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Strengthening Social Life Cycle Assessment for a just bioeconomy: Insights from Namibia's bush-based value chains☆

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ABSTRACT

The bioeconomy has the potential to contribute significantly to sustainable development and a just transition. To ensure the sustainable production of bio-based products, it is essential to understand their potential environmental, economic, and social impact. However, the social dimension receives far less attention in sustainability literature and assessments than the environmental and economic dimensions. Especially in the Global South, where a large part of the world's biomass is produced, vulnerable communities are at higher risk of being negatively affected by the bioeconomy. These risks include food insecurity, monoculture expansion, and unequal wealth distribution. Therefore, it is crucial to understand new bio-based value chains' (potential) social impacts better.

This paper contributes to this debate by developing a prospective Social Life Cycle Assessment (SLCA) for a bush-based value chain in Namibia. We assessed the existing charcoal value chain and identified potential social risks, impacts, and opportunities of a prospective value chain to produce marine biofuels from encroacher bush. We use this case study to reflect on the SLCA methodology and compare the SLCA results with our qualitative fieldwork based on interviews and a multi-stakeholder workshop. We found that the current methods for SLCA do not adequately capture salient aspects of the local context. SLCA is a good method to quantify some social impacts and to identify social risks in the value chain, such as labor conditions and existing policies. However, the methodology of SLCA currently misses a more nuanced understanding of the context and potential social issues, like issues related to gender and ethnicity, and the adherence to existing policies. We propose adding more context-specific indicators to the risk assessment. In addition, stakeholder engagement is crucial for identifying and assessing relevant social impact categories, and we advocate for incorporating local stakeholders' subjective assessments. This approach allows for the inclusion of softer social impact categories, such as gender and ethnicity-related social norms, which are not easily captured by general indicators.

1. Introduction

The bioeconomy is a promising concept to advance sustainable development and a just transition (Lewandowski et al., 2018; Kumar Sarangi et al., 2023). Creating value chains based on biomass from agricultural or forestry residues instead of fossil-based resources can have multiple economic, environmental, and social benefits. These benefits include emission reduction, improvement of residue management, and additional income for biomass producers (Ladu and Morone, 2021; van der Veen et al., 2024). Because of this potential, over 50 countries have developed bioeconomy-related policy strategies to achieve sustainability targets (Zeug et al., 2023). However, introducing new bio-based value chains could also lead to negative instead of positive outcomes (Hoffman et al., 2021).

To ensure the sustainable production of bio-based products, it is essential to understand the potential environmental, economic, and social impacts (Lago-Olveira et al., 2024). Even though the social dimension is equally important to sustainable development, it receives

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less attention in sustainability literature. Current sustainability assessments focus on the environmental and economic dimensions and often, the social dimension is left out of the analysis (Janker and Mann, 2018). This is also prominent in the literature on bioeconomy, where the social dimension is the least analyzed sustainability dimension (Ferreira et al., 2022). Moreover, when the social dimension is included, social impact analyses of the bioeconomy mainly focus on employment-related variables, leaving out other important social impact factors (ibid). This is an issue since research has shown that bio-based value chains could create negative social impacts, especially for populations in the Global South where vulnerable communities are more likely to bear greater proportions of the risks of the growing demand for biomass, such as monoculture expansion, uncertain investments, and unequal wealth distribution (Lima, 2022). Developing new bio-based value chains should help improve the quality of life for all those affected, or at least not exacerbate or intensify existing social inequalities (van der Veen et al., 2024). Therefore, it is crucial to understand their (potential) social impact.

One of the reasons the social dimension is less represented in sustainability assessments is the difficulty of understanding and quantifying social issues (Janker and Mann, 2018; Lago-Olveira et al., 2024). One of the most advanced methods to assess the social impacts of products throughout their life cycle is the Social Life Cycle Assessment (SLCA) (Cadena et al., 2019). While the field of SLCA is growing, it is still less advanced than environmental Life Cycle Assessment (LCA) (Lago-Olveira et al., 2024). Even though the SLCA has advanced in recent years, there is no standardized approach yet (Huarachi et al., 2020). The selection of indicators can vary, which can already define the study results. The indicator sets established in the literature can be too unspecific for a case study, and therefore specific indicator sets should be selected for each case (Fürtner et al., 2021). This complicates the comparison of social performances of value chains (Kühnen and Hahn, 2017). In addition, there is increasing attention to SLCA studies in the bioeconomy field (Macombe et al., 2013; Cadena et al., 2019; Huarachi et al., 2020; Fürtner et al., 2021; Ladu and Morone, 2021), however, the majority have a general focus or focus mainly on the European context (Ferreira et al., 2022). There is a need for SLCA studies on bio-based value chains in the Global South.

An advantage of SLCA is that it uses steps and approaches similar to environmental LCA. This makes it feasible to integrate SLCA into an overall sustainability assessment and enables the quantification of potential sustainability impacts. At the same time, quantifying social impact risks losing important qualitative and nuanced information. This paper addresses these issues by answering the following research question: *How can social impact be incorporated into sustainability assessments of bio-based value chains?* In doing so, we contribute to the field of SLCA and address its potential and challenges for assessing social impact in the context of bio-based value chains in the Global South.

We answer our research question by presenting a real-life case study of a prospective value chain to produce marine biofuels from encroacher bush in Namibia. Encroacher bush affects about 45 million hectares in the country and grows at the expense of Savannah grasslands. This harms the ecological balance and affects people's livelihoods due to reduced grazing capacity for cattle and loss of tourism (MEFT, 2022). Creating new value chains from the bush can have significant environmental, economic, and social benefits (MITSMED, 2017). This offers a unique case to study the potential social impact of a prospective bio-based value chain in a Global South context. We conducted an SLCA based on the existing charcoal value chain and identified potential social impacts, risks, and opportunities of a new biofuel value chain from the bush. This can help decision-makers and value chain actors in a new value chain to address these potential social risks and impacts and identify opportunities. Apart from the SLCA, we conducted broader qualitative fieldwork, consisting of semi-structured interviews with open-ended questions, observations, and a multi-stakeholder workshop. We use this case study to reflect on the methodology of SLCA by comparing the results of the SLCA with our qualitative fieldwork to identify what the SLCA was able to capture and what was missing from the analysis. We then propose new factors that could be added to the SLCA method to create a more nuanced and realistic assessment of the potential social impacts, risks, and opportunities.

We argue that while SLCA is a good method to quantify some social impacts and to identify social risks in the value chain, the methodology of SLCA currently misses a more nuanced understanding of the context and potential social issues. Even though in our SLCA case study we followed a qualitative and participatory approach, we found that the SLCA did not fully represent the social issues and potential social impact of the value chain based on our interviews, observations, and workshop discussions. Therefore, it is crucial not to rely solely on generic indicators but to complement them with more fine-grained, context-specific information. Moreover, engagement with local stakeholders during the SLCA process is essential. Not only to receive feedback on the important subcategories, but also to assess and rank those subcategories.

We start this paper with a short literature overview of the research on the social dimension of sustainability and the SLCA. We then present our methodology, followed by a reflection on the results of the SLCA and recommendations.

2. Social dimension of sustainability

Sustainable development is commonly defined as ‘the ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). While this definition strongly focuses on people, most developed concepts, strategies, and measures in this field have an environmental focus. Even though there is increased attention to social and ethical issues in the bioeconomy literature, social impact is not represented equally in sustainability assessments (Janker and Mann, 2018). Consequently, the extent to which poverty or social inequalities are reduced or exacerbated for those affected remains unknown (Sanz-Hernández et al., 2019; Postal et al., 2020).

Social Life Cycle Assessment (SLCA) is one of the most advanced techniques to assess the social impacts of products throughout their life cycles (Macombe et al., 2013; Huarachi et al., 2020). SLCA was developed as part of the Life Cycle Sustainability Assessment (LCSA) tools. In the guidelines for SLCA, developed by UNEP/SETAC (2009), SLCA is defined as a technique of assessing products' social and socio-economic aspects and their positive and negative (potential) impacts along their life cycles. SLCA is an evaluation method that can be used to compare sectors, industries, or companies. It could also be used within companies or organizations to help decision-making and identify potential positive or negative social impacts (Lago-Olveira et al., 2024). The ultimate goal of conducting an SLCA is to improve a product's social conditions and socio-economic performance throughout its life cycle for all stakeholders involved. SLCA results can be used to stimulate these improvements and dialogue among stakeholders and decision-makers (UNEP/SETAC, 2009). SLCAs are mostly performed to evaluate the social impact of existing value chains (Ferreira et al., 2022). However, it can also identify potential social impacts and risks in new value chains (Yupanqui et al., 2024). This is especially interesting for the bioeconomy since bio-based value chains are often built on existing ones (Robaey et al., 2022).

Over the past three decades, the literature on SLCA has increased. SLCA has been applied in different contexts and multiple databases and methodological frameworks for impact assessments were developed (Huarachi et al., 2020). Despite the increased interest in SLCA, it remains less advanced than environmental LCA and no standardized approach exists (ibid). Various challenges have been identified by researchers who applied SLCA in different fields. First, there is a large number of socio-economic impacts that may arise, and impact categories need to be adapted to individual cases. This makes it difficult to standardize the approach (Fürtner et al., 2021). In addition, proper

indicators and consensus over metrics are lacking, since conceptualization is diverse (Ladu and Morone, 2021; Fürtner et al., 2021). Unlike environmental LCA, cause and effect are difficult to correlate, which makes it hard to select appropriate indicators (Siebert et al., 2018). Data availability is highly diverse (Siebert et al., 2018; Rafiaani et al., 2020) and social assessment is often based on qualitative information, which makes it complicated to express results based on the unit of system output (Rebolledo-Leiva et al., 2023).

One of the main challenges of SLCA is that, compared to the environmental and economic dimensions of sustainability, the social dimension is more open and contested (Lago-Olveira et al., 2024). Social impact is much more value-laden and normative. There is no common understanding of what 'social' means in the context of sustainability. We can use well-established indicators such as CO_2 equivalent or Gross Domestic Product (GDP) to determine environmental and economic impact. For social impact, a standardized or generally accepted operationalization is lacking (Reitinger et al., 2011; Huarachi et al., 2020; Lago-Olveira et al., 2024). What is understood as socially sustainable can differ over time and space. Even though these perceptions differ, the social dimension is essential for fulfilling people's needs, which is central to sustainable development. It should therefore not be neglected (Janker and Mann, 2018). Especially in the bioeconomy, there is a need to analyze the social implications of emerging bio-based value chains (Sanz-Hernández et al., 2019). Moreover, there is a need for studies on the potential impact of the bioeconomy in a Global South context, since a large part of the available biomass is located in the Global South. Here, the bioeconomy presents an important opportunity to contribute to people's livelihoods, since many households depend on agriculture. On the other hand, vulnerable communities are at higher risk of being negatively affected by the bioeconomy (Hoffman et al., 2021; Lima, 2022). More research is needed to help improve existing social sustainability practices and a structure for assessing social impact (Kaur and Sharma, 2017; Janker and Mann, 2018). We contribute to this growing field by reflecting on an SLCA on a bush-based value chain in Namibia and proposing concrete recommendations to strengthen the SLCA methodology.

3. Methods

3.1. Case study Namibia

Namibia is facing the major challenge of bush encroachment, caused by the spread of an indigenous woody species like blackthorn (*Senegalia mellifera*) at the expense of Savannah grassland. It affects about 45 million hectares, roughly a third of the country. This harms the ecological balance as it causes soil infertility, biodiversity loss, and groundwater depletion (MEFT, 2022). In addition, bush encroachment affects people's livelihoods due to the reduced grazing capacity of cattle. >70 % of the Namibian population directly or indirectly depends on agriculture for their livelihoods, of which most are cattle farmers. The reduced grazing capacity can lead to poverty and food insecurity (Lesoli et al., 2013; MEFT, 2022). The challenge of bush encroachment also presents an opportunity for Namibia's economic development. Creating new value chains based on the bush can offer considerable environmental, economic, and social advantages.

Namibia knows a complex social context, mainly due to the land tenure structure that resulted from land reform policies implemented after independence. First, commercial land is privately owned and used for commercial farming, mostly cattle farming, with an average farm size of 7000 ha, typically owned by European descendants. Second, communal land is owned by the state and managed by traditional authorities following customary laws. Communal land covers a significant part of the country (38 %), accommodating about half of the Namibian population (Beck, 2019). The land is mainly used for subsistence farming and grazing. Different tribes with unique characteristics, agricultural practices, beliefs, and customs inhabit and share the land. This makes the bush that grows on communal land a common-pool resource (Sato, 2022). Third, the government has acquired resettlement land from commercial farmers to resettle previously disadvantaged communities. The challenge of bush encroachment affects all land tenure systems. However, the capabilities and challenges faced are different for the three types of farmers.

Several smaller-scale value chains have been set up based on the bush, such as animal feed, fence posts, firewood, and wood chips. With an annual production of over 200.000 t, the most established value chain is the one for charcoal. Commercial farmers produce charcoal on their land, often using the manual labor of migrant workers, which is then processed and exported to Europe (MEFT, 2022). To date, communal farmers are prohibited from participating in this commercial value chain due to a moratorium placed by the government because of concerns about unequal benefit sharing and overexploitation, which might result in worse bush encroachment (Hindjou, 2021). Several pilots have been conducted in communal areas, which so far have been unsuccessful. Even though several value chains have been set up, the current utilization of 1.85 million tonnes of the bush is only 1 % of the total available biomass (Heck et al., 2021). So there is a large potential to create more value chains with larger market demand, such as biofuels for the shipping sector. However, new value chains could impose new social risks and negative social impacts. Therefore, it is important to understand the potential social implications of this new value chain.

The case study on encroacher bush in Namibia is part of a larger multi-stakeholder and multi-disciplinary research project to design inclusive and sustainable biofuels for the marine industry. Apart from Namibia, two other case studies have been selected in an iterative process with project partners who represent stakeholders in a biofuel value chain (shipping company, (bio)fuel producers, renewable energy platform, and an NGO). The selection was based on criteria to filter the options (e.g., biomass availability, utilization potential, infrastructure, and enabling policies) and features to compare potential cases (e.g., source of feedstock, geographical location, and Human Development Index). The other case studies focus on olive oil residues in Spain and coffee and cocoa residues in Colombia. Only for the Namibian case study, an SLCA was performed.

3.2. Goal and scope

The goal of the SLCA is to assess the social impacts of a bush-based value chain in Namibia. Because this case study focuses on a potential biofuel value chain, collecting reliable data on its social impact is challenging. Therefore, the SLCA focuses on the existing charcoal value chain. Because the charcoal and biofuel value chains use similar upstream processes, social impact is expected to be similar in the beginning part of the value chain (see Fig. 1). The charcoal value chain has an operational history and available data which ensures a more robust assessment that can be used in decision-making for the prospective biofuel value chain.

The functional unit used in this study is one tonne of charcoal produced from encroacher bush. To produce one tonne of charcoal, three to four tonnes of solid wood are needed (MEFT, 2022). Since the majority of the charcoal is produced for European markets, most charcoal producers are certified by Forest Stewardship Council (FSC). The functional unit of the biofuel value chain is one tonne of biofuel produced from encroacher bush that can be used in the maritime industry. The biofuel must comply with maritime industry standards and be tested in engines. It needs to be a drop-in fuel that can be blended with fossil fuels. The chosen technology for the biofuel value chain is hydrothermal liquefaction (HTL).

The SLCA considers the whole value chain, but more emphasis is put on the upstream part since this will be more similar for both the charcoal and biofuel value chains regarding activities and social issues. The case study focuses on the provinces of Otjozondjupa and Windhoek, where bush encroachment is most severe (Hengari, 2018).

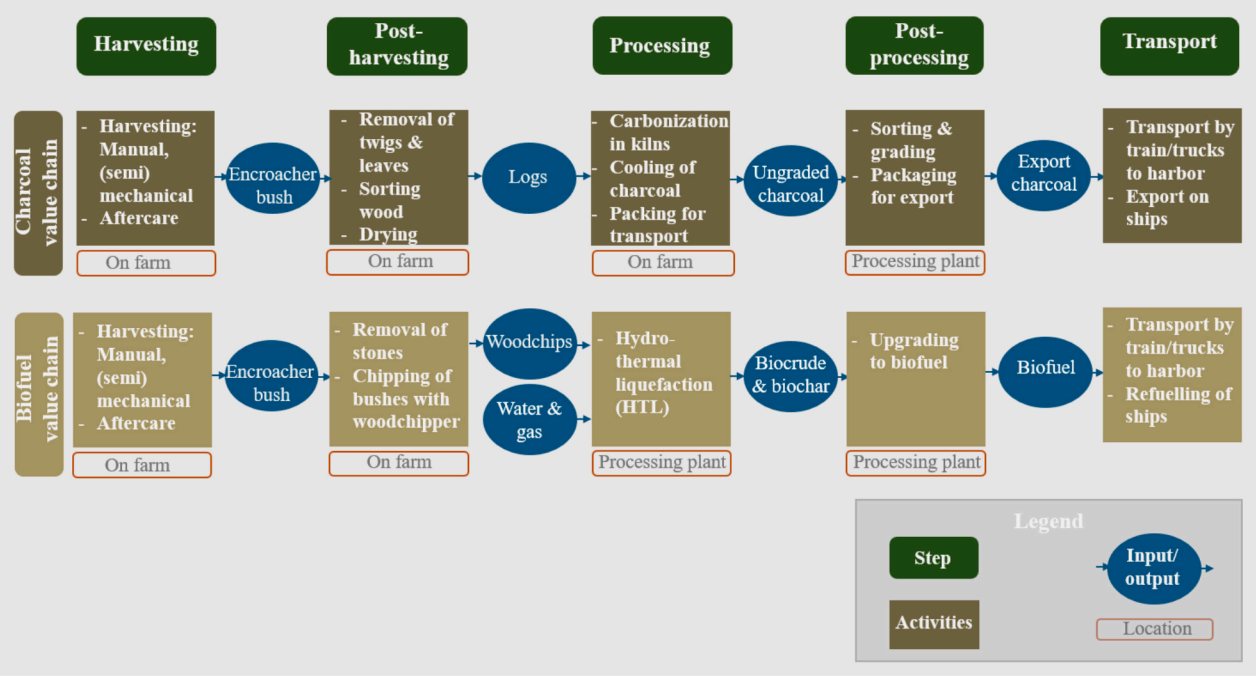

Fig. 1. Product system of the charcoal and biofuel value chain.

3.3. Stakeholders

The different stakeholders involved in the charcoal value chain are farmers (unions), workers, conservancies, the government, the private sector, researchers, and civil society organizations. These stakeholders are included through interviews and a multi-stakeholder workshop during the fieldwork of five weeks in January and February 2023. These stakeholders are divided into four groups, following the UN guidelines (UNEP/SETAC, 2013) (Table 1).

Table 1
Number of interviews per stakeholder category.

Type of stakeholder	Code	Nr. interviews
Workers		
Workers	Bush workers (BW)	6
	Farmworker (FW)	2
Value chain actors		
Farmers	Commercial farmers (F)	5
Farmers unions	Farmers Union (FU)	3
Biomass processors	Charcoal producer (CP)	1
	Charcoal processor (CPc)	1
	Biomass power station (P)	1
Transport company	Transport (T)	1
Conservancies	Conservancy (C)	1
Local community		
Communal farmers/leaders	Communal farmers (CF)	4
Society		
Government	Government (G)	4
	Developmental Agency (DA)	1
Researchers	University (U)	2
Civil society	Nature conservation (N)	1
	Certification body (Cert)	1
Investors	Fund management (FM)	1
	Bank (B)	1
	Total	36

3.4. Impact assessment method

In this study, we use a reference scale assessment (UNEP/SETAC, 2013), which is a method that employs performance reference points to assess inventory data without establishing a causal relationship. It uses a multi-level scoring system with benchmarks (basic requirements) to assess the subcategories. These benchmarks are based on international laws and conventions and serve as a threshold to evaluate the collected data (Haryati et al., 2022).

Reference scales can measure positive and negative social performances or the low or high levels of social risks. There are two types of impact assessments, social performance and social risk. Social performance measures the principles, practices, and outcomes of the relationship between businesses and people, organizations, institutions, communities, and societies. The social performance assessment often uses site-specific data. Social risk is understood as the probability of social effects on stakeholders through a company's activities. Social risk is often assessed from generic country-level data. As a result, the term "risk" is frequently used to refer to data of lower resolution, making it impossible to assess social performance, but instead just pointing out the risk of experiencing negative social impacts. It is useful to do both assessments because it provides more contextual information on social performance (Norris et al., 2020). The indicators are assessed using a risk level scale, ranging from low risk to very high risk. For each indicator, a risk level scale is developed and characterized by values from indexes or global performance indicators of countries (Supplementary Information, Table S8). For the performance assessment, we followed the Subcategory Assessment Method (SAM) developed by Ramirez et al. (2014), shown in Fig. 2.

The SAM uses basic requirements (BR), based on international agreements, existing regulations, SLCA methodological sheets, and company management policies to assess social performances. The level definition is based on the fulfillment of the BR (level A or B) or the non-compliance with the BR (level C or D). Levels C and D indicate that the BR has not been met and is based on the social conditions under which the organization operates. Level C operates in a negative context, where there is a small possibility of achieving the BR and level D operates in a positive context, meaning that there is a chance the BR can eventually be

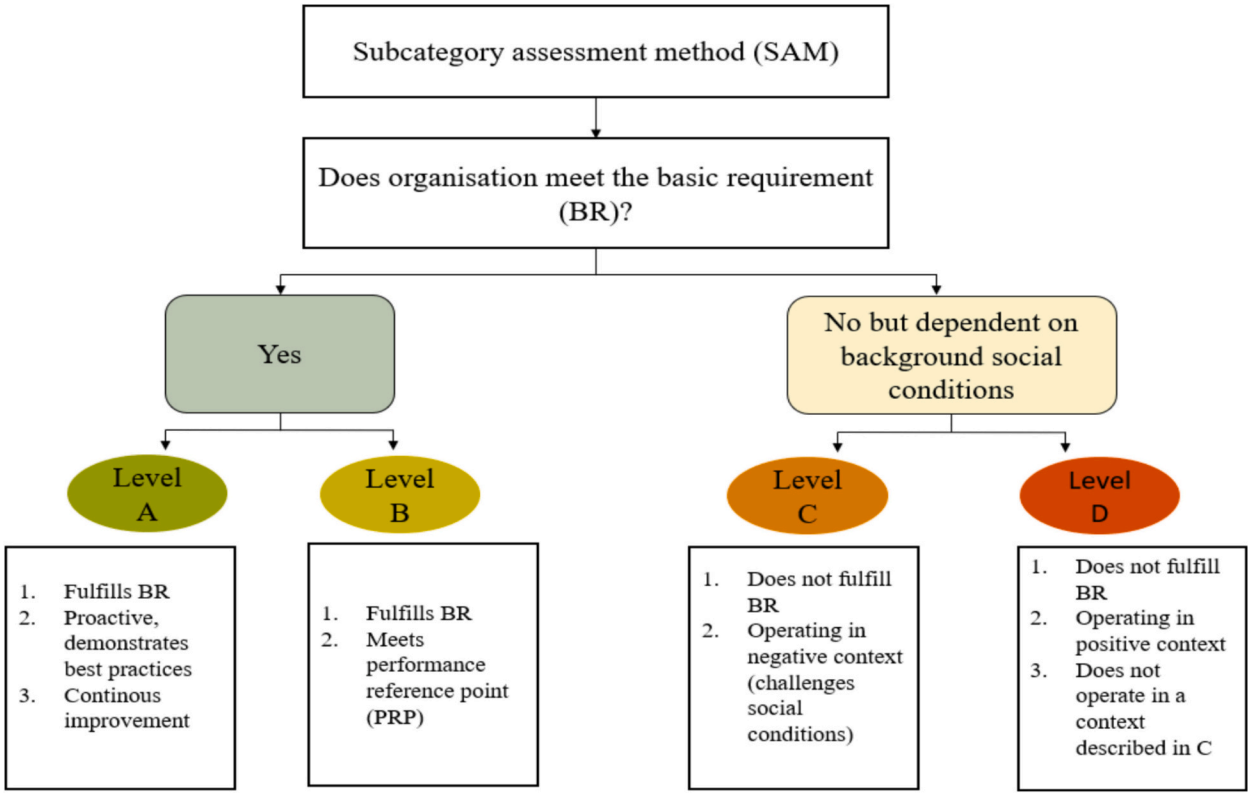

Fig. 2. Scoring method of SAM (Ramirez et al., 2014).

accomplished (Haryati et al., 2022).

When the data for levels C and D given by Ramirez et al. (2014) were unavailable for Namibia, the levels were adapted to the available data in the Namibian context. For this study level A was specifically defined, since Ramirez et al. (2014) did not provide a definition. Level A is assigned to organizations that fulfill the BR, show proactive behavior, and promote best practices (Rafiaani et al., 2018). The reference scales were initially developed before the field visit and updated and refined after the visit to more accurately reflect the Namibian context (Supplementary Information, Table S9).

3.5. Selection of subcategories

Based on the 37 subcategories provided by the UN guidelines, the most relevant categories for the context of Namibia were selected, using the following criteria: 1) relevance of the subcategory for the Namibian or value chain context, 2) ability to assess and measure the subcategory by indicators. Based on this evaluation, subcategories were included, excluded, aggregated, or considered in the impact assessment. Some subcategories were moved from their original stakeholder category and assessed under another subcategory after fieldwork since they were found more appropriate for another stakeholder category (Supplementary Information, Table S1, Table S2, Table S3, Table S4).

The selection of the indicators is done based on an initial screening of indicators in literature, SLCAs performed on bio-based value chains, and the methodological sheets of the UN guidelines. The following criteria were used to select the initial indicators (Buchholz et al., 2009; Sawaengsak et al., 2015; Kamali et al., 2018):

- **Data availability:** is the data available, reliable, and valid? How reproducible are the results?
- **Practicality:** Are there existing reference scales or measurement units? Is data easy, timely, and cost-effective to measure?
- **Relevance:** How relevant is the indicator for the value chain? Is the indicator prioritized in other bio-based value chain SLCAs?

Since indicators are context-specific, the selection was re-iterated after the fieldwork and engagement with relevant stakeholders (Supplementary Information, Table S5, Table S6, Table S7). In addition, a choice was made for which type of assessment the indicator would be used, to assess performance or risk. The final set of subcategories and indicators can be found in Table 2.

3.6. Data collection

Data was collected during fieldwork in January and February 2023 through semi-structured interviews, observations, and a multi-stakeholder workshop. During the interviews, roles and responsibilities were discussed, and questions regarding the basic requirements and performance reference points were asked. Follow-up questions were asked to determine if the organization could be assessed with level A or B, or to find out why the BR was not fulfilled. In addition, participants were shown an infographic of the potential biofuel value chain, and questions were asked about their possible roles, challenges, benefits, and harms (Supplementary Information, Fig. S1). Moreover, a power-interest grid was prepared to ask for feedback on the positions of the stakeholders and to identify missing actors (Supplementary Information, Fig. S2). Table 1 shows the number of interviews done. The case study protocol can be found in the Supplementary Information, Table B.1.

At the end of the field stay, a multi-stakeholder workshop was organized for stakeholders who participated in the study. The participants were divided into three smaller groups, where different stakeholder groups were mixed, to discuss the following topics:

- Participants were asked to envision the ideal scenario for a new bush-based value chain, choosing the best options for variable choices

Table 2
Subcategories with their corresponding set of indicators and assessment focus.

Stakeholder category	Subcategory	Indicator	Type of assessment
Workers	Freedom of association and collective bargaining	Freedom to join a union	Performance
	Fair salary	Minimum wage	Performance
	Working hours	Working hours	Performance
	Equal opportunities	Policies for equal opportunities	Performance
		Gender gap index	Risk
	Health and safety	Presence of policy concerning health and safety	Performance
	Social benefits	Social benefits provided to workers	Performance
	Employment relationship	Formal employer contract	Performance
	Safe and healthy living	Standard of living workers	Performance
Value chain actors	Supplier relationships	Code of conduct	Performance
	Wealth distribution	Gini coefficient	Risk
	Public commitments to sustainability	Certifications	Performance
	Local employment	Unemployment statistics	Risk
		Workforce hired locally	Performance
	Access to material resources	Sustainable harvesting	Performance
Local community	Cultural heritage	Traditional way of living	Performance
	Respect of communal rights	Communal rights policy	Performance
	Community engagement	Community engagement	Performance
	Smallholder	Food security	Risk
		Standard of living	Risk
Society	Contribution to economic development	GDP	Risk
		Contribution to economic development	Performance
	Technology development	Technology transfer	Performance
	Corruption	Corruption index	Risk
	Poverty alleviation	Multidimensional poverty index	Risk

(such as feedstock type, type of suppliers, harvesting method, biorefinery ownership, contracts, and location) (Supplementary Information, Fig. S3, Fig. S4, Fig. S5),
- Participants were asked to rank the subcategories and indicators based on their perceived importance. In addition, they were asked to identify subcategories that were missing. For this, the tool Mentimeter was used (Supplementary Information, Fig. S7, Fig. S8).
- Based on the ideal scenario identified in the first step, participants were asked to create a roadmap with steps to realize the ideal scenario (Supplementary Information, Fig. S6).

To determine the weightage of each stakeholder's input for the ranking of the subcategories, their input was weighted based on their level of involvement (Table 3). Stakeholders received a weightage of three if they were directly involved, two if they were indirectly involved, and one if they were not involved in a particular subcategory. After points were assigned and weighted, the total points were calculated for each subcategory by summing up the contributions from all stakeholders.

Interviews were transcribed verbatim, anonymized, and coded using MAXQDA 12 software with the consent of participants. Summaries of the workshop discussions were created. Interview guides and workshop materials can be found in the Supplementary information, section S8. Fig. 3 represents the process of data collection and interpretation of the data.

4. Results

4.1. Risk assessment

First, a risk assessment was performed based on general indicators, to understand potential social risks in the context of the bio-based value chain (Table 4). It shows that the highest social risk is the high unemployment rate, followed by unequal wealth distribution, low GDP, and a high corruption rate. According to this assessment, gender inequality, and multi-dimensional poverty are rated low risk.

When comparing these results with our interviews, workshop, and other secondary sources, we see that a risk assessment based on general indicators oversimplifies complex issues and does not represent the social risks involved in the specific context of a bio-based value chain operating mainly in a rural context.

First, Namibia scores well on the gender gap index. With a score of 0.807, the indicator is assessed with low risk. The country especially scores high on educational attainment and health (World Economic Forum, 2022). Even though Namibia scores well on the gender gap index, it still faces various other socio-economic issues such as an increase in gender-based violence, occasional harmful cultural practices, and gender stereotypes (Sioka, 2022). Moreover, there are still gaps in economic participation and political empowerment of women (World Economic Forum, 2022). The index provides a tool for cross-country comparison but it does not represent the nuances of gender gaps within a country. While the government has made efforts to empower women, the impact of these initiatives has predominantly been experienced by urban women, who have witnessed improvements in their socio-economic status. In contrast, rural women have seen minimal to no change in their circumstances (Mwetulundila, 2022; Sioka, 2022; Gierse-Arsten, 2024). This was illustrated during an interview with a commercial farmer with a foundation for improving working conditions on farms. She said: "*I realized that a lot of women in this area have no jobs and they prostitute themselves to get a little income here and there. And that made me sad and shocked me because is it really necessary? Can't we find jobs for women that they can also work on farms?*" (F2). In addition to difficulty in finding jobs, women suffer from domestic violence. She continues: *It's also a problem always with abuse when alcohol comes into play. When I came to the farm four years ago, I sat down and wrote some contracts and farm rules. Two of my guys learned that no women are being hit on the farm by getting a final warning, I think still that they obviously deserve a second chance, it's a learning curve. But they just realize that on this farm the women and the children are not getting hit.*" (F2).

Second, assessing the multidimensional poverty index (MPI) as low-risk does not represent reality well. Namibia has an MPI of 0.191, with 43.3 % of Namibia's population suffering from multidimensional poverty. The top five factors influencing this number are food security, child nutrition, transportation assets, sanitation, and cooking and lighting energy (NSA, 2021). Even though almost half of the population is multidimensionally poor, it is classified as low-level risk, due to the nature of the scales, which range from 0 to 1 (Supplementary Information, Table S8). Even though a high percentage of Namibians are multidimensionally poor, Namibia performs relatively well compared to other countries. However, poverty remains a significant challenge, with rural areas most affected (NSA, 2021).

Third, no general indicators were available on food security and living standards in the communal areas to make the assessment. These indicators belong to the stakeholder category of local community, which in this study is defined as the communities living in communal areas within the system boundaries. While country-level statistics on food security are available, no statistics indicate food security in the

Table 3
Stakeholders present during the workshop and the weighting for the ranking.

Stakeholders	Workers			Value chain actors			Local community			Society		
	3×	2×	1×	3×	2×	1×	3×	2×	1×	3×	2×	1×
Farmers Union (FU2, FU3)	x			x			x		x		x	
Charcoal producer (CP1)		x		x					x		x	
Conservancy (C1, C2)		x		x					x		x	
Communal farmers (CF5, CF6, CF7)	x					x	x				x	
Government (G1, G5, G6, G7, G8)			x		x			x		x		
Development agency (DA3)			x		x			x		x		
University (U6, U7)			x		x			x		x		
Nature conservation (N2)			x			x			x	x		
Bank (B1)			x			x			x	x		
Industrial Association (IA1, IA2, IA3, IA4)			x		x			x			x	

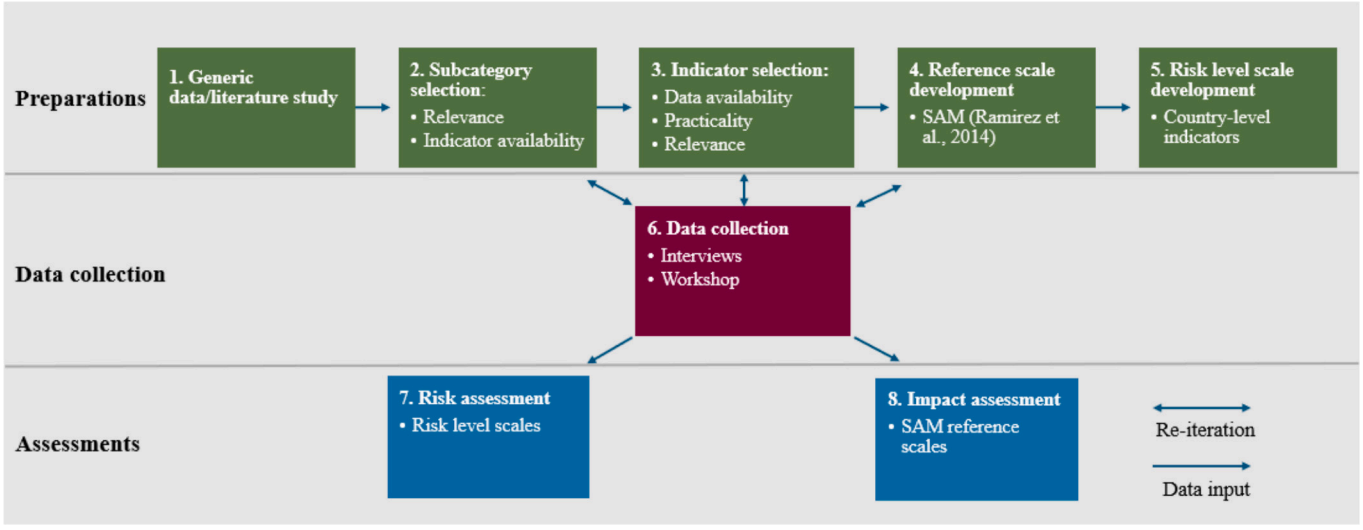

Fig. 3. Process of data collection and assessment.

Table 4
Risk assessment scores.

Stakeholder category	Subcategory	Indicator	Risk level
Workers	Equal opportunities	Gender gap index	Low risk
Value chain actors	Wealth distribution	Gini index	High risk
	Local employment	Unemployment rate	Very high risk
Local community	Smallholders	Food security	No data
		Standard of living	No data
Society	Economic development	GDP	High risk
	Poverty alleviation	Multidimensional poverty index	Low risk
	Risk of corruption	Corruption index	High risk

communal areas specifically. The same is the case for living standards. Based on other sources, we found that in the Otjozondjupa region, food security and living standards are an issue, so leaving these indicators out of the assessment obscures the identification of potential risks. People in poverty most often lack necessities like transportation assets (38.3 %), sanitation (34.6 %), and cooking and lighting energy (34.6 %) (NSA, 2021). Housing structures in Otjozondjupa are quite basic but decent. They are built from various building materials, such as bricks (51.0 %) and corrugated iron (33.1 %). Sanitation is a challenge with 35.1 % of the people resorting to the bush for their toilet needs (ibid). Access to energy is a significant issue in rural areas, with the majority of families lacking electricity. National efforts to address this have been largely unsuccessful (MME, 2021). One communal leader (CF2), shared in an interview that their home lacked electricity because it was too expensive

to connect their house to the grid in the village. Another communal leader explains: "*Rural electrification is an issue. It is a very expensive project for rural community households to get electricity from the main grid. In this area, we have more than 80 villages. We have to come one by one. Yeah, but if you have to look at the villages that have electricity, maybe in our area we can count them quickly. Less than 30%.*" (CF1). Given how difficult it is to obtain some of the most basic needs, it is evident that inadequate living conditions can be a potential social risk. It was however not possible to assess this risk on a scale due to a lack of data to assess this using general indicators.

To conclude, while the risk assessment highlights some important social risks, it does not represent the social risks in the rural context of Namibia adequately. In this risk assessment, global indicators and scales are based on assessments from international institutions such as the World Bank and World Economic Forum that developed indicators to compare different countries on specific issues. While this is useful, it does not always sufficiently assess the potential context-based social risks. Especially in a rural context, as is the case for a bio-based value chain, country-wide statistics do not always represent the reality in rural areas. Therefore, we recommend complementing the general indicators with other sources to gather a more complete and nuanced picture.

Table 5
Impact assessment workers.

	Basic requirements fulfilled		Basic requirements not fulfilled	
Indicator	**Level A**	**Level B**	**Level C**	**Level D**
Social benefits	The organization offers more than the legally required amount of social benefits.	As required by Namibian law, the organization provides the compulsory benefits; Maternity Leave, Sick Leave, and a Death Benefit Fund to all of its employees (Labor Act, 2007).	The organization provides at least 2 basic social benefits/ social security requirements.	*The organization does not provide any basic social benefits/social security requirements.*
Working hours	Average weekly hours worked were less than 9 in the day and 45 in the week.	Average weekly hours worked do not exceed 9 in the day and 45 in the week (Labor Act, 2007).	The average weekly hours worked exceed 45 but are less than the average weekly hours worked in the sector/country.	*The average weekly hours worked exceed 45 and the average weekly hours worked in the sector/country.*
Health and safety policy	The organization implements health and safety practices beyond the industry standard.	The organization has a policy related to health and safety and provides a working environment that is without risk to the employees (ILO Convention nr. 161 & Labor Act, 2007).	*No strong health and safety policy is in place with evidence of workers not fully complying with obligations on safety practices.*	The organization has no health and safety policy in place.
Policies for equal opportunities	The organization proactively implements this policy and ensures equal pay and equal opportunities.	*The organization has a management system, policy or actions to prevent discrimination and promotes equal opportunities for workers, according to ILO Conventions No.100, and No. 111.*	There is evidence in the organization of discrimination and the country where the organization is located has a Global Gender Gap Index lower than 0.5.	There is evidence in the organization of discrimination and the country where the organization is located has a Global Gender Gap Index higher than 0.5.
Formal contract	Formal contracts that provide fair and equitable compensation and benefits packages.	A formal contract is given and the employee is covered by the Labor Act (2007).	*Contracts are temporary and are not covered by the Labor Act (2007).*	The employee only has an informal contract with the employer and is not covered by the Labor Act (2007).
Minimum wage	The lowest salary is equal to the living wage of the country.	*The lowest salary is equal to or higher then the minimum wage in the sector/ country where the organization is located.*	The lowest salary is below the minimum wage but above the poverty line wage.	The lowest salary is equal to or below the poverty line wage.
Housing standards	The organization provides a higher standard of housing to employees than the minimum requirements.	*The organization must provide the employee with adequate housing, including sanitary and water facilities that meet the standards set by the FSC.*	The organization fails to meet the minimum housing standards.	No housing is provided to the employee.

4.2. Social performance impact assessment

4.2.1. Workers

The stakeholder category workers is where the least indicators fulfill the BRs, compared to other stakeholder categories (Table 5). According to the impact assessment, workers are most at risk of being negatively impacted by a new bio-based value chain. Workers are involved in various stages of the charcoal value chain, with the majority of workers being employed in the charcoal production phase, including bush harvesting and processing.

The assessment of this stakeholder category is similar to the outcomes of the interviews, observations, and workshop discussions. Most indicators in this stakeholder category are relatively easy to assess on a scale. It is possible to check the type of contracts workers are employed under, how many hours they work a week, and if there is a union. These indicators are representative of the kind of protection workers receive and how they are compensated for their work.

Because charcoal workers perform mostly temporary work on a contract basis for a few months a year, they are treated as independent contractors (FU3). In this type of contract, they are not covered by the Labor Act (2007) and are not required to receive any social benefits (Republic of Namibia, 2007). Because workers are employed under a performance-based work structure where their income is directly linked to the tonnes of charcoal they produce, they can exceed working hours to increase their output and wages (NCA, 2019). In addition, there are currently no workers unions available for charcoal workers. This is mainly due to the impracticality of doing so, as they move around working on different farms and do not have permanent employment (FU3, CP1, BW2). Even though health and safety policies are in place since this is required for FSC certification, this is often not implemented in practice. The policy requires the supply of personal protective equipment (PPE) such as overalls, gumboots, hats, gloves, and dust masks. In addition, training on health and safety is provided (FSC, 2019). However, while provided to the workers, they do not always wear the PPE because it is uncomfortable. Farmers cannot control this constantly (F3, F4).

The indicator that is more difficult to assess in this stakeholder category is policies for equal opportunities. In this assessment, this indicator focuses only on gender equality, which can be asked about and evaluated. Whereas work in bush harvesting and charcoal production is mainly done by male workers, in charcoal processing a higher percentage of women is employed (CPc1). In addition to gender dynamics, another type of inequality is more prominent in the context of Namibia, and this is inequality based on ethnicity. The population of Namibia has a high ethnic diversity, with European descendants and people who belong to different tribes. Norms and ideas about these ethnic groups play a role in the bio-based value chain. This is illustrated by a commercial farmer who explains why they mainly employ workers from the Oshiwambo and Kavango tribes: "*The work motivation of the Oshiwambo and the Kavango tribe is really not bad. That is just the experience of farmers in this area. The unemployment rate in Namibia is that high, I don't need to motivate people to work, I want people who are motivated already and we just found that also alcoholism is not such a big problem with the Oshiwambo and with the Kavango tribe.*" (CF2). Even though these norms related to ethnicity play a role in the social impact of the value chain, this is much more difficult and sensitive to assess based on an indicator.

4.2.2. Value chain actors

Value chain actors in this study are defined as key participants in the charcoal value chain that can employ people. They include charcoal producers (commercial farmers), processors, transporters, and end consumers. The only indicator that does not fulfill the BR is 'workforce hired locally' (Table 6). Similar to the indicators in the stakeholder category of workers, the indicators for value chain actors are quite easy to assess and rank. The assessment of this stakeholder category represents the findings from our interviews, workshop, and observations well. However, there are nuances in two of the indicators.

First, the indicator workforce hired locally is assessed with level C because workers are generally not hired within the system boundaries, even though unemployment levels are high. The majority of the charcoal workers are migrant workers coming from the Kavango and Northern Central regions whose tribal borders span into Angola, with

Table 6
Impact assessment value chain actors.

	Basic requirements fulfilled		Basic requirements not fulfilled	
Indicator	**Level A**	**Level B**	**Level C**	**Level D**
Workforce hired locally	The organization can demonstrate that the majority of its employees are hired locally.	There is evidence of equal employment opportunities for local workers.	*The organization is located in a country with an employment-to-population ratio lower than 50.*	The organization is located in a country with an employment-to-population ratio equal or higher than 50.
Certifications	Multiple public commitments to sustainability by the organization, showcasing proactive behavior towards sustainability.	*The evidence of any promise or agreement related to sustainability and social responsibility is disseminated to the public.*	There is no record of proven cases that the organization has violated its commitments to sustainability within the last three years.	There is a record of proven cases that the organization has violated its commitments to sustainability within the last three years.
Sustainable harvesting	There is evidence that the organization implements multiple additional measures to ensure sustainable harvesting.	*Presence of an internal management system, such as FSC certification that is concerned with sustainable and selective harvesting.*	Absence of an internal management system, coupled with unsustainable and unselective harvesting practices.	Absence of an internal management system, coupled with harvesting practices removing or killing all encroacher bushes.
Code of conduct	*The organization possesses a code of conduct and demonstrates strong supplier relationships.*	The presence of a code of conduct with clearly defined ethical standards that are communicated to the organization's suppliers.	The organization lacks a code of conduct but does have a supplier relationship.	The organization lacks a code of conduct and has no supplier relationship beyond basic purchasing transactions.

communities living on both sides. These regions are characterized by high poverty and unemployment rates and a poor educational system. The reason that charcoal workers are not employed within the system boundary is that the local population is generally not willing to perform hard physical labor on the land (FU3). This makes it difficult to assess the indicator, because there are opportunities for local employment, but migrant workers are performing the work because the local population does not want to do this type of work. According to a leader of a farmers union, this has to do with the working conditions in the charcoal industry. A new biofuel value chain has the potential to improve working conditions and local employment. He states: "*If it can be a cleaner job, for instance where you use equipment that's not this hard work, then it can be a good alternative that a lot of people will consider. Especially if it need not be with many workers on the farm.*" (FU3). This is an issue that was not picked up in the impact assessment.

Second, the indicator of sustainable harvesting is assessed with B because the majority of the charcoal producers are FSC-certified, which requires compliance with environmental, social, and economic standards in forest management (Hindjou, 2021). Charcoal producers must have a forest management plan to address sustainable and selective harvesting because if the wrong species are harvested or too much bush is removed, the problem will deteriorate (G1). To start producing charcoal, producers need to obtain a harvesting permit from the Directorate of Forestry, where they have to specify biomass density estimates for the area to be thinned, target specific species, and desired quantities to be harvested. However, adherence to these guidelines by charcoal producers and workers is not always guaranteed due to a lack of monitoring and enforcement (G3, Cert1, MITSMED, 2017).

Sustainable harvesting was also a key concern that was raised during the workshop discussions and interviews with forestry experts and government officials. A government representative states: "*The biggest challenge for monitoring by Forestry is the equipment, the vehicles, internet, computers' that stuff. They hardly have such stuff and it's easy for me to sit here and say they should have been doing this and that. But I mean you come to an office where there's only one person. And even the internet to check on Google Earth sometimes lacks*." (G1). In addition, FSC auditors only visit annually (Cert1). Due to inadequate law enforcement, unsustainable harvesting practices are not consistently penalized. Although the Directorate of Forestry can revoke harvesting permits and FSC auditors can withdraw FSC certificates, these actions are not always carried out (G1, G3). Charcoal producers also face challenges in establishing effective penalty systems for charcoal workers who partake in improper harvesting practices (CP1). Thus, the absence of robust monitoring and control poses a challenge in ensuring that sustainable harvesting practices are performed consistently everywhere. The concern related to sustainable harvesting is not represented in this SLCA due to the definition of the indicator. It assesses whether an internal management system is in place, but does not assess the compliance with that management system.

4.2.3. Local community

The stakeholder category local community is the most difficult category to assess based on this assessment method. Local community in this context is defined as communities living in communal lands. However, the community lacks access to the overall charcoal value chain as the communal areas are legally restricted from producing charcoal from encroacher bush due to a moratorium from the government. Some individuals from the local community are involved in the charcoal value chain as workers. Thus, while the local community as a whole does not have direct participation in the value chain, some of its members are engaged as workers within this industry.

All indicators in this stakeholder category are assessed with B because FSC certification requires organizations in the charcoal value chain to have a communal rights policy, preserve cultural heritage, maintain positive community relations, and contribute to the social and economic well-being of the local communities near charcoal operations (Table 7). This however does not represent the key concerns raised by stakeholders on the inclusion of local communities during our interviews and workshop discussions.

As a result of the government's moratorium on harvesting permits for communal areas, the opportunity to (individually) participate in charcoal production is currently unavailable to local communities. This moratorium was placed by the government due to concerns about overexploitation, unsustainable harvesting practices, and unequal benefit-sharing within the communities since the bush in these areas is a common pool resource (Hindjou, 2021). However, bush encroachment is most severe in these communal areas due to these harvesting restrictions and a lack of resources. In addition, in communal areas, people suffer more from poverty and unemployment compared to other areas. The history of colonialism and Apartheid makes the dynamic sensitive

Table 7
Impact assessment local community.

	Basic requirements fulfilled		Basic requirements not fulfilled	
Indicator	**Level A**	**Level B**	**Level C**	**Level D**
Communal rights policy	The organization has a communal rights policy and engages in regular consultation and engagement with communities and incorporates their feedback into its operations.	*The organization has a communal rights policy or a commitment to adopt free prior informed consultation in its operations when its operations involve communal lands.*	There is no communal rights policy and there are no cases in the country of discrimination against community members within the last three years.	There is no communal rights policy and there are cases in the country of discrimination against community members within the last three years.
Traditional way of living	The organization actively promotes the preservation of cultural heritage by promoting the use of traditional products and craftsmanship in their production methods.	*There is evidence that the organization contributes to the preservation of cultural heritage by example through contributions to traditional agricultural practices.*	The country where the organization operates has no cultural heritage sites in danger (UNESCO, 2023)	The country where the organization operates does have cultural heritage sites in danger (UNESCO, 2023).
Community engagement	The organization demonstrates proactive efforts to improve the community's environment, health, and welfare and engages the community in decision-making processes	*There is evidence that community environment, health or welfare are of importance to the organization.*	There is no record of proven cases that community groups/ members were affected by the actions or products of the organization within the last three years.	There is a record of proven cases that community groups/ members were affected by the actions or products of the organization within the last three years.

between commercial charcoal producers, who by the majority are European descendants, and communities in communal areas, who belong to different tribes. Even though people in communal areas are in higher need of bush control, employment opportunities, and additional income sources, their participation in a new bio-based value chain is restricted. One communal representative states: "*We are eager for any change and we are ready for any cooperation. Our people are so eager. There is always progress if there is change. There's no progress now.*" (CF1).

To obtain resource rights, the community has to register as a community forest or a cooperative which requires them to have a Forest Management Plan. A Forest Management Committee is elected for the development of the forest management plan, and the subsequent implementation and monitoring of the plan (Benkenstein et al., 2014). In the community forests, a few small-scale projects such as bush to feed or production of biochar are currently being piloted (CF1). However, previously pilots have failed to work in communal areas due to difficulties in structuring a framework for equitable benefit sharing and various other reasons (Cert1, G4). A civil society representative involved in these pilots explains: "*We've been struggling to get that structure in place also with the communal areas because it is, you know, millions of hectares belonging to hundreds of thousands of people equally. They all get the same benefit out of the land. Getting a structure in place where one guy does not have a bigger benefit than the other. Other than just the time that he's putting in, it's very difficult.*" (Cert1).

These dynamics are difficult to assess with indicators. In addition, the social impact in this stakeholder category is not directly linked to a company's behavior since it is a result of government regulations. However, the exclusion of communal areas is an important social impact of commercial bush-based value chains. Moreover, it was highlighted by all participants in the workshop that ideally, all different types of farmers should be able to supply the value chain.

Even though companies have communal rights policies in place, local communities do experience social impact from the bush-based value chain, as they lack access to the value chain due to structural factors. An SLCA based on the indicators below alone cannot grasp these dynamics. This highlights the need to gather more context-specific, qualitative information in addition to the indicators and to include factors, such as policies and land ownership, that are out of the direct sphere of influence of companies but that are very important for the social impact of their operations.

4.2.4. Society

The assessment of the stakeholder group society focuses on evaluating the broad social and socio-economic effects of the charcoal value chain on society. This stakeholder group thus includes a wide range of actors, such as the government, researchers, and civil society organizations, who can be impacted by the charcoal industry.

The two indicators in this stakeholder category fulfill the BR, with one going above and beyond (Table 8). Both indicators are quite easy to assess and rank and are adequate to assess the social impact. The BR for the indicator technology transfer is fulfilled, as there is evidence of research and development of technology within the charcoal industry that is publicly available. Level A is assigned to the charcoal industry's contribution to economic development, as it is the largest and most developed subsector in the bush biomass sector. Most of the charcoal is destined for international markets and Namibia consistently ranked among the top ten exporters in the last decade (Markstein, 2020). Beyond its direct economic contribution, the charcoal sector also contributes by bush control and rangeland restoration to the economy. A local fund manager states: *"What you also need to realize is that 70% of Namibians are directly or indirectly linked to agriculture. And if you can have an impact there, you will naturally have an impact on communities."* (FM1). By controlling bush biomass, the industry helps create opportunities for increased livestock production, tourism, groundwater recharge, and biodiversity conservation (De Klerk, 2004).

4.3. Prioritization

In addition to the risk assessment and social impact assessment, a ranking exercise was done with participants in the multi-stakeholder workshop to identify which subcategories were perceived as more important than others (Table 9). This exercise was insightful as it helped to identify the social impacts with the most risks and challenges. This can help decision-makers allocate resources and attention to areas with the greatest potential for improvement.

This ranking exercise provided some new insights that were not identified in the social impact assessment. In the category of value chain actors, sustainable harvesting and local employment were ranked as important. While the social impact assessment did not assess sustainable harvesting as a concern, workshop participants highlighted this as one of the main concerns for this stakeholder category. If the wrong species are harvested, too much bush is removed, or aggressive aftercare is used, this can impact the rangeland negatively. In that way, bush control has a negative environmental impact. This is an issue since one of the key goals of creating bush-based value chains is to control the bush and restore the savannah grasslands. For the stakeholder category of local community, respect for communal rights was prioritized, with the reasoning that communal areas should be included in the value chain. This was not identified in the social impact assessment.

The ranking exercise also confirmed some conclusions from the social impact assessment. In the subcategory of workers, stakeholders prioritized fair salaries and safe and healthy working conditions. This is in line with the social impact assessment, only with the difference that workshop participants emphasized fair salary above working hours and

Table 8
Impact assessment society.

	Basic requirements fulfilled		Basic requirements not fulfilled	
Indicator	**Level A**	**Level B**	**Level C**	**Level D**
Technology transfer	The organization has a higher expenditure on research and development of technologies compared to other organizations Within the same sector	*The organization demonstrates participation in joint research and development for efficient and environmentally sound technologies*	The organization operates in a country with low research and development expenditure (0-2.35% GDP)	The organization operates in a country with high research and development expenditure (>2.35% GDP)
Contribution to economic development	*The organization demonstrates a higher level of contribution to economic development than other o rganizations within the same sector.*	The organization contributes to the economic development of a society.	There is no record of proven cases of the organization damaging or restraining the economic development of the region within the last three years	There is a record of proven cases of the organization damaging or restraining the economic development of the region within the last three years

Table 9
Prioritization of subcategories.

Stakeholder category	Subcategory/Indicator	Less Important	Neutral	Important
Workers	Working hours			
	Safe and healthy living conditions			
	Fair salary			
	Social benefits			
	Safe and healthy working conditions			
	Equal opportunities			
	Freedom to join a union			
Value chain actors	Sustainable harvesting of biomass			
	Local employment			
	Wealth distribution			
	Feedback mechanism			
	Contractual relationships			
	Public commitments to sustainability			
	Sustainable use of water			
Local community	Respect for communal rights			
	Community engagement			
	Cultural heritage			
	Standard of living			
	Food security			
Society	Contribution to economic development			
	Poverty alleviation			
	Tranfer of technology			
	Corruption			

freedom to join a union. They reasoned that when workers are compensated fairly for their work, they don't need to exceed working hours to make a decent income and the need for joining a union is less prominent. Lastly, for society, the contribution to economic development was ranked most important, since Namibia has a relatively low GDP (12.31 billion in 2021) and experiences a low-growth environment (African Development Bank, 2021). The charcoal industry is a major contributor to Namibia's economy and the development of new bush-based value chains could significantly contribute to the country's economy.

In the workshop, participants were also asked to propose subcategories that were missing in their view. Categories that were mentioned were inequalities related to social identities (ethnicity, gender, religious beliefs), access to join value chains, finance, and benefits, capacity building/skills development for workers, education, law enforcement, and atmosphere for entrepreneurship. These are issues that are not (sufficiently) addressed in the SLCA and are more difficult to assess using indicators but represent important social issues related to the bush-based value chain.

So through the ranking exercise, some social issues and concerns were raised and prioritized that did not come forward in the social impact assessment. This highlights the need for gathering subjective information about how stakeholders experience social impact, in addition to assessing social impact based on the indicators. Because this ranking exercise was insightful in identifying the key concerns within the prospective value chain, this could also be done for the social impact assessment. In addition to the assessment based on indicators definitions, it could be helpful to ask stakeholders to assess the indicators with A, B, C, or D. This could give a more complete and nuanced picture of the actual social impact of the value chain.

The findings of the SLCA and the qualitative field study pointed out several issues that need to be addressed for a prospective biofuel value chain in Namibia. Establishing a biofuel value chain offers promising opportunities for enhancing social impacts compared to the existing charcoal value chain. Therefore it is crucial to acknowledge and address the risks associated with biomass harvesting, especially related to workers' wellbeing and working conditions, and sustainable harvesting. Additionally, although the involvement of communal farmers is restricted by government policies, it is important to explore alternative avenues to include them in the operations or benefits of the value chain.

5. Discussion

5.1. Recommendations for SLCA

In this study, we have performed an SLCA for a prospective biofuel value chain based on an existing charcoal value chain in Namibia. We reflected on the assessment based on our qualitative fieldwork, which consisted of semi-structured interviews, observations, and workshop discussions. We showed that while the SLCA captured and assessed certain social impact categories well, it also missed some key indicators and concerns raised by local stakeholders.

The SLCA successfully identified labor issues, such as wages, health and safety, and working hours, and assessed whether an organization or company has a certain policy in place or adheres to certification. Those indicators are relatively easy to evaluate on a scale and can be verified and captured under the SLCA framework. However, it is more challenging to assess the more sensitive social issues, such as social norms related to gender and ethnicity, structural factors like policies and land ownership, and the subjective experience of stakeholders. Those factors are crucial for the social impact of a value chain, but are less easy to grasp with an indicator. That is a limitation also identified by Rebolledo-Leiva et al. (2023), who argue that it is needed for SLCA to take a broader focus.

Moreover, the SLCA is often performed from the perspective of a company or organization. This is a limiting focus since the transition towards a bioeconomy involves changes across the value chain and social processes where multiple actors interact, such as farmers, governments, and companies (Rebolledo-Leiva et al., 2023). This limited focus on a company's perspective risks missing potential negative impacts, such as the issue with communal farmers in this case. It can also miss possible positive impacts, as shown by Postal et al. (2020), who evaluate the social impact of sugarcane expansion in Brazil. They conclude that there are differences between global and local perceptions of the sugarcane expansion. While there were global concerns about the negative social impact of sugarcane expansion, local stakeholders generally perceived this expansion as positive, since it provided them with more economic opportunities. Therefore, it is meaningful to assess the actual opportunities that are created for local stakeholders by the value chain.

Besides the perspective of local stakeholders, a key actor that is not considered a stakeholder in the SLCA is the public sector. According to the UNEP/SETAC guidelines, the State is not proposed as a separate stakeholder category because it is not a dimension in Corporate Social

Responsibility (CSR) frameworks and literature (UNEP/SETAC, 2009). However, the bioeconomy involves interactions between different stakeholders, including the State. The State plays a crucial role in promoting the bioeconomy and the institutional environment that influences social and socioeconomic conditions of value chain actors such as farmers (Postal et al., 2020). Therefore, SLCA should pay attention to multiple dimensions in society and factors that influence the transition to a bioeconomy, for instance, government policies, regulatory conditions, human resources, and social acceptance (Rebolledo-Leiva et al., 2023). These factors are currently excluded from the SLCA since they are out of the sphere of influence of a company. That is limiting the assessment of the social impact of a bio-based value chain.

We therefore propose a few changes to the SLCA methodology. First, we recommend broadening the scope of the risk assessment. Currently, the risk assessment utilizes various general country-level indicators. This does not always represent the social risks of the context in which a value chain operates, which is, in the case of the bioeconomy, often a rural context. In addition to country-level indicators, more context-specific sources can be used to make a more realistic risk assessment, and additional relevant indicators should be added. These additional indicators should include more contextual factors that influence the social risks of the value chain, such as land ownership, monitoring and enforcement capacities, education levels, and social norms related to gender, ethnicity, and religion. These indicators can be identified and verified by local stakeholder engagements.

We propose incorporating these contextual factors into the risk assessment to obtain a broader view of the social context and potential social risks of a (new) bio-based value chain. These factors are mostly beyond the influence of a company and are more associated with social norms and government policies in a certain context. However, they highly influence a value chain's (potential) social impact, risks, and opportunities. For example, in the case of Namibia, the structural factors of land ownership and the government's moratorium influence local communities' access to participate and benefit from a commercial bush-based value chain. These factors cannot always be addressed by a company directly, but a company should be aware of the social context when starting operations like biomass procurement. Through multi-stakeholder collaborations, these risks could be addressed. Moreover, improving the risk assessment will also make the SAM assessment more robust, because the results from the risk assessment are used to determine if the indicator is ranked with level C or D, depending on the context (Ramirez et al., 2014).

In addition to broadening the risk assessment, we suggest complementing the social performance impact assessment based on indicators with a subjective evaluation by local stakeholders. Since the ranking exercise on the subcategories' prioritization provided insights missed in the social performance impact assessment, it could be useful to ask local stakeholders to rank the indicators on the same scale (A, B, C, D). This way, crucial knowledge can be gathered on how social impact categories are experienced by those stakeholders affected, in addition to assessing whether the right policies are in place.

The proposed changes would make the SLCA more subjective and qualitative, which further complicates the standardization of the SLCA method. However, unlike environmental LCA, social impact is more value-laden and normative (Reitinger et al., 2011; Lago-Olveira et al., 2024). As shown in our SLCA case study in Namibia, performing a social impact and risk assessment based on more 'objective' indicators does not always reflect the social reality well. Specific assumptions may be made about the context that do not reflect actual reality, such as the availability of infrastructure and equipment. Therefore, it is imperative to complement the social performance assessment with more subjective information to examine how the social impact is experienced and which social issues are deemed more important to address. Local stakeholders should actively participate in this assessment. We argue that it is undesirable to standardize the SLCA method in the sense of selecting a general set of indicators that can be applied in multiple contexts, since that will differ per context. The selection and definition of the subcategories and indicators should be tailored to the specific context. Otherwise, the resulting analysis would be less meaningful.

5.2. Research implications

With the proposed suggestions, SLCA can be an important tool to assess the social impact of bio-based value chains. This is not only promising for evaluating existing value chains but also for identifying potential social impacts and risks of a new bio-based value chain, as we have shown in this paper. Decision-makers can use the results from the SLCA to prioritize which social impact categories need to be improved to prevent potential negative impacts, or where opportunities are for positive social impact. This is especially promising for the bioeconomy since many bio-based value chains build on existing ones (Robaey et al., 2022). This is relevant since choices made in the early stages determine to a large extent the outcomes in a later stage (van der Veen et al., 2024). Apart from bio-based value chains, this method can be used for other value chains or (new) technologies.

Additionally, allowing more stakeholder engagement prevents a 'Western' understanding of which subcategories and indicators are important to consider. Moreover, by only adding subcategories that can be measured quantitatively, important information on (potential) social impact can be missed. This compromises 'data justice' which is the fairness in the way people are made visible and represented in data (Pritchard et al., 2022). What can be standardized is the process of conducting an SLCA, which includes the different steps to be taken. The guidelines of UNEP/SETAC (2009, 2020) provide a good basis for this.

Apart from research implications, our findings also have practical implications. The rising demand for more sustainable alternatives to replace fossil fuels intensifies biofuel production and increases the competition for biomass (Yupanqui et al., 2024). At the same time, biofuel value chains are often scrutinized for their potential negative social impact (Lima, 2022). Conducting an SLCA can help companies evaluate the social impact of their operations and can help in decision-making around potential new value chains to improve social conditions. A limitation for companies can be that our proposed changes to the SLCA methodology are time- and resource-consuming. Companies can use the existing databases and general indicators when there are time restrictions. However, then they risk missing important social impacts, as we have shown. This does not contribute to adequate decision-making or improvements in the social performance of that value chain. In addition, it can compromise the social acceptance of a new technology or new value chain, which is important for its success (Sanz-Hernández et al., 2019; Velasco-Herrejon and Bauwens, 2020).

In addition, our research has policy implications. Over 50 countries adopted bioeconomy strategies because of their economic, environmental, and social potential (Zeug et al., 2023). For the evaluation of these policies, adequate methodologies are needed to assess the actual (social) impact of the implementation of new bio-based value chains. Our recommendations help in getting a more accurate understanding of the real social impact of the bioeconomy.

5.3. Limitations and recommendations for future research

This study also has some limitations. First, our reflection is based on qualitative research. This allows a deeper understanding of real-life contexts and complex relationships. However, qualitative research also has limitations due to subjective input from stakeholders and interpretation by researchers. Data is triangulated using semi-structured interviews, observations, secondary sources, and a workshop to overcome these limitations. Moreover, the research is carried out by a research team, and the interpretation and analysis of the data are discussed among different researchers. In addition, research findings were discussed with local partners, such as research institutes and a multi-stakeholder platform.

Second, this research is based on one case study which limits the possibility of generalizing the results. It does offer in-depth insights into the social impact of a bio-based value chain and the limitations of the SLCA methodology. Even though the findings on the social impact of the bush-based value chains in Namibia cannot be generalized to other contexts, our reflections and recommendations are relevant for future SLCA studies in the bioeconomy and beyond.

Future research can build on our analysis and implement our suggestions in real-life case studies. In addition, future studies can use this SLCA methodology for decision-making for new (bio-based) value chains. Finally, our study focused specifically on the bioeconomy. Future research can expand the scope and apply this methodology to other types of value chains and (new) technologies.

6. Conclusion

In this paper, we addressed the issue of including social impact in sustainability assessment. We reflected on an SLCA that we conducted on a bush-based value chain in Namibia and identified its strengths and weaknesses in assessing the social impact of a bio-based value chain. We conclude that while the SLCA can identify and assess certain social issues, such as working hours, health and safety, and contribution to economic development, it is more difficult to assess more sensitive issues like inequality based on ethnicity, social norms, and structural policies and regulations. We, therefore, propose to broaden the risk assessment with more context-specific factors that do not only focus on factors a company can address directly, but that involve multiple stakeholders such as governments, farmers, and local communities. Moreover, we suggest that the social performance impact assessment should be complemented with a more subjective assessment by local stakeholders about how these social impact categories are experienced. This would further complicate the standardization of the SLCA method, but we argue that standardization is not always desirable. A social impact assessment based solely on 'objective' indicators does not represent the social impact in a meaningful way.

CRediT authorship contribution statement

Susan van der Veen: Writing – original draft, Visualization, Supervision, Investigation, Formal analysis, Conceptualization. **Elisabeth van Rechteren Limpurg:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Lotte Asveld:** Writing – review & editing, Supervision, Funding acquisition, Formal analysis, Conceptualization. **Sivaramakrishnan Chandrasekaran:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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