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SUSTAINABILITY AND SOCIO-ECONOMIC POTENTIAL OF SISAL (*Agave sisalana*) FIBRE PRODUCTION IN CROSS RIVER STATE, NIGERIA: A CIRCULAR ECONOMY AND LIVELIHOODS PERSPECTIVE

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ABSTRACT

The growing demand for sustainable and environmentally responsible materials has renewed global interest in natural fibres such as sisal (Agave sisalana). This study empirically examines the sustainability, socio-economic, and agro-industrial potential of sisal fibre production in Cross River State, Nigeria, using an integrated analytical framework grounded in circular economy principles, the Sustainable Livelihoods Framework, and agro-industrial value chain analysis. A mixed-methods research design was adopted, combining semi-structured interviews, field observations, and secondary data to assess cultivation practices, fibre extraction methods, livelihood contributions, environmental performance, and value chain dynamics. The findings reveal that sisal cultivation in the study area is small-scale and largely informal, relying predominantly on traditional fibre extraction techniques. Despite these limitations, sisal production contributes meaningfully to income diversification, employment generation, and skill development among rural households. Environmentally, sisal exhibits strong sustainability credentials, including low water and chemical input requirements, biodegradability, soil conservation benefits, and alignment with circular economy objectives. However, the sisal value chain is fragmented, with weak downstream processing, limited mechanisation, inadequate institutional support, and poor market integration constraining its commercial viability. The study concludes that sisal fibre production holds substantial potential to support sustainable rural livelihoods, agro-industrial diversification, and environmental stewardship in Cross River State. Realising this potential will require coordinated policy interventions, technological investment, value chain development, and the integration of indigenous knowledge with modern processing systems. The findings provide empirical evidence to inform sustainable fibre development policies and contribute to natural fibre scholarship in sub-Saharan Africa.

Keywords: *Sisal fibre; Sustainable textiles; Circular economy; Rural livelihoods; Agro-industrial value chain.*

INTRODUCTION

Natural fibres have re-emerged as critical materials within global efforts to transition towards environmentally sustainable and socially responsible production systems. Among these fibres, sisal (Agave sisalana) (Figure 1) has attracted renewed attention due to its exceptional tensile strength, durability, biodegradability, and low environmental footprint.

Historically utilised for ropes, twines, sacks, and coarse textiles, sisal has recently found expanded applications in polymer composites, geotextiles, automotive interiors, filtration systems, and eco-textiles. These attributes position sisal as a strategically important fibre within contemporary textile and material science research.

The resurgence of interest in sisal is closely linked to increasing concerns over the environmental impacts of synthetic fibres, including greenhouse gas emissions, microplastic pollution, and non-biodegradability.

Fig.1 The Sisal Plant
Source: Umana Nnochiri (2023)

Natural fibres such as sisal align strongly with sustainability-oriented policy agendas and circular economy principles, as they are renewable, biodegradable, and capable of supporting closed-loop material systems.

Life-cycle assessments indicate that sisal cultivation exhibits a favourable carbon balance, with net carbon sequestration over the plant's life cycle (Perkasa *et al.,* 2021). Furthermore, sisal requires relatively low water input and minimal agrochemical application, making it particularly suitable for regions experiencing climatic stress and resource constraints.

Beyond environmental considerations, sisal offers socio-economic benefits, particularly in rural and agrarian contexts. Its cultivation and processing are labour-intensive (Figure 2), creating employment opportunities along the value chain, from farming and fibre extraction to processing, manufacturing, and marketing. These characteristics align sisal production with sustainable livelihood strategies and inclusive rural development objectives.

Fig. 2: Beating the heated sisal leaf to soften
Source: Umana Nnochiri (2023)

Despite its recognised potential, sisal remains underutilised in many producing regions, including Nigeria. In Cross River State, sisal has historical and cultural significance, particularly among the Obudu people, where traditional fibre extraction and rope-making practices once played a central role in local livelihoods (Figures 3 and 4). However, the erosion of indigenous knowledge, limited technological adoption, weak market integration, and insufficient policy support have constrained the contemporary development of the sisal sector in the region.

Fig. 3: Traditionally Extracted Sisal Fibres
Source: Umana Nnochiri (2023)

Fig. 4: Traditionally Extracted Sisal Fibres used for Artistic Purposes
Artist: Adida Francis (2023)

THEORETICAL FRAMEWORK

This study is anchored in three complementary theoretical frameworks that collectively inform its empirical design and analytical approach.

Circular Economy Framework

The circular economy framework emphasises resource efficiency, waste minimisation, material regeneration, and closed-loop production systems. Within this framework, sisal is conceptualised as a renewable biological resource capable of supporting circular material flows.

Fibre extraction residues and processing waste can be repurposed for composting, bioenergy, or composite fillers, thereby reducing environmental burdens and enhancing resource efficiency. Applying the circular economy lens enables an assessment of sisal's environmental performance beyond linear production

models, aligning with sustainability metrics relevant to Sustainability and Journal of Natural Fibres.

Sustainable Livelihoods Framework (SLF)

The Sustainable Livelihoods Framework provides a structured approach for analysing how sisal production contributes to livelihood assets—human, natural, financial, physical, and social capital. This framework is particularly relevant for assessing rural development outcomes, including income diversification, skill acquisition, employment generation, and resilience to economic and climatic shocks. By applying the SLF, this study evaluates sisal not merely as a fibre resource, but as a livelihood-enhancing activity embedded within local socio-economic systems.

Agro-Industrial Value Chain Framework

The agro-industrial value chain framework enables a systematic examination of sisal production from cultivation to end-use. It highlights value addition opportunities, governance structures, technological constraints, and market linkages across upstream, midstream, and downstream actors. This framework supports the identification of structural bottlenecks and intervention points necessary for scaling sisal production and integrating it into formal textile and industrial markets.

Aim and Objectives of the Study

This study aims to empirically evaluate the sustainability, socio-economic, and industrial development potential of sisal fibre production in Cross River State, Nigeria, using frameworks of circular economy, sustainable livelihoods, and agro-industrial value chains. Specifically, it examines existing cultivation and fibre extraction practices, assesses the contributions of sisal production to rural livelihoods, evaluates environmental sustainability, analyses value chain constraints and opportunities for value addition, explores the role of indigenous knowledge and cultural practices, and proposes evidence-based strategies for revitalising the sisal industry in the state.

METHODOLOGY

Research Design

This study adopted a mixed-methods empirical research design. This design is particularly suitable for studies on sustainability and natural fibres, where environmental, socio-economic, and cultural dimensions intersect.

Study Area

The study was conducted in selected communities within Cross River State (Figure 5), with a particular focus on areas historically associated with sisal cultivation and utilisation, including Obudu and surrounding local government areas.

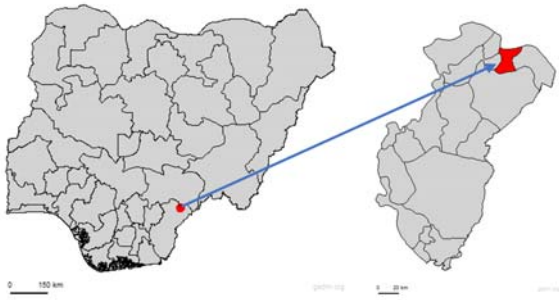

Fig. 5: Map of Obudu L.G.A., Cross River State, Nigeria. Source: Oden et al. (2012).

The state lies within Nigeria's humid tropical zone and possesses favourable agro-ecological conditions for sisal cultivation, including adequate sunlight, suitable soil types, and marginal lands that are underutilised for conventional agriculture.

Data Collection Methods

Semi-structured oral interviews were conducted with key informants in Obudu, Cross River State, Nigeria, to gather in-depth perspectives on the socio-economic potentials of sisal fibres, such as historical practices, cultural significance, and policy-related issues.

All interviews took place in Obudu to ensure contextual relevance and participant comfort. Participant details are summarised in Table 1 to maintain anonymity while providing relevant demographic and background information.

Participants were selected purposively based on their experiential knowledge and roles within the community. Pseudonyms (e.g., Participant group 1) are used to protect confidentiality.

Table 1: Characteristics of Interview Participants

Participant	Age	Occupation	Interview Date
Group 1	87/95	Community leader	February 23, 2023
Group 2	70/75	Retired headmaster	June 16, 2023
Group 3	60/65	Traditional herbalist	March 10, 2023

In addition, direct field observations documented traditional and semi-mechanised sisal fibre extraction processes, material handling, and product applications. Secondary data were obtained from

academic journals, government publications, development reports, and institutional documents relating to sisal production, sustainability, and rural development.

RESULTS

Sisal Cultivation and Fibre Extraction Practices

The findings reveal that sisal cultivation in Cross River State is currently limited in scale and largely informal. Most respondents reported that sisal plants grow naturally or are cultivated on marginal lands with minimal agronomic inputs. Fibre extraction is predominantly manual, relying on traditional methods involving leaf harvesting, thermal softening, water retting, and manual scraping.

Despite the labour-intensive nature of these methods, respondents consistently noted that traditionally extracted fibres exhibit high tensile strength and durability. However, limited access to mechanical extraction equipment significantly constrains productivity and scalability.

Socio-Economic Contributions to Livelihoods

The findings indicate that sisal production contributes modest but meaningful income to households engaged in cultivation and fibre processing.

Respondents reported that sisal-related activities serve as supplementary income sources, particularly during off-farming seasons. Employment opportunities were observed across multiple stages of the value chain, including harvesting, fibre extraction, rope-making, and artisanal product development.

Application of the Sustainable Livelihoods Framework revealed that sisal production enhances financial capital through income generation, human capital through skill acquisition, and social capital through cooperative labour practices and knowledge sharing.

Environmental Sustainability Performance

From an environmental perspective, respondents highlighted the low-input nature of sisal cultivation. The crop requires minimal irrigation and agrochemicals, contributing to reduced environmental degradation. Field observations confirmed that sisal cultivation supports soil stability, particularly on sloped and erosion-prone lands.

The findings further indicate that sisal fibre waste is biodegradable and, in some cases, reused for composting, aligning with circular economy principles. However, systematic waste valorisation practices remain largely absent.

Sisal Value Chain Structure and Constraints

Analysis of the sisal value chain revealed fragmentation and weak market integration. While upstream activities such as cultivation and fibre extraction exist, downstream activities, including large-scale processing, product diversification, and market access, are underdeveloped.

Key constraints identified include limited access to modern extraction equipment, inadequate technical training, weak institutional support, and the absence of organised marketing structures.

Indigenous Knowledge and Cultural Significance

The study documented extensive indigenous knowledge related to sisal processing, particularly among older community members. This knowledge encompasses fibre extraction techniques, product applications, and medicinal uses of sisal leaves. However, the transmission of this knowledge to younger generations is declining, posing a risk to cultural continuity.

DISCUSSION

The findings of this study underscore the untapped potential of sisal fibre production as a sustainable material and livelihood resource in Cross River State. Consistent with previous studies (Perkasa *et al.,* 2021; Cantalino *et al.,* 2021), the results confirm sisal's favourable environmental profile, including low water requirements, biodegradability, and soil conservation benefits. These attributes strongly support the positioning of sisal within circular economy frameworks.

From a livelihood's perspective, the study demonstrates that sisal production contributes to income diversification and rural employment, aligning with the Sustainable Livelihoods Framework. Although current income levels remain modest, the expansion of sisal production and value addition could significantly enhance livelihood outcomes, particularly for rural households, women, and youth.

The agro-industrial value chain analysis highlights structural weaknesses that hinder the growth of the sisal sector. The dominance of upstream activities and the absence of robust downstream processing mirror patterns observed in other underdeveloped natural fibre industries in sub-Saharan Africa. Addressing these gaps through targeted investment, capacity building, and policy support is essential for transforming sisal from a subsistence activity into a commercially viable agro-industrial sector.

The erosion of indigenous knowledge observed in this study raises important cultural sustainability concerns. Integrating traditional knowledge with modern processing technologies offers a pathway for preserving cultural heritage while enhancing productivity and product quality. Such integration aligns with contemporary sustainability discourses that emphasise inclusive and culturally grounded development.

POLICY IMPLICATIONS AND RECOMMENDATIONS

Policy Implications

The findings of this study have several important policy implications for sustainable fibre development, rural livelihoods, and agro-industrial diversification in Cross River State and similar contexts.

First, the persistence of traditional sisal cultivation and fibre extraction practices, despite decades of decline, indicates the presence of latent productive capacity and indigenous knowledge that can be strategically leveraged through supportive policy interventions. This underscores the need for policies that recognise natural fibres not merely as agricultural commodities but as integral components of sustainable industrial and rural development strategies.

Second, the environmental performance of sisal, characterised by low water requirements, minimal chemical input, biodegradability, and soil conservation benefits, positions it as a suitable crop for inclusion in climate-smart agriculture and climate adaptation policies. Integrating sisal into state and national environmental policies could contribute to carbon sequestration targets, land restoration initiatives, and sustainable land-use planning.

Third, the fragmented nature of the sisal value chain revealed by this study highlights the limitations of production-focused policies that do not address downstream processing, market access, and value addition. Without coordinated policy support across the entire value chain, sisal production risks remaining confined to low-income, informal activities, thereby limiting its contribution to economic transformation.

Fourth, the gradual erosion of indigenous knowledge associated with sisal processing presents a cultural sustainability challenge. This finding suggests that cultural heritage preservation should be integrated into agricultural and industrial development policies, particularly in regions where traditional knowledge systems underpin sustainable resource use.

Finally, the limited outcomes of previous government-led sisal initiatives, such as the pilot plantation established in Cross River State, point to the need for stronger monitoring, evaluation, and stakeholder engagement mechanisms in policy implementation. Evidence-based policy design, informed by empirical research and community participation, is essential for ensuring long-term sustainability and impact.

Policy Recommendations

Based on the study's empirical findings and theoretical frameworks, several policy recommendations are proposed to support the sustainable development of the sisal sector in Cross River State. First, sisal should be formally integrated into agricultural diversification and climate adaptation policies as a climate-resilient and environmentally sustainable crop. Incentives such as access to land, improved planting materials, and extension services should be provided, particularly for cultivation on marginal or degraded lands unsuitable for food crops.

Second, enhancing productivity and scalability requires targeted investment in affordable, locally adaptable sisal fibre extraction technologies. Public–private partnerships can facilitate access to mechanised decorticators, training programmes, and maintenance services for smallholder farmers and cooperatives, reducing labour intensity and improving fibre quality.

Third, policy support should prioritise the development of integrated sisal value chains, promoting downstream processing and value addition through small- and medium-scale enterprises in textiles, rope making, composites, handicrafts, and packaging. Strengthening linkages between producers, manufacturers, and export markets will improve market stability and income generation.

Further, policies should promote circular economy practices by encouraging the utilisation of sisal processing residues for composting, bioenergy, animal bedding, and composite fillers, thereby enhancing resource efficiency and reducing environmental burdens.

Capacity-building initiatives should strengthen human capital in sisal-producing communities, focusing on agronomic practices, fibre extraction, quality control, entrepreneurship, and marketing, with particular emphasis on women and youth.

Policies should also support the preservation and integration of indigenous knowledge, combining

traditional practices with modern technologies to enhance sustainability and cultural heritage.

Finally, effective sector development requires coordinated institutional frameworks and policy coherence, including dedicated oversight units and systematic evaluation of pilot projects to inform adaptive policy refinement.

Implications for Sustainable Development

Collectively, these policy recommendations highlight the potential of sisal fibre production to contribute meaningfully to sustainable development objectives, including rural poverty reduction, environmental conservation, industrial diversification, and cultural preservation.

By adopting an integrated, evidence-based policy approach, Cross River State can reposition sisal as a strategic natural resource within the emerging sustainable textile and materials economy.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Conclusion

This study demonstrates that sisal (Agave sisalana) fibre production in Cross River State, Nigeria, holds significant environmental, socio-economic, and agro-industrial potential. Sisal cultivation is low-input, environmentally compatible, and adaptable to marginal lands, making it a climate-resilient crop. Environmentally, sisal contributes to biodegradability, carbon sequestration, and soil conservation, while socio-economically it supports income diversification, employment, and skill development, though these benefits are limited by low mechanisation, weak institutional support, and poor market integration. The value chain is fragmented, with underdeveloped downstream processing and limited value addition. While indigenous knowledge persists, its gradual loss highlights the need to integrate traditional practices with modern technologies. Overall, sisal represents a strategic opportunity to promote sustainable rural development, agro-industrial diversification, and environmental stewardship, contingent on coordinated policy, technological, and market interventions.

Future Research Directions

Future research should address several key areas to strengthen the evidence base for sisal fibre development. These include conducting quantitative life-cycle assessments to evaluate environmental performance, economic feasibility and cost–benefit analyses of mechanised production, and material performance characterisation for high-value textile and composite applications. Longitudinal studies are needed to assess the long-term livelihood impacts, including gender and youth participation, while investigations into policy implementation and governance mechanisms can clarify the role of institutional coordination, financing, and public–private partnerships. Additionally, comparative studies across Nigerian states or sub-Saharan Africa would provide broader insights into contextual factors affecting sisal production and sustainability outcomes.

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