Indigenous Knowledge, Innovation and Utilization Technologies of Bamboo: a Case of Southern Highlands of Tanzania

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Abstract

Bamboo is a potential source of climate-smart income generation. However, bamboo has not gained significant influence on the farming-production lands, furniture and construction industries, thereby missing the substantial contribution it could make to local community development. This study aimed to fill the information gap concerning indigenous knowledge, innovation and utilization technologies performed by the local communities in the Iringa, Njombe and Mbeya regions of the Sothern Highlands of Tanzania. Systematic random sampling using a sampling frame generated with the help of village leaders was employed to draw the respondents. Focus group discussion, household survey and key informant interview were used to obtain information from consumers, bamboo producers and enterprises. Data collected were analysed using descriptive statistics. Findings on the sources of innovation demonstrate that indigenous knowledge (42.27%) and personal technical skills (30.2%) are main sources of knowledge for product innovation. Majority of traditional bamboo enterprises gain the necessary skills, knowledge and creativity via local competitors, mass media and internet. Information exchange (80%), joint buying of inputs and selling of products (73.3%), experience sharing (73.3%), and group works (26.67%) are most tactics that aid improvement and spread of innovation technologies. The study reveals that local communities utilise bamboo for food and drinks (bamboo juice and ulanzi), basketry, miscellaneous crafts, house construction, furniture, medicine and fuel use. Therefore, local community's indigenous knowldege promote innovation through use of bamboo to guarantee their livelihood and improved environmental conservation.

Keywords: Bamboo, Innovation, Indigenous knowledge, Technology and Tanzania

Introduction

Bamboo is a fascinating plant species that belongs to the grass family, but unlike most grasses, it has a woody stem that makes it a woody grass. It is widely distributed across the globe, mainly in tropical, subtropical, and mild temperate zones (Canavan *et al.,* 2017; Kaur, 2018; van Dam *et al.,* 2018; Cédric *et al.,* 2021). It is an essential component of the forest ecosystem, serving as a food source for many animals, providing an important habitat for various species and carbon sequestration (Basumatary *et al.,* 2015). However, bamboo is not just confined to forests; it is also found growing in diverse areas such as farmlands, riverbanks, roadsides, and urban areas (Paudyal *et al.,* 2019; Jember *et al.,* 2023). In farmlands, bamboo is sometimes used for various

purposes, such as for fencing, providing shade for crops, or as a natural windbreak. It acts as a natural barrier against landslides and aids in minimizing soil erosion along riverbanks and roadside. In urban areas, bamboo is widely used in landscaping and as an ornamental plant due to its striking appearance and durability (Nfornkah *et al.,* 2020).

Aspirations in the use of bamboo for livelihood improvement throughout the globe are real. In international sustainable development agenda, bamboo has gained noteworthy with the potential to contribute to the United Nations 2030 Sustainable Development Goals (SDG's). It play part in SDG 1 to ensure end of poverty in all its forms, SDG 7 to ensure access to affordable, reliable, sustainable and modern energy, SDG 11 making cities and human settlements inclusive, safe, resilient and sustainable, and more important are SDG 13 taking urgent action to combat climate change and its impacts by recognising the potential of bamboo in climate change mitigation through the carbon offsetting projects and SDG 15 protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably managing forests, combating desertification, halting and reversing land degradation and halting biodiversity loss (FAO, 2013; Lyimo *et al.,* 2019). These goals may be met through various actions, such as integration of bamboo into indigenous cropping systems (Partey *et al.,* 2017; Emamverdian *et al.,* 2020), fighting climate change with bamboo (Masisi *et al.,* 2022; Jember *et al.,* 2023) and restoration of the marginal and degraded landscapes with bamboo (Singh *et al.,* 2020; Kaam *et al.,* 2023).

Furthermore, bamboo has been mentioned in several discussions regarding sustainable development as a potential method of generating revenue in a way that is climate-smart for communities. (Partey *et al.,* 2017; Binfield *et al.,* 2022). This is due to its fast growth, intricate structural root network called rhizome (Mohan, 2022) that creates new bamboo shoots without cultivation, tangible environmental benefits, promising material properties, diverse applications and relative underdevelopment as a global industrial product (Lyimo *et al.,* 2019; Binfield *et al.,* 2022). Bearing the recognizable potential of bamboo, a number of interventions aiming to develop sustainable livelihoods with myriad environmental co-benefits through bamboo industry development are implemented. Many perceive bamboo industry growth as a climate resilient and an income generation source, providing numerous potential ecological co-benefits such as land restoration, watersheds regulation, soil erosion potential reduction (Paudyal *et al.,* 2019; Goswami *et al.,* 2022) and carbon credits generation through carbon offsetting projects such as carbon farming and carbon trading (Dwivedi *et al.,* 2019). In fact, the lives and livelihoods of the local community are closely related to this vital resource for a long time. (Lee *et al.,* 2021; Mwanja *et al.,* 2023).

Nevertheless, bamboo has not yet gained a significant influence on not only the farming-production lands, but also it has even less of an impact on the furniture and construction industries, thereby missing the substantial contribution it could make to local community development (Cédric *et al.,* 2021; Endalamaw and Darr, 2021). The local community needs to increase food production to meet demand and predicted dietary changes under an increasingly inhospitable climate (Tilman and Clark, 2014; Kurgat *et al.,* 2020). This may be achieved by appropriate implementation of climate-smart farming approach through use of innovative options such as the holistic approach of integrating bamboo to attain the prospers it hosts in farming. This study examines the indigenous knowledge, innovations, and utilization technologies required to convert the resources of bamboo into novel uses in an effort to narrow this gap in the context of the Southern Highlands of Tanzania. The study also looks at the importance of indigenous technologies acting as a springboard for innovations in bamboo-based production and processing, given that innovation is path-dependent and a result of the existing technological base and absorptive capacity.

Indigenous technical knowledge practices are farmer-friendly, socially accepted, economic, environmentally sound, and suited to certain local and environmental conditions (Sharma *et al.,* 2009). In addition, the local technical

knowledge of traditional crafts, processing and harvesting methods represents a valuable cultural heritage in bamboo-producing areas and also provide a source of supplementary income for vulnerable communities (Luo *et al.,* 2020; Binfield *et al.,* 2022). Actually, they are origins of innovative solutions that may be needed by the current world of sustainability. Despite their importance, indigenous technical knowledge practices are neglected and often disregarded on the pretext of being unscientific (Sharma *et al.,* 2009). Therefore, in order to fully understand on the contribution of indigenous knowledge, utilization technologies of bamboo, as well as to document on the innovation sources in bamboo enterprises an integrated investigation was carried out. This study on indigenous knowledge, innovation and utilization technologies of bamboo was conducted to (1) identify the indigenous knowledge, innovations and utilization technologies of bamboo (2) assess the extent of knowledge and technological sources of innovation which may be crucial for development of local bamboo entreprises.

Materials and Methods

Study area

This research was carried out in the in Southern Highlands of Tanzania situated between 6°-12°S and 29°-38°E. These highlands have temperate climate, accompanied with high annual rainfall and cool weather. The annual temperatures range from 13°C and 19°C and the characteristic rainfall patterns are unimodal, with a single and long rainy season from November to April or May (FAO, 2016). We studied bamboo products consumption, bamboo resource production and bamboo processing enterprises from the bamboo-based communities in the Mbeya, Njombe and Iringa regions of the southern highlands (Fig. 1). The detailed descriptions of the study areas conditions are in (Table 1). The particular districts where the study was conducted in these three regions are Njombe rural of Njombe region, Mufindi of Iringa district, Rungwe and Mbeya rural of Mbeya Region. The study area is prioritised since it hosts the high value taxa of bamboo (Lyimo *et al.,* 2019). The dominant bamboo species found in these regions are *Oxytenanthera abyssinica* (A.Rich.) Munro (syn. *Oxytenanthera braunii*), *Bambusa vulgaris*, and *Yushania alpina*.

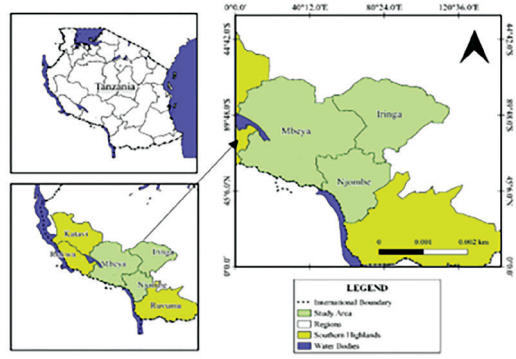

Figure 1: Study area map showing Mbeya, Njombe and Iringa regions of the southern highlands.
Source: (Authors, 2023)

Research Design

The study sites ware purposively selected based on the bamboo produce, use and availability. Multistage stage sampling techniques were employed to draw sample household heads. In the first stage, potential villages in bamboo produce and use were

Table 1. Description of the study areas

Region	Climate	Location	Elevation (m. asl)	Mean Annual Temperature (°C)		Mean annual rainfall (mm)	
				Low	High	Low	High
Iringa	Warm-temperate	7°46'S, 35°42'E	242-2328	14.3	24.9	900	1400
Mbeya	Tropical highland	8°54'S, 33°27'E	475-2960	13.5	22.9	650	2700
Njombe	Temperate highland tropical	9°19'S, 34°46'E	471-2931	19.7	26.9	600	1600

Source: (Authors, 2023)

identified with assistance from the local leaders. The villages selected for this study include Matanana, Mtwango, Bumilayinga, Mbalamaziwa, Kihanga, Changarawe, Igolowe, Kitasengwa, Igombavunu, Isalavunu, Kinyanambo C, Mkwawa, Nzivi, Makungu, Ihalimba, Lugolofu and Itimbo of Mufindi district, Iringa region, Luanjiro of Mbeya rural, Unyamwanga and Mwanzasi of Rungwe both in Mbeya region and Hagafilo, Kibena, Nundu, Uwemba and Iboya of Njombe rural, Njombe region. In the second stage, the number of sample households from each sample village was determined from the recent lists of households using a probability proportional to the size sampling approach adopted from Yamane (1967). With relation to the households in terms of their socioeconomic characteristics and livelihood styles, bamboo-growing sample households were drawn using a systematic random sampling method from each village.

Data collection

This study was based on primary data obtained through a household survey, key informant interviews and focus group discussions. The household survey was conducted in June and July 2022. The household survey covered socio-demographic characteristics, bamboo use and utilization, bamboo harvesting, bamboo processing and bamboo products. In addition, key informants (bamboo small-medium enterprises) were interviewed using a semi structured questionnaire. Focus group discussions were conducted in each region consisting of local bamboo processors or harvesters, community leaders and were mobilized with a facilitator. The survey employed kobotool box a free-software for data collection and which simplified data entry process.

Data analysis

The main analytical technique was descriptive statistical analysis. The data collected were directly exported to Microsoft Excel from kobotool box, where they were correctly filtered, coded and imported into RStudio software version 4.2.3 for analysis. Descriptive statistics such as mean, frequency and percentage of variables were computed to describe bamboo use in the research sites.

Results and Discussion

It is crucial to understand the essential characteristics of the sampled bamboo users before we know more on their indigenous knowledge. The socio-demographic characteristics of the respondents are summarized in Table 2. Consequently, the analysis considered factors such as education level, marital status, land ownership, age, sex, family size, and ethnic group of the respondents. Out of the total sample households, 65.56% and 34.44% of respondents were male and female-headed, respectively. The majority of the respondents (81%) were married, followed by 14% and 5% of single and widowed household heads, respectively (Table 2).

Among the important aspects of the household characteristics is age as it affects the general state of health in the community; it has implications on the productivity of the individuals. The majority (53%) of the respondents were aged between 36 and 60, followed by youth (38%) aged between 18 and 35. This shows that it is mainly the youths and middle-aged group that engage in bamboo activities while the older age group probably participates in less labor-intensive activities. The youths and middle-aged group are still actively seeking for livelihood options. Thus, they engage more in cash generating activities such as bamboo product processing and marketing (Kalanzi *et al.,* 2017).

Majority of the respondents (99.6%) had at least gone to school. However, many of them (64%) had attained primary education, while 29% and 7% had completed secondary school and tertiary education respectively. Only 0.4% were illiterate. The total of 13 ethnic groups were among the respondents. The Hehe ethnic group were the dominant tribe (45.8%) among the bamboo harvesters followed by the Bena (25.2%), Kinga (15.4%), Nyakyusa, Chagga, Ndali, Safwa, Ngoni, Pangwa, Wanji, Maasai, Malila, Nyiha and Zigua. Hehe are famously known for processing bamboo juice and bamboo beer (*ulanzi*). Out of the sample respondents 49%, 48% and 3% had family members below

4, between 5 and 8, and above 9 respectively. Majority of the respondents (94%) had private land (up to 20 acres of bamboo) of which they used to harvest bamboo while 6% were obtained bamboo from the general lands.

Table 2: Socio-demographic characteristics of the respondents

Parameter	Category	Percentage
Sex	Male	65.56
	Female	34.44
Age	18-35	38.15
	36-60	52.59
	>60	9.26
Education level	Primary	64.07
	Secondary	28.52
	Tertiary	7.04
	Not educated	0.37
Marital status	Married	80.56
	Single	13.89
	Widowed	5.56
Land ownership	General land	5.77
	Private	94.23
Family members	Below 4	49.07
	5-8	48.15
	Above 9	2.78

The study reveals that local communities use bamboo for a diversity of purposes. The interviewees for this study apply bamboo for around 20 different local uses (Fig. 2). The frequently mentioned uses are food (young edible shoots) and drinks such as bamboo juice and bamboo beer (ulanzi), basketry (hand baskets, winnowing trays, hats), miscellaneous crafts (mats, rugs, fish trapping cages, utensils, decorative materials), house construction, furniture (chair, bed and table), medicine (treating fever) and fuel use. Iringa region ranked high in the use of bamboo for basketry, drinks, house construction and miscellaneous crafts. However, the presented frequently used bamboo products are utilised by respondents from three regions at different rates (Fig. 3). Fuel use has low rate of use to all the three regions. This presents the gap in the use of bamboo in confronting energy poverty. Sovacool (2013) reviews the challenges and discusses the mechanisms to overcome the challenge with use of bamboo.

Many people in the southern highlands use bamboo juice and bamboo beer (ulanzi) tapped from *Oxytenanthera abyssinica* bamboo specie as their favorite drink. An interesting fact, the bamboo beer alcohol content increases as it continues to be stored. This differentiates bamboo juice which is freshly tapped few hours from bamboo culms to bamboo beer which is stored for some days after being tapped. Kaale (2022) researched the alcohol levels this bamboo beverage and scientifically proved a significant increase in the alcohol content. Some community groups in Iringa utilizes young edible shoots of bamboo as food after cooking them and they argued that they have delicious taste. The local knowledge of edible bamboo is also evidenced by Irawan *et al.* (2019). With an increasing demand of food in the era of inhospitable climate, bamboo shoots an overlooked commodity can ensure food security (Basumatary *et al.,* 2015). Bamboo baskets of diverse styles are also used by local community and the respondents revealed that the bamboo baskets are durable and they real help them in carrying their stuffs especially when they attend market places. The results is evidenced by Liu *et al.* (2018) reviewing resources and utilisation of bamboo resources in China which is the most abundant bamboo resources worldwide and with the richest bamboo culture.

The respondents utilize their traditional technical knowledges to produce many of their

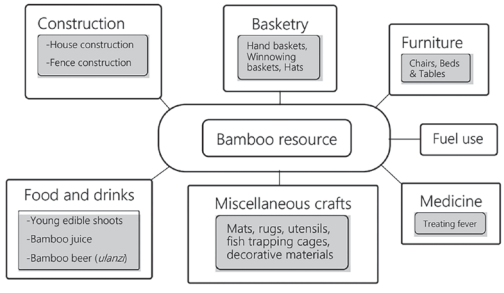

Figure 2: Different uses of bamboo resources by the local community in the study sites

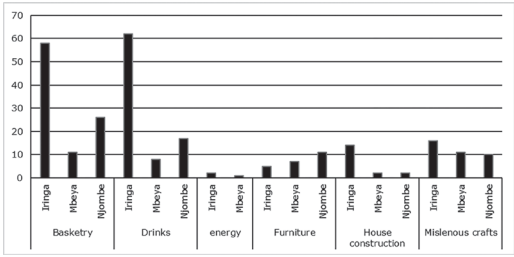

Figure 3: Frequently mentioned bamboo uses in the three selected regions

products such as bamboo juice, bamboo beer (*ulanzi*), miscellaneous crafts like bamboo jars, bamboo basket cages for carrying luggage, winnowing baskets, bamboo decorative materials and mats. They obtain direct benefits of bamboo through various produced goods. These bamboo products produced by these communities presents the innovation of which they have utilised the available resource to produce the various products, food and drinks which are useful to their lives and the business improve their livelihood. (Irawan *et al.,* 2019; Sharma, 2009). The results are the are related with the studies by Seyoum *et al.* (2018) and Cédric *et al.* (2021) revealing the common indigenous knowledge and utilisation practises of bamboo in the highlands areas of Africa.

The findings on sources of innovation of this study demonstrate that indigenous knowledge (42.27%) and personal technical skills (30.28%) are main sources of knowledge for product innovation. Local competitors (10.1%), mass media (6.31%) and internet (4.42%) aid the enterprises to obtain skills and innovation creativity. Majority of traditional bamboo enterprises gain the necessary skills, knowledge and creativity via local competitors, mass media and internet. In addition, the results shows that respondents with little experience in the business had many to learn from their local competitors. In business environment, it is true that the starting enterprise usually obtains their necessary skills, knowledge and innovations from their competitors or neighbors. Similar results are elaborated by Endalamaw and Darr (2021) on the traditional and semi-modern bamboo enterprises.

Mass media such as televisions, social medias and online publicity were mentioned by respondents to be used for the enterprises to obtain the critical skills and innovations. These methods are suggested to be among the ways to adress the awareness gap (Sovacool, 2013). The respondents may surf on the internet to obtain some additional skills and innovations. The results (Table 3) shows that internet is preferred by few respondents compared to other methods, however it is used. This may be due to the fact that, local respondents do not know exact websites or platforms where they may obtain knowledge and skills and lack of variety of platforms giving skills in relation to their culture and market around these local enterprises. The study by Borowski (2021) shows an exemplification of bamboo innovation theory which is used in practice.

Table 3: Percentage source(s) of innovation employed by respondents in the study

Source of innovation	Percentage (%)
Indigenous knowledge	42.27
Personal technical skills	30.28
Local competitors	10.1
Mass media	6.31
Internet	4.42

The results (Fig. 4) reveal that respondents that had more years of experience uses their local knowledge in processing various bamboo products. Most of the enterprises especially family-based enterprises have the processing skills since they are taught by their relatives and these products are highly demanded. Personal technical skills is the second most important source of innovation to these enterprises. The respondents report that they use their own ideas and technical skills adopted from their neighbors and the trainings from BUSIA bamboo school. The personal technical skills are accompanied with experience in working with bamboo of which may be locally attained or initated from trainings.

Experience in working with bamboo is an important factor (Tsegaye *et al.,* 2022). Years of experience in the business and various sources of knowledge and innovation were related (Fig. 4).

This was done to identify the preferred method of obtaining knowledge, skills and innovation creativity in processing bamboo. Majority of respondents who reported to use their own ideas had above 15 years of experience in the business. Indigenous knowledge and personal technical skills such as use of own ideas had high frequency of count to the respondents with experience above 15 years. The respondents in the study areas prefer these two knowledge and innovation sources throughout various years of experience in the business with regard to the bamboo products they produce and the locality nature. The respondents with little years of experience uses nearly all mentioned sources to obtain skills and innovation for their businesses. They have higher frequency of count in seeking expert advice than other groups of years of experience. The respondents with experience above ten years were few (below 5 frequency of count) on local competitors, expert advice, mass media and internet sources of knowledge and innovation.

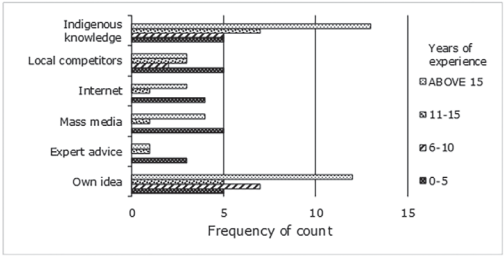

Figure 4: Years of experience in the business related to knowledge and innovation sources

This survey reveals that information exchange (80%), joint buying of inputs and selling of products (73.3%), experience sharing (73.3%), and group works (26.67%) are most tactics that aid improvement and spread of innovation technologies (Fig. 5). Networking provides room for information exchange and knowledge sharing (Kazungu and Kumburu, 2023). Networking among enterprises results to significant success in innovation as major new technologies are attained (Endalamaw and Darr, 2021). The respondents reports that they usually share knowledge, innovation and market information. Furthermore, it is reported that information and skill exchange among bamboo enterprises is mainly restricted to friends, family or neighbors. Information from outside the closed family or friend circle is usually obtained indirectly though staff mobility between enterprises, seeking expert advice, and by observing processing and product displays. The results by Soh and Omar (2012) also shows the potential of sharing indigenous knowledge on the sustainable livelihood.

Bamboo enterprises also do share work force and borrow tools and equipment for working to produce different bamboo enterprises. The survey shows that sharing of resources is less frequent than networking for information exchange, experience sharing, joint buying of inputs and selling of products. The innovativeness of an enterprise depends on availability of knowledge and its appropriate selection and application (Borowski, 2021). Bamboo enterprises in the study sites are typically characterized by a limited knowledge and skills, poor communication networks, and absence of research and development sections. The study by Li and He (2019) mentioned the problems related to usage and development of bamboo resources, including overexploitation, low utilization efficiency, the shortage of bamboo raw material, and environmental issues. All these pose limitation in bamboo industry development and external knowledge is needed for their improvement.

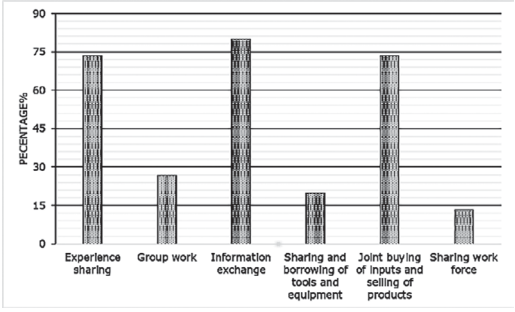

Figure 5: Percentage of results showing the tactics that aids in dissemination of innovation technologies

Bamboo producers also obtain indirect benefits that contribute to climate change adaptation. It proves to be a crop that can adress both climate change and livelihoods (Lobovikov *et al.,* 2012; Dwivedi *et al.,* 2019)

The respondents reveal that bamboo provides them a good animal fodder especially in the dry season when other grass species are scarce. They argue that bamboo leaves remain green and palatable during dry season and hence substantially improve the quality of fodder mixes. Bamboo grown on the agricultural farms protect the farms from flooding and soil erosion during the rainy season, the role of bamboo which is also elaborated by Goswami *et al.* (2022). In many areas of the study sites bamboo was grown at the border of farm fields and river banks. They facilitate protection of the rivers and their ecosystem by regulating the quality and quantity of water. The grown bamboo on their farming fields increases ecological and economic resilience of these cropping systems. Additionally, it was noted that the bamboo forest is still intact and rhizome-rich, shielding the soil from too much sunshine and other disturbances. This ensures crop production even when there are unpredictable rainfalls. The same practice is evidenced on the study by Endalamaw and Darr (2021) in the context of Ethiopia and Partey *et al.* (2017) study on bamboo based agroforestry.

Conclusion and Recommendation

The survey shows that enterprises are utilizing indigenous knowledge and technology, their own technical expertise, such as acquired training and creativity, and networking through experience sharing and information exchange. By employing this expertise, bamboo producers and firms may be able to create new goods and utilize bamboo in new ways, greatly enhancing its quality, competitiveness, and durability. The survey also finds that stakeholders in the bamboo industry encourage innovation by offering training, institution growth, policy reform, and extension assistance. This is to mention the contribution of responsible supporting functions such as the respective ministries and agencies, research institutions, finance agencies, and bamboo related organizations such as BUSIA bamboo school under INBAR, BINAPO and BARATA. The bamboo industry is increasingly shifting from sales of raw materials to more inventive goods such as long-lasting products. However, further innovation is required to boost the competition of these items in international markets. The existing innovations are still primarily gradual with a limited scope. They are limited by the structural, financial, and capacity issues preventing more radical developments.

The study further reveals that bamboo plays great role in community livelihood provision and climate change mitigation as far as environmental conservation is concern. First, it stores carbon during its production at the farm at a pace that was unsurpassed by slow-growing species. Second, the creative use of bamboo components in various long-lasting goods and building constructions extends the life of bamboo and delays the release of carbon into the environment. Lastly, increased value-added product returns would probably encourage farmers to further expand their bamboo farms. This study has demonstrated that bamboo products are mainly produced in the study region using local expertise. The socioeconomic well-being of the locals is influenced by these goods, some of which serve to supplement household income. Through capacity building interventions on product development to increase their quality, these items' economic worth may be raised. This may help the local community to generate carbon credits from bamboo carbon farming.

Therefore, it is recommended that farmers and knowledge-intensive start-up organizations receive more coordinated support and technical training in order to encourage enterprises to structurally restructure themselves and successfully compete with the global markets. Expanding bamboo processing businesses is necessary to meet the urgent need for wood-based products including plywood, pulp, and paper. More opportunities related with effective use of bamboo should be exposed to the community. The opportunity for carbon farming and carbon trading with bamboo as the carbon offset mechanism and the use of bamboo for energy access. In perspective, more research on the value chain and the best native bamboo management techniques will be needed for improved bamboo sector planning in the southern highlands.

Conflict of Interests

All authors declare that they have no

conflict of interest regarding the content and publication of this paper.

Acknowledgments

We express our sincere gratitude to the Sokoine University of Agriculture Research and Innovation Support (SUARIS) for the financial support that made this work possible. Without their invaluable support, this project titled "Enhancing commercialization of Bamboo farming for poverty alleviation and conservation in the Southern Highlands of Tanzania" could not have been realized. Their contribution has been instrumental in advancing our understanding and contributing to the Bamboo industry. We distinctively acknowledge SUARIS for their noteworthy support.

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