularly in terms of wages and working hours, has been less evident. Moreover, the translation from increased awareness for child labour may require time or targeted efforts for tangible changes observed on the cotton production fields.

Environmental and social impact of better Cotton is also dependent on the regional context it is referring to. Davis et al. (2021) compared the carbon footprint of BCI cotton lint and comparison production for 9 regions in India. At both national and state levels, Better Cotton had a lower carbon footprint than comparison production in all regions except the Haryana region (Davis, 2021). Fertiliser production was found to be the largest driver for differences in emissions between Better Cotton and comparison production (Davis, 2021). Soth (2023) reviewed LCA related studies that deal with cotton and textiles. The author concluded that methodically properly conducted LCAs show that sustainable cotton initiatives (such as organic and Better Cotton) keep their promise to lower the environmental impact of cotton production when benchmarked against conventional peers. However, the LCA data regarding the impact on toxicity is incomplete and do not allow for a conclusive assessment (Soth, 2023). Future studies should focus on these aspects to obtain better insight in the environmental costs and benefits of certified cotton.

Due to the lack of specific company production and revenue data, the quantification on social costs using the Social Hotspot Database and eco-cost Values is not applicable. Therefore, we have relied on three secondary literature studies. Positive to neutral impacts were observed for occupational health, child labour, and forced labour. In contrast, daily wages showed negative to neutral impacts, with more negative effects for female workers.

## 4.3 Case study 3: Wood

The impact of FSC and PEFC certification in the wood value chain is diverse. On internal costs, studies from regions such as the Nordic countries indicate that certification has not significantly improved the cost-benefit balance for forest owners, even though it enhances the environmental image of timber on international markets (Wolff and Schweinle, 2022). In several European contexts, modest or no price premiums were observed (Paluš et al., 2018; Halalisan et al., 2019; Romaniuk, 2008), though group certification can help reduce audit costs for small-scale nonindustrial forest owners. Regarding external environmental impacts, there are only limited number of studies that analysed effects of FSC on biodiversity (Matias et al., 2024). FSC certification tends to enhance biodiversity. This is especially observed by flora richness and mammal abundance (Matias et al., 2024; Afonso et al., 2021) and it generally has a positive impact on carbon stocks (Wolff and Schweinle, 2022). Certification has also been linked to improved ecosystem services in certain cases (Pezdevšek Malovrh et al., 2019; Paluš et al., 2018). However, its social benefits remain limited, with only some negative to neutral evidence found in terms of worker safety (Konstantinaviciene et al., 2024; Hain and Ahas, 2011; Gómez-Zamalloa and Caparrós, 2011). Overall, while FSC and PEFC certifications enhance ecosystem services, biodiversity, and market legitimacy in the wood value chain, their economic and social impacts vary, highlighting the need for long-term assessment and stronger social indicators and monitoring efforts.

## 4.4 Synthesis of discussion on all three case studies

The feasibility of certification adoption in selected value chains is influenced by a complex interplay of economic, environmental, social, and policy-driven factors. While CBA provides insights into the economic viability of certification, it does not fully capture the motivations behind adoption. The case study findings indicate that while certification can improve efficiency, market access, and sustainability outcomes, its impact is highly context dependent.

One of the main drivers for certification adoption is direct financial incentives, such as price premiums and cost savings from improved efficiency. The case studies demonstrate mixed economic outcomes, while some certifications led to higher producer prices and cost reductions, others showed negligible or regionally dependent benefits. Certification can also enhance bargaining power and facilitate entry into global markets, particularly when demand for certified goods is strong. However, in cases where producers remain dependent on intermediaries, such as in cotton value chains, certification alone does not necessarily translate into better market conditions. The presence of supporting infrastructure, such as training programs and market linkages, can further enhance the economic viability of certification.

Beyond economic factors, environmental and social impacts also play a role. Certification schemes often contribute to improved biodiversity, carbon sequestration, and ecosystem services, as seen in the forestry and agricultural sectors. However, the extent of these benefits varies depending on prior land use and regional conditions. Socially, certification can reduce harmful labor practices, such as child and forced labor, and improve workplace safety, but its impact on wages and working conditions remains uncertain. This highlights the need for complementary policies and institutional support to maximize social benefits.

The influence of policy on certification adoption can be observed in the timber sector, where public procurement policies in the Netherlands, Germany, and Belgium seem to have contributed to a rise in the market share of certified timber products. These examples suggest that regulatory frameworks can create demand for certification by setting sustainability criteria for public procurement, thereby encouraging producers to obtain certification to access these markets. While a direct causal relationship is difficult to establish, the observed increase in certified timber following public procurement policies' implementation stresses the potential of policy-driven market incentives to promote certification uptake.

Despite the clear drivers of certification adoption, the collection of data to assess its effectiveness has been challenging. Various barriers have impeded data availability, including companies' concerns about the sensitivity of the data, the lack of internal systems to track or quantify the required environmental and social performance indicators, and the general hesitation to invest time and resources in providing detailed responses to our survey. In some cases, companies expressed concerns about confidentiality or feared competitive disadvantages if their data were disclosed, even in anonymized formats. These challenges were discussed extensively in collaboration with sister projects, Harmonitor and STAR4BBS, through online meetings and workshops. Despite continuous efforts to mitigate these issues, data availability remains a significant hurdle for calculating costs and benefits and will likely continue to pose challenges for future projects aiming to assess certification impacts. Because of limited availability of data, some environmental and social externalities were excluded from the analysis. This implies that the results from CBA presented in this study do not provide a complete insight in the external costs and benefits associated with certification. Additionally, the scope of analysis varied by case. For example, the plastic chain was assessed from cradle to factory gate, while the cotton chain was evaluated from cradle to farm gate. The CBA analysis is from a very small sample size due to the difficulties to get company specific data. All these aspects should be considered when interpreting the results.

This study focused on costs and benefits associated with certification, including environmental and social costs. These costs can be affected not only by the requirements of a certification scheme, but also by other factors such climatic change (e.g. extreme climate effects), soil conditions, technological advancements and different management practices. Particularly in agricultural production, soil and climatic conditions strongly affect the sustainability performance. Flack-Prain et al. (2020) show that sugarcane yields are affected by extreme climate effects. These effects were not separated from the certification effect because data was lacking for these variables.

These findings suggest that the feasibility of adopting certification schemes is shaped by market conditions, environmental considerations, social governance structures, and policy support, with cost-benefit analysis serving as a crucial component of the overall feasibility assessment. Certification schemes are more likely to be successful when they are backed by strong market demand, cost-effective implementation strategies, and regulatory incentives. However, the difficulty in collecting reliable data highlights the need for better systems and processes to track certification performance over time. Future assessments should explore how policy instruments, such as subsidies, tax incentives, or mandatory sustainability requirements, can further enhance certification adoption and ensure its benefits are equitably distributed across value chains. Furthermore, overcoming data collection challenges—particularly for pre- and post-certification data, environmental indicators, and quantitative social indicators—will be crucial for more accurately assessing the costs and benefits of certification schemes.

# 5. Conclusion

In conclusion, the feasibility of certification adoption is a complex process influenced by a range of economic, environmental, social, and policy factors.

This study represents the first attempt to conduct a feasibility assessment of certification schemes in biobased value chains by adopting a new CBA approach, which includes the internalization of externalities. Through this exercise, we have identified both the opportunities and gaps in current certification practices. The study highlights the critical need for comprehensive data collection to accurately measure the impacts of certification, as without reliable data, it is impossible to assess the true costs and benefits. In principle, comprehensive data collection includes comprehensive economic, environmental and social indicators as well as data collected from baseline, midline and endline of the certification adoption. While the internal benefits of certification generally outweigh the costs, the evaluation of external costs and benefits remains incomplete due to data limitations. Certifications show potential to reduce environmental and social externalities, though the effects vary. The results show significant gaps in data availability, particularly for environmental and social externalities, which limited the ability to conduct comprehensive CBA. Additionally, sustainability outcomes were influenced by external factors such as climate variability, soil conditions, and management practices, complicating the isolation of certification impacts. The lack of data, particularly on externalities is not only due to data sensitivity and organizations' reluctance to share information but also stems from the fact that measuring these externalities is often not mandatory and/or not possible to carry out due to a small size of the organizations and limited resources to do it. As a result, if something is not measured, its impact remains unknown, making it difficult to assess the true costs and benefits of certification. Addressing these data limitations is critical to better align certification practices with sustainability goals and to enhance the accuracy of cost-benefit analyses for biobased value chains.

## 5.1 Recommendations

To address the data gap, policymakers and certification bodies may consider introducing standardized reporting requirements for key externalities and developing standardized, transparent metrics such as greenhouse gas emissions, water use, and social impacts across different certification schemes, which could be feasible to include in CBA as external costs and benefits. This will enable more accurate comparisons and better monetization of externalities. One way the BIOBASEDCERT cluster is addressing the lack of standardisation within certification of bio-based markets is through the development of a so-called BIOBASEDCERT Monitoring Tool or BMT. The

BMT aims to assess the comprehensiveness, robustness, and effectiveness of sustainability certification schemes and labels (CSLs) for biobased value chains. The tool is currently in its final stages of development and can help to pinpoint strengths and weaknesses of CSLs and thus eventually contribute to their improvement. Hereby there is a crucial role also for the researchers in developing of the harmonised methodology to standardise the key metrics. At the same time, we recommend further research into the types of support, incentives, and motivations (e.g., business case elements) that would most effectively enable companies to collect and monitor such data, especially in under-researched areas.

To enhance the economic viability of certification schemes, policymakers and value chain actors can complement certification with direct financial incentives, robust support infrastructure (e.g., training programs and market linkages), and strategies to reduce producer dependence on intermediaries—especially in sectors like cotton. Tailoring support to regional market conditions can also help ensure that the benefits of certification are equitably realized.

Policy-driven market incentives, such as sustainability criteria in public procurement, can effectively promote certification adoption. Expanding similar regulatory frameworks in timber could further drive certification uptake.

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# Appendix

## Appendix 1: Questionnaires

### I. Questionnaire Related to the certified ethanol

Thank you for agreeing to respond to this questionnaire. If you would like to have your company's name appear in project materials, such as publicly available reports, please indicate so below:

| |
|---|
| I consent to my company's name being included in e.g. public reports: ☐Yes ☐No<br>Company name (please fill in only if you would want it to be included): Click or tap here to enter text. |

*Kindly respond to the following questions and statements about your certification. In the third column, you are welcome to provide an explanation for each response.*

*If a statement is not relevant for your company or you would prefer not to answer, please specify this in the text column.*

| Question | Response | Kindly provide an explanation here |
|---|---|---|
| a. The main motivation for being certified is export to Europe | ☐Yes<br>☐No | Click or tap here to enter text. |
| b. Getting this certification results in an increase in the selling price | ☐Yes<br>☐No | Click or tap here to enter text. |
| c. Getting this certification is needed to sell our products to | ☐Europe<br>☐North America<br>☐Asia<br>☐Other, please specify | Click or tap here to enter text. |
| d. Being certified enables me to negotiate a higher price for my products for different markets: | ☐Yes<br>☐No | **By how much?**<br>Europe: XX%<br>North America: XX%<br>Asia: XX%<br>Other markets, please specify which [enter here]: XX% |
| e. The main market for sugar we sell is: | ☐Europe<br>☐North America<br>☐Asia | Click or tap here to enter text. |

| | | |
|---|---|---|
| | ☐Other, please specify | |
| f. The main market for ethanol we sell is: | ☐Europe<br>☐North America<br>☐Asia<br>☐Other, please specify | Click or tap here to enter text. |
| **Do you agree with the following statements:**<br><br>g. The price of our product (<u>sugar</u>) is global and does not differ much in different countries | ☐Yes<br>☐No | Click or tap here to enter text. |
| h. The price of our product (<u>ethanol</u>) is global and does not differ much in different countries | ☐Yes<br>☐No | Click or tap here to enter text. |
| i. Getting certified does not result in a higher selling price but increases our reputation | ☐Yes<br>☐No | Click or tap here to enter text. |
| j. We are required, by regulators or customers, to get this certification | ☐Yes<br>☐No | Click or tap here to enter text. |
| k. Being certified gives my company a better market position | ☐Yes<br>☐No | Click or tap here to enter text. |
| l. Being certified improves the management or production efficiency within my company | ☐Yes<br>☐No | Click or tap here to enter text. |

<u>General company information</u>

*Kindly complete the following tables to the best of your ability, with information from the most recent year for which data is available.*

| Item | Value | Unit | Further specification, if applicable |
|---|---|---|---|
| Total volume of sugar produced | [enter here] | Ton | Click or tap here to enter text. |
| Total amount of sugarcane processed | [enter here] | Ton | Click or tap here to enter text. |

| | | | |
|---|---|---|---|
| | | | |
| Total amount of sugarcane produced | [enter here] | Ton | Click or tap here to enter text. |
| Total area of sugarcane that is certified | [enter here] | Hectares | Click or tap here to enter text. |
| Total soil area of sugarcane that is not certified | [enter here] | Hectares | Click or tap here to enter text. |
| Total number of employees | [enter here] | People (total amount of full-time equivalent employees working in the company | Click or tap here to enter text. |

## Certification

| Item | Description | Value | Unit | Further specification, if applicable |
|---|---|---|---|---|
| Administration costs | Administrative costs related to adapting company or farm processes to align with the certification requirements or to prove compliance | [enter here] | Brazilian Real | Click or tap here to enter text. |
| Costs related to compliance with the certification requirements | Man-days needed to train staff members to work with the certification requirements | [enter here] | Man-days | Click or tap here to enter text. |
| | Investment in equipment required for complying with the certification requirements | [enter here] | Brazilian Real | Click or tap here to enter text. |
| | Consultancy service cost to prepare for certifications | [enter here] | Brazilian Real | Click or tap here to enter text. |
| | Other costs needed to comply with the certification requirements | [enter here] | Brazilian Real | Click or tap here to enter text. |

Many thanks for your replies!

We will treat all responses with full confidentiality and aggregate all data so nothing can be traced back to individual companies.

## II. Questionnaire Related to the Better Cotton (BC) Certification

Thank you for agreeing to respond to this questionnaire. If you would like to have your company's name appear in project materials, such as publicly available reports, please indicate so below:

| |
|---|
| I consent to my company's name being included in e.g. public reports: ☐Yes ☐No<br><br>Company name (please fill in only if you would want it to be included): Click or tap here to enter text. |

Any information you would be able to provide in the following tables would be much appreciated. Your contributions to the following tables will ultimately enable this project to better understand the environmental and social benefits of BC certification, thereby providing valuable insights on sustainability certification schemes and labels for the textile industry!

Kindly respond to the following questions and statements about BC certification to the best of your ability. Additionally, you are welcome to provide a brief explanation or clarification for your responses when applicable.

***Business Operations- Please fill in what applies to your business***

| **Question** | **Answer** | **Explanation** |
|---|---|---|
| What is your company's main business activity?<br><br>If applicable, you are welcome to select multiple answers. | ☐Cotton farming<br><br>☐Cotton processing<br><br>☐Production of cotton-based textiles<br><br>☐Other: [please specify here] | [optional: provide explanation or clarification here] |
| What is the scale of your operations? | ☐Local<br><br>☐National<br><br>☐Europe<br><br>☐Global<br><br>☐Other: [please specify here] | [optional: provide explanation or clarification here] |
| Where do your primary sources of BC-certified products come from? | ☐India<br><br>☐Pakistan<br><br>☐Brazil<br><br>☐Turkey<br><br>☐Mozambique<br><br>☐Other: [please specify here] | [optional: provide explanation or clarification here] |

***Business activities in relation to BC certification***

| | |
|---|---|
| **Product types and name with BC Certification** | [enter product type(s) and name here] |
| **What percentages of your products are BC certified (%)?** | [enter value here] |

*Adoption of BC certification*

| **Questions** | **Answers** | **Explanation** |
|---|---|---|
| a. The main motivation for being BC certified is (select up to three answers): | ☐ Our commitment to sustainability<br>☐ Because our clients demand it<br>☐ Because regulators demand it<br>☐ To improve production efficiency<br>☐ To improve management practices<br>☐ To improve our market position<br>☐ To get access to new market(s)<br>☐ To strengthen our brand image<br>☐ Other: [specify here] | [optional: provide explanation for selected answers] |
| b. The estimated increase in sales facilitated by BC certification is: | ☐ 0-5%<br>☐ 6-10%<br>☐ 11-15%<br>☐ More than 16%<br>☐ None | [optional: provide explanation or clarification here] |
| c. Being BC certified enables me to negotiate a higher selling price for my products for different markets: | ☐ Yes<br>☐ No<br><br>If yes, which?<br>☐ Europe<br>☐ North America<br>☐ Asia<br>☐ Other: [specify here] | If yes, by how much compared to before BC certification?<br><br>Europe: XX%<br>North America: XX%<br>Asia: XX% |

| | | |
|---|---|---|
| | | Other: [specify] \| XX% |
| d. What is the largest market for your company's main BC-certified product? | ☐ Europe<br>☐ North America<br>☐ Asia<br>☐ Other: [specify] | [optional: provide explanation or clarification here] |
| e. Getting BC results in a change of the cost price | ☐ The cost price increases<br>☐ The cost price does not change<br>☐ The cost price decreases | If change, how much?<br>☐ 0-5%<br>☐ 6-10%<br>☐ 11-15%<br>☐ More than 16%<br>☐ Other: [specify here] |
| f. Our company received subsidies from NGOs or the government to pursue BC certification | ☐ Yes<br>☐ No<br>☐ I don't want to say | [optional: provide explanation for selected answers] |

*BC certification costs - Please fill in what applies to your business*

| **Item** | **Description** | **Value** | **Unit** |
|---|---|---|---|
| Auditing costs | Audit fees | [enter value here] | Euros<br>Other: [specify here] |
| Certification costs | Costs for the certification process, including application fees and membership fee | [enter value here] | Euros<br>Other: [specify here] |
| Administration costs | Administrative costs incurred in adapting the company's process to align with BC requirements | [enter value here] | Euros<br>Other: [specify here] |

| | | | |
|---|---|---|---|
| Costs related to compliance with BC requirements | Extra costs related to training staff members to work with BC requirements along the supply chain | [enter value here] | Euros<br>Other: [specify here] |
| | Investment in equipment required for complying with the BC requirements | [enter value here] | Euros<br>Other: [specify here] |
| | Consultancy service cost to get certificates | [enter value here] | Euros<br>Other: [specify here] |
| | Costs associated with ensuring fair labor practices and safe working conditions across the supply chain | [enter value here] | Euros<br>Other: [specify here] |
| | Costs associated with energy and water use for recycling processes | [enter value here] | Euros<br>Other: [specify here] |
| | Operational costs related to managing the environmental impact of the recycling processes (e.g., emissions control, waste management) | [enter value here] | Euros<br>Other: [specify here] |

**Questions Related to Social and Environmental Benefits**

Social Benefits

1. Do you collect indicators related to the social information of your company's contribution to social sustainability? If yes, please fill in the table below and you may fill in more than the listed indicators.

| Social Indicator | Unit | Value | Explanation (if applicable) |
|---|---|---|---|
| Community and indigenous rights protection | [enter here] | [enter here] | [enter here] |
| Fair wage for labors | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

2. What was the social performance of your company **at the time of the initial audit** and **5 years after the initial audit**? If the company was certified less than 5 years ago, refer to the most recent year for which data is available. Please fill out the information below and you may fill in more than the listed indicators:

| | **At the initial audit** | **5 years after audit** | Explanation |
|---|---|---|---|
| Wage paid to the workers on the cotton field | [enter here] $/hour (or local currency/hour) | [enter here] $/hour (or local currency/hour) | [enter here] |
| Local minimum income | [enter here] $/hour (or local currency/hour) | [enter here] $/hour (or local currency/hour) | [enter here] |
| Income farmer | [enter here] $/hectare (or other currency) | [enter here] $/hectare (or other currency) | [enter here] |
| Work-related injury rate | [enter here] number of lost-time due to injures per million hours worked | [enter here] number of lost-time due to injures per million hours worked | [enter here] |
| Child labor used | [enter here] hours/year | [enter here] hours/year | [enter here] |
| Involuntary work | [enter here] hours/year | [enter here] hours/year | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

<u>Environmental Benefits</u>

1. Do you collect environmental information for your company's contribution to environmental sustainability? If yes, please fill in the table below and you may fill in more than the listed indicators.

| Environmental Indicator | Value | Unit | Explanation (if applicable) |
|---|---|---|---|
| Reduction in use of pesticides | [enter here] | Kg/hectare | [enter here] |
| Reduction in use of fertilizer | [enter here] | Kg/hectare | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

| | | | |
|---|---|---|---|
| [enter here] | [enter here] | [enter here] | [enter here] |

2. What was the environmental performance of your company at the time of **the initial audit**? Kindly provide information that you have access to in the fields below. (Please provide your answer under the last column if your functional unit used to quantify these impacts is not per tonne).

| Indicator | Value | Unit | Explanation (if applicable) |
|---|---|---|---|
| Greenhouse gas emissions | [enter here] | Kg $CO_2$ eq./tonne | [enter here] |
| Water use | [enter here] | $m^3$ water/tonne | [enter here] |
| Fossil energy use | [enter here] | Electricity: kWh/tonne | [enter here] |
| | [enter here] | Natural gas: $m^3$/tonne | [enter here] |
| | [enter here] | Diesel: L/tonne … | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

3. What was the environmental performance of your company **5 years after the initial audit**? If the company was certified less than 5 years ago, refer to the most recent year for which data is available. (Please provide your answer under the last column if your functional unit used to quantify these impacts is not per tonne).

| Indicator | Value | Unit | Explanation (if applicable) |
|---|---|---|---|
| Greenhouse gas emissions | [enter here] | Kg $CO_2$ eq./tonne seed cotton | [enter here] |
| Water use | [enter here] | $m^3$ water/tonne seed cotton | [enter here] |
| Fossil energy use | [enter here] | Electricity: kWh/tonne seed cotton | [enter here] |
| | [enter here] | Diesel: L/tonne seed cotton | [enter here] |
| | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

**Many thanks for your replies!**

**We will treat all responses with full confidentiality and aggregate all data so nothing can be traced back to individual companies.**

# III. Questionnaire Related to the Forest Stewardship Council (FSC) Certification

Thank you for agreeing to respond to this questionnaire. If you would like to have your company's name appear in project materials, such as publicly available reports, please indicate so below:

| |
|---|
| I consent to my company's name being included in e.g. public reports: ☐Yes ☐No<br>Company name (please fill in only if you would want it to be included): Click or tap here to enter text. |

Kindly respond to the following questions and statements about FSC certification to the best of your ability. Additionally, you are welcome to provide a brief explanation or clarification for your responses when applicable.

***Business Operations***

| Question | Answer | Explanation |
|---|---|---|
| What is your company's main business activity?<br>If applicable, you are welcome to select multiple answers. | ☐Forest management<br>☐Timber harvesting<br>☐Wood processing and manufacturing<br>☐Trading and distribution<br>☐Print and publishing<br>☐Production of furniture and home goods<br>☐Other: [please specify here] | [optional: provide explanation or clarification here] |
| What is the scale of your operations? | ☐Local<br>☐National<br>☐Europe<br>☐Global<br>☐Other: [please specify here] | [optional: provide explanation or clarification here] |
| Where do your primary sources of FSC-certified products come from? | ☐FSC-certified forests or plantations<br>☐ FSC-certified processing and manufacturing companies<br>☐FSC-certified products from companies<br>☐Other: [please specify here] | [optional: provide explanation or clarification here] |

***Business activities in relation to FSC certification***

| | |
|---|---|
| **Product types with FSC Certification** | [enter product type(s) here] |

| | |
|---|---|
| **What percentages of your products are FSC certified (%)?** | [enter value here] |
| **What climatic zone do your FSC-certified products come from?** If applicable, you are welcome to select multiple answers. | ☐Tropical climatic zone<br>☐Subtropical climatic zone<br>☐Temperate climatic zone<br>☐Boreal climatic zone<br>☐Mediterranean climatic zone<br>☐Montane climatic zone<br>☐Other: [please specify here] |
| **What forest type do your FSC-certified products come from?** If applicable, you are welcome to select multiple answers. | ☐Boreal forest<br>☐Temperate forest<br>☐Tropical rainforest<br>☐Tropical dry forest<br>☐Mangrove rainforest<br>☐Plantation forest<br>☐Other: [please specify here] |

***Please fill in the table below for only products with FSC certification***

| Item | Value | Unit |
|---|---|---|
| Annual production volume of FSC-certified products at your company | [enter value here] | Ton<br>Other: [specify here] |
| Percentage of your total product line that is FSC-certified | [enter value here] | % |
| Total number of full-time employees working at the company | [enter value here] | Full-time equivalent |

***Adoption of FSC certification***

| Questions | Answers | Explanation |
|---|---|---|

<table>
<tr>
<td>a. The main motivation for being FSC certified is (select up to three answers):</td>
<td>☐ Our commitment to sustainability<br>☐ Because our clients demand it<br>☐ Because regulators demand it<br>☐ To improve production efficiency<br>☐ To improve management practices<br>☐ To improve our market position<br>☐ To get access to new market(s)<br>☐ To strengthen our brand image<br>☐ Other: [specify here]</td>
<td>[optional: provide explanation for selected answers]</td>
</tr>
<tr>
<td>b. The estimated increase in sales facilitated by FSC certification is:</td>
<td>☐ 0-5%<br>☐ 6-10%<br>☐ 11-15%<br>☐ More than 16%<br>☐ None</td>
<td>[optional: provide explanation or clarification here]</td>
</tr>
<tr>
<td>c. Being FSC certified enables me to negotiate a higher selling price for my products for different markets:</td>
<td>☐ Yes<br>☐ No<br>If yes, which?<br>☐ Europe<br>☐ North America<br>☐ Asia<br>☐ Other: [specify here]</td>
<td>If yes, by how much compared to before FSC certification?
<table>
<tr><td>Europe</td><td>XX%</td></tr>
<tr><td>North America</td><td>XX%</td></tr>
<tr><td>Asia</td><td>XX%</td></tr>
<tr><td>Other: [specify]</td><td>XX%</td></tr>
</table>
</td>
</tr>
<tr>
<td>d. What is the largest market for your company's main FSC-certified product?</td>
<td>☐ Europe<br>☐ North America<br>☐ Asia<br>☐ Other: [specify]</td>
<td>[optional: provide explanation or clarification here]</td>
</tr>
</table>

***FSC certification costs***

| Item | Description | Value | Unit |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Auditing costs | Audit fees | [enter value here] | Euros<br>Other: [specify here] |
| Certification costs | Costs for the certification process, including application fees and membership fee | [enter value here] | Euros<br>Other: [specify here] |
| Administration costs | Administrative costs incurred in adapting the company's process to align with FSC requirements | [enter value here] | Euros<br>Other: [specify here] |
| Costs related to compliance with FSC requirements | Extra costs related to training staff members to work with FSC requirements along the supply chain | [enter value here] | Euros<br>Other: [specify here] |
| | Investment in equipment required for complying with the FSC requirements | [enter value here] | Euros<br>Other: [specify here] |
| | Consultancy service cost to get certificates | [enter value here] | Euros<br>Other: [specify here] |
| | Costs associated with ensuring fair labor practices and safe working conditions across the supply chain | [enter value here] | Euros<br>Other: [specify here] |
| | Costs associated with energy and water use for recycling processes | [enter value here] | Euros<br>Other: [specify here] |
| | Operational costs related to managing the environmental impact of the recycling processes (e.g., emissions control, waste management) | [enter value here] | Euros<br>Other: [specify here] |

**Would you like to provide more information related to the social and environmental factors associated with being FSC certified?** If so, kindly scroll to the next page and fill out the subsequent tables to the best of your ability. If you are unsure of the answer to any of the fields in the table, feel free to skip them. Any information you would be able to provide in the following tables would be much appreciated. Your contributions to the following tables will ultimately enable this project to better understand the environmental and social benefits of FSC certification, thereby providing valuable insights on sustainability certification schemes and labels for the entire wood industry!

**Questions Related to Environmental and Social Benefits**

<u>Environmental Benefits</u>

1. Do you collect environmental information for your company's contribution to environmental sustainability? If yes, please fill in the table below and you may fill in more than the listed indicators.

| Environmental Indicator | Value | Unit | Explanation (if applicable) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Sustainable harvesting | [enter here] | [enter here] | [enter here] |
| Protection of high conservation value areas | [enter here] | [enter here] | [enter here] |
| Species protection | [enter here] | [enter here] | [enter here] |
| Habitat preservation | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

2. What was the environmental performance of your company at the time of **the initial audit**? Kindly provide information that you have access to in the fields below. (Please provide your answer under the last column if your functional unit used to quantify these impacts is not per tonne).

| Indicator | Value | Unit | Explanation (if applicable) |
|---|---|---|---|
| Greenhouse gas emissions | [enter here] | Kg $CO_2$ eq./tonne | [enter here] |
| Water use | [enter here] | $m^3$ water/tonne | [enter here] |
| Fossil energy use | [enter here] | Electricity: kWh/tonne | [enter here] |
| | [enter here] | Natural gas: $m^3$/tonne | [enter here] |
| | [enter here] | Diesel: L/tonne … | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

3. What was the environmental performance of your company **5 years after the initial audit**? If the company was certified less than 5 years ago, refer to the most recent year for which data is available. (Please provide your answer under the last column if your functional unit used to quantify these impacts is not per tonne).

| Indicator | Value | Unit | Explanation (if applicable) |
|---|---|---|---|
| Greenhouse gas emissions | [enter here] | Kg $CO_2$ eq./tonne | [enter here] |
| Water use | [enter here] | $m^3$ water/tonne | [enter here] |
| Fossil energy use | [enter here] | Electricity: kWh/tonne | [enter here] |

| | | | |
|---|---|---|---|
| | [enter here] | Natural gas: $m^3$/tonne | [enter here] |
| | [enter here] | Diesel: L/tonne | [enter here] |

Social Benefits

4. Do you collect indicators related to the social information of your company's contribution to social sustainability? If yes, please fill in the table below and you may fill in more than the listed indicators.

| Social Indicator | Unit | Value | Explanation (if applicable) |
|---|---|---|---|
| Community and indigenous rights protection | [enter here] | [enter here] | [enter here] |
| Fair wage for labors | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |
| [enter here] | [enter here] | [enter here] | [enter here] |

5. What was the social performance of your company **at the time of the initial audit** and **5 years after the initial audit**? If the company was certified less than 5 years ago, refer to the most recent year for which data is available. Please fill out the information below:

| | **At the initial audit** | **5 years after audit** | Explanation |
|---|---|---|---|
| Living wage gap (living wage minus current wage) | [enter here] $/hour | [enter here] $/hour | [enter here] |
| Work-related injury rate | [enter here] incidence/hours worked | [enter here] incidence/hours worked | [enter here] |
| Child labor used | [enter here] hours/year | [enter here] hours/year | [enter here] |
| Involuntary work | [enter here] hours/year | [enter here] hours/year | [enter here] |

**Many thanks for your replies!**

**We will treat all responses with full confidentiality and aggregate all data so nothing can be traced back to individual companies.**

# Appendix 2: Eco-cost values

*Table A1 Eco-cost values of selected externalities*

| Externality | Unit | Value |
|---|---|---|
| Climate change | Euro/kg $CO_2$ eq. | 0.133 |
| Water stress | Euro/$m^3$ water | 1 |
| Fossil resource scarcity | Euro/kg oil | 0.78 |
| | Euro/$m^3$ natural gas | 0.66 |
| | Euro/kg diesel (transport) | 0.429 |
| Acidification | Euro/kg $SO_2$ eq. | 10 |
| Workplace injuries* | DALY / hr (Disability adjusted life year/hour) | 0.00001 – 0.00002 |
| Forced labour* | DALY / hr (Disability adjusted life year/hour) | 0.000162 – 0.000223 |
| Child labour* | DALY / hr (Disability adjusted life year/hour) | 0 – 0.000446 |
| Fair wage* | Int $ PPP / hr (hourly wage or income converted to international dollars using Purchasing Power Parity) | 0 – 5.79 |
| Workplace injuries** | Euro/hour | 1.097 |
| Forced labour** | Euro/hour | 11.060 |
| Child labour** | Euro/hour | 18.150 |
| Fair wage** | Euro/hour | 3.050 |

* The monetization factor for workplace injuries, forced labour, child labour and fair wage is dependent on the risk factor. **social eco-cost values V3.3. in Simapro also provides these monetization factors in the unit of euro/hour or dollar/hour. For workplace injuries, we have taken the average value for work related mortality and injuries across all the countries in the database as a proxy for the first case as the specific value is not available for Brazil. For forced labour, we have taken the average value of all the endpoint values of excessive involuntary working hours. For child labour, we have taken the average value for child labour agriculture and child labour general, without child labour industrial. For fair wage, we have taken the average value of all the endpoint values of fair wage deficit.

# Appendix 3: Explanation of the environmental externalities calculation for the cotton case

The calculation of the selected environmental externalities for the cotton case is based on the data (Environmental impacts in Table V2 & Production data in Table V3) provided by the study of Shah et al., 2018 as well the monetization factor from EcoCost (2024 values). The environmental impacts for climate change, acidification, water scarcity and eutrophication is a simply multiplication of environmental impacts in Table V2 and the matching eco-cost values in Table V4. For the fossil resource scarcity, diesel use in Table V3 was first converted to kg/ha*year use the conversion factor provided by CBS (Statistics Netherlands), then the eco-cost value for diesel for transport in Table V4 was used to calculate the cost. Table V5 explains the detailed calculation for the final results in Table 7.

Table A2: Environmental impacts of selected environmental externalities (taken from Table 2 of (Shah et al., 2018))

| Environmental impact | Unit (per tonne of cotton seed) | Conventional Value | Better Cotton Initiative Value |
|---|---|---|---|
| Climate change | kg CO2-eq | 731 | 435 |
| Acidification | kg SO2-eq | 14,06 | 12,14 |
| Blue water consumption | m3 blue water | 541 | 330,61 |
| Eutrophication | kg P-eq. | 12,14 | 7,07 |
| Total primary energy demand | MJ | 5375 | 2510 |

Table A3: Production data BCI cotton and conventional cotton (taken from Table 1 of (Shah et al., 2018))

| | Variable | Unit | Conventional | Better Cotton Initiative |
|---|---|---|---|---|
| Production | Yield seed cotton | Kg fresh weight/ha | 2000 | 2.097 |
| Input | Seeds | Kg/ha*year | 1.530 | 2.175 |
| | Fertilizer NPK use | Kg/ha*year | 39,5 | 40 |
| | Diesel use | l/ha*year | 85 | 44 |
| | Pesticide use (kg /ha) | kg active ingredient/ha | 2,4 | 1 |
| | Irrigation water use (m3/ha) | m3/ha | 1080 | 692 |

(Diesel weight (kg/liter) = 0,84. source: https://www.cbs.nl/en-gb/onze-diensten/methods/definitions/weight-units-energy)

Table A4: Eco-cost values of selected externalities used in the cotton case

| | Unit | EcoCost (2024 values) |
|---|---|---|
| *Prices environmental externalities* | | |
| Climate change | €/kg CO2-eq | 0,133 |
| Acidification | €/kg SO2-eq | 10 |
| Water scarcity (2022 values) | euro/m3 | 1 |
| Eutrophication | euro/kg P equivalent | 16,46 |
| Diesel for transport | €/kg | 0,429 |

Table A5: Detailed calculation for the environmental costs in Table 7

| Costs | Item | Value in euro/ton seed cotton |
|---|---|---|
| **Environmental** | Climate change | -39,37 = 435*0,133 – 731*0,133 |
| | Water use | -210,39 = 330,61*1-541*1 |
| | Fossil resource scarcity | -14,77 = 44*0,84*0,429 - 85*0,84*0,429 |
| | Eutrophication | -83,45=7,07*16,46-12,14*16,46 |
| | Acidification | -19,20=12,14*10-14,06*10 |
| | Total | -367,18 |

## About SUSTCERT4BIOBASED

SUSTCERT4BIOBASED is an EU funded (Horizon Europe) project aiming at defining and promoting the adoption of effective and robust sustainability certification schemes and business-to-business labels for industrial biobased systems to support tracing the sustainability (environmental, social, economic) of biobased products along the value chains and trades within the EU and globally for responsible production and consumption. This objective is realised by the development of a monitoring system, mapping of the current situation in global trade flows of biological resources and biobased products, and feasibility assessment from the adoption of certification schemes and labels considering actual economic as well as internalized environmental and social costs and benefits. The results of the project are leveraged to provide recommendations to four key target groups: policy makers, sustainability system community, industrial biobased value chain actors, and regional bioeconomy stakeholders. These ambitions are addressed by a strong, well-balanced and multi-disciplinary consortium comprised of 5 complementary partners. SUSTCERT4BIOBASED thereby supports the development of harmonized system requirements, continuous improvement of sustainability certification schemes and labels and contributes towards establishing a circular, climate-neutral and sustainable biobased industry.

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