NIRDA
National Industrial
Research and Development
Agency

NATIONAL INDUSTRIAL RESEARCH AND DEVELOPMENT AGENCY

TECHNOLOGY AUDIT OF BAMBOO VALUE CHAIN REPORT

JANUARY 2021

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LIST OF ACRONYMS AND ABBREVIATIONS

CAPI	Computer-Assisted Personal Interviewing
COVID 19	Corona Virus 2019
CORAR	Compagnie Rwandaise d'Assurances et de Re-assurance
EIA	Environmental Impact Assessment
EICV	Integrated Household Living Conditions Survey
ENABEL	Belgian Development Agency
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GHG	Green House Gas
GGGI	Global Green Growth Institute
GIS	Geographical Information System
GPS	Global Positioning System
GoR	Government of Rwanda
Ha	Hectare
IER	Institute of Engineers of Rwanda
ILO	International Labor Organization
KII	Key Informant Interviewees
MIFOTRA	Ministry of Public Service and Labour
MININFRA	Ministry of Infrastructure
MINICOM	Ministry of Trade and Industry
MoE	Ministry of Environment
NIRDA	National Industrial Research and Development Agency
NISR	National Institute of Statistics of Rwanda
NST 1	National Strategy for Transformation One
ODK	Open Data Kit
R&D	Research and Development
RCA	Rwanda Cooperative Agency
REMA	Rwanda Environment Management Authority
RHA	Rwanda Housing Authority
RMB	Rwanda Mines, Petroleum and Gas Board
Rwf	Rwandan Francs
SKAT	Swiss Resource Centre and Consultancies for Development

RSB	Rwanda Standards Board
RSSB	Rwanda Social Security Board
SME	Small Micro Enterprises
SPSS	Statistical Package for the Social Science
SWOT	Strengths, Weaknesses, Opportunities, and Threats
VC	Value Chain
TVET	Technical and Vocational Education and Training

EXECUTIVE SUMMARY

This report presents the findings of the value chain analysis including the technology audit of the bamboo value chain for construction materials. It was conducted by Sustain Consortium, on behalf of NIRDA in collaboration with ENABEL in the period of September 2020 to February 2021. The overall objective of the study was to conduct a value chain analysis including a technology audit of bamboo value chain for construction materials by assessing the following: (i) assess each value chain in terms of efficiency, (ii) assess each value chain in terms of existing quality, (iii) assess each value chain in terms of product differentiation, (iv) assess each value chain in terms of social and environmental standards, (v) assess each value chain in terms of business environment and (vi) assess the carbon impact (CO^2) of these materials.

Approach and methodology

A desk review of all relevant documents related to the aspects of the study, including but not limited to national development plans and strategies, value chain, Tech Audit, legislation, market data and other studies related to bamboo were reviewed prior to the field data collection . Through the initial desk review, key stakeholders and the bamboo key actors were identified. Furthermore, bamboo product markets were assessed as well as end-user to have general view of Rwandan bamboo value chain including technology audit of bamboo value chain for construction materials.

The primary data were collected on the field from various bamboo value chain actors and key informants in all districts of the country. Closed ended questionnaires were used to collect quantitative data while interview and focus group discussions (FGD) were used to collect qualitative data. Purposive/judgmental sampling and simple random sampling techniques were used to determine the sample size. The sample were selected in two stages: The first stage focused on the key stakeholders who responded to the individual questionnaire. The list included all actors involved in processing bamboo products up to the end-users (e.g. nursery operators, growers, processors, traders and users/constructors). The 193 stakeholders (respondents) were given an individual digital questionnaire uploaded on SAMSUNG Galaxy 2016 tablets. At the second stage, qualitative data were collected using interview guides to the Focus Group and Key Informants (28 respondents). The latter includes non-profit and governmental agencies along with researchers and academia who are interested to studies related to clay.

Summary of the main findings

The results of this study were grouped according to the key aspects analyzed.

i. **Demographic characteristics of respondents:** It was revealed that 48.7% of bamboo operators are aged between 36 and 55 years old with 33.7% have between 18 and 35 years of age. The bamboo value chain actors with more than 56 years old are representing less than 17.6%. This implies that more than 80% of bamboo value chain actors are in the age group varying between 18 and 55 years. More males (more than 80%) were interviewed compared to the females (20%).

ii. **Description of firms:** A high percentage of firms performs single activity (58%) while 42% perform multiple activities and 59.1% of them have between 6 and 20 employees with 34.2% having between 1 and 5 employees. Most of firms (76.2%) are under sole proprietorship while 12.4% are owned by cooperative with less than 15% of firms are registered under unlimited (5.2%), limited by shares (1.6%) or partnership (4.2%) and limited shares by guarantee. Furthermore, 83% of firms are informal operating with only 17% operating formally. Additionally, 97% of the firms are owned by Rwandans with only 2% under hands of foreigners while 1% are owned by both Rwandans and foreigners.

iii. **Working conditions of employees:** Results from the survey revealed that only 18% of firms' employees have appropriate clothes and other protection tools to reduce or/and avoid accidents at the work place but more than 75% of investigated bamboo value chain actors possess an activated health insurance of "Mutuelle de Santé". It was found that the majority of the bamboo actors did not receive any incentive as declared by the highest number of traders (85.7%), nursery operators (63%), bamboo growers (61.4%), and end users (57.6%) processors (37.5%) respectively. Moreover, there are bamboo growers (26.1%), nursery operators (22.2%), processors (25%) and end users (15.2%) who confirmed to have received bonus on done activity in past 12 months. It was seen that that the highest number of firm's employees by category are full time employees working as either users (88.9%), traders (66.8%), bamboo growers (61.3%) or nursery operators (53.3%). The study reveals that the highest number (41.7%) of bamboo value chain actors spend between 5 and 7 days a week in bamboo related activities. Moreover 22.2% of respondents confirmed to occasionally be engaged in bamboo related activities with 11.1% who declared to use only 1 to 3 days per week for the same purpose

iv. Business relationships network between bamboo value chain actors and other stakeholders: There have been three main projects that have been carried out with the aim of promoting bamboo planting and associated livelihood improvement. These projects represent the primary flow of financing into the bamboo sector to date: Government Partnership - The China Bamboo Aid Project, Non-Profit - ARECO's - The Project Bamboo Burera (BamBu), conjoint project of International Organization and FAO's Securing Community Livelihoods with Bamboo Program. The study revealed that the majority of firms do not have any contract between firm and various stakeholders as only 19.5% and 6.7% of firms have confirmed to have written contracts with employee and with traders respectively while only 2.9% of firms have contract with transporters.

v. **Productivity and financial assets:** The highest number of respondents (40.7%) declared to have produced less than 5000 bamboo seedlings in a year with 18.5% who produced between 5001-10000, between 11,001 and 50,000 respectively. 11.1% of respondents said to have produced between 51,000 and 100,000 and above 100,000 respectively. The highest number of respondents (64.8%) declared to have produced less than 5000 bamboo trees with 24.1% and 1.9% of respondents who produced between 5001-10000, between 11,001 and 50,000 respectively. 7.4% and 1.9% of respondents said to have produced between 51,000 and 100,000 and above 100,000 respectively. This study conducted by Ministry of Lands and Forestry showed that a total of 523.5 hectares were covered by bamboo in 2017. Of this total area, 192.7 hectares are highlighted as having suffered from high damages and are at high risk of survival. The study reveals that the majority (58.5%) actors in bamboo sector have invested less than 500,000 with only 0.7% of respondents who confirmed to have invested between 50 million and 100 million.

vi. **Competitiveness of bamboo based construction materials on internal and external market:** the competitiveness of bamboo sector can be assessed by analyzing the interaction of the following aspects; firstly, the availability of labor and skills they possess and raw materials. Secondly, the status of domestic demand in pressuring companies into making their products more competitive. Thirdly, the received supports from various stakeholders and inputs that are advantageous for internationalization and innovation and lastly, the factors regards how companies are managed and organized. The study revealed that bamboo can be considered as more competitive than other trees used in construction like like Eucalyptus, Pinus, and grevillea as the take much more years to mature (7 years) compare to bamboo (3 to 5 years). Additionally, after the first harvest many trees (more than 20) are harvested from the original bamboo tree while the tree like Grevillea will be harvested once only. Therefore, bamboo tree earns potentially more income than other trees used in construction in period of 10 years.

The majority of respondents (95.2% and 70%) highlighted limited capital and high cost of processing raw materials as the main problems hindering the competitiveness of bamboo products. The poor/limited technology for bamboo processing comes to the third position among the others main challenges facing bamboo sector. The improvement of financial and technical support (34%) and importation of modern processing technologies (28%) were suggested to be the best solutions to the market competition. Growing bamboos on hillsides (15%) and the provision of trainings in the use of construction sector (14%) along sensitization bamboo profitability (9%) were also mentioned as appropriate solutions to deal with market competitions.

vii. **Infrastructure and technology in place**:

Agricultural practices applied to grow bamboo seedlings and trees: The study revealed that there are different methods in use across the country for growing bamboo seedlings. Some are grown in open areas, others are grown in green houses depending on the types of grown seedlings and the expected quality of mature bamboo trees. Manure and fertilization are important when the seedling is transplanted in the main field. As the bamboo plants are heavy feeders, even the richest soil will get washed-out after few years, if fertilizers are not applied on them. But it is always suggested to apply fertilizer after harvesting and previous to irrigating the plants. Potassium and Nitrogen are vital components of the fertilizer due to which the bamboo trees respond and grow well.

Engineered bamboo: Though the engineering of bamboo timber in Rwanda is not yet at advanced stage. The following three categories were subjected by the Ministry of Lands and Forestry, 2017 to be developed in Rwanda: (a) Oriented strand board, (b) Plywood and (c) Medium Density fibre board (MDF) as also reported by the Ministry of Lands and Forestry, 2017.

Common technologies in construction with bamboo trees: The study shows different ways Rwandans have been able to manage to construct walls of houses with help of bamboo trees and they are used for making roofs or the doors of houses. It is worth noting that the majority of the bamboo value chain actors (54.1%) make use of their working experience to perform daily duties. Only 20.5% and 4.3% are applying what they have learnt from trainings and schools respectively while 17.3% and 3.8% use personal insights and guidance form their supervisors. Hence, 72% of firms are still traditional in nature with only 20% and 8% which were classified as semi-modern and advanced firms respectively. Moreover, the other country have been managed to use of bamboo products to construct touristic areas, making corrugated and galvanized bamboo roofing sheets. Bamboo trees are also used for scaffolding in construction of tall houses and making MDF.

viii. **Quality control and standards status assessment:**

The study revealed that the identification of a bamboo as raw material with good quality is done using personal experience as declared by 91.9.% of respondents with 2.2% who use expertise they have in the domain. Only 0.5% of respondents confirmed to use internal R&D and lab tests. Additionally, 69.9% of respondents revealed that they do not follow any standard in processing stages of bamboo product. It was reported by majority (80.8% of end-users, 73.7% of traders and 68.7% of growers) that they have no standard control system of their products. Only 51.9% of nursery operators and 30.4% of processors confirmed to have standard control system on bamboo seedling and bamboo trees.

ix. Environmental issues resulting from the use of clay

It was further encouraging to hear from that the majority of respondents that bamboo trees are useful to be grown on degraded land, for erosion control, restoring organic soils and stabilizing water tables. Furthermore bamboo has the potential to contribute significantly towards the fight against global climate change through removal of atmospheric carbon dioxide. For instance, 1,000 ha covers by bamboo plantation absorb 495,000 tCO_2e

Key recommendations: The following are some of the key recommendations from the study. Improvement of designs, innovative use of bamboo should be the focus to upgrade the value of bamboo.

The industrial manufacturing units are recommended to be developed in Rwanda.

To move from using bamboo as trees only towards to production of more competitive products like MDF, roofing sheets, among others.

The Government of Rwanda make available attractive financing options and incentive schemes for private sector involvement in the sector. The proposed projects are unlikely to be attractive for private sector for foreign direct investment without a blended public and private finance strategy. If such financing is made available, the impact towards a green economy for Rwanda and the stimulation of domestic manufacturing is considerable.

Rwanda's existing bamboo resources to be enacted, clear clarification and policies on harvesting and other licenses for this resource, taking into account the unique attributes of bamboo not only to the environmental protection by also its commercial roles, are recommended.

1. GENERAL INTRODUCTION

1.1. Context of bamboo in Rwanda

Approximately 3.2% of the world's total forest area is made up of bamboo (common name known as *Bambusa vulgaris*). Its potential as a traded commodity and as a key resource with social and environmental benefits is increasingly being recognized. Rwanda has bamboo resources scattered around the country. It is a member of the International Network for Bamboo and Rattan (INBAR), and Rwanda has undertaken bamboo projects to promote furniture, handicrafts, toothpicks and skewers. Yet there is desire for increased private investment in bamboo plantations and industries to shift the focus towards industrialization and meet markets for wood and fibre products.

The study carried out on status of bamboo in Rwanda revealed that out of a projected 800 hectares to be in place by 2017, only 523 hectares were remaining in varying stages of maturity and health (Bizimana, 2015[1]). Based on a combination of factors such as maturity, logistics, and planted areas, approximately 300 hectares of bamboo trees were deemed to be suitable to be commercialized by 2017. Additionally, it was seen that there is a possibility to produce molded pulp products to supply domestic markets for single use food and beverage items to replace unsustainable plastics, styrofoam and aluminium packaging. It was also seen that the bamboo waste would be converted into biochar and a steep liquor. This facility would utilize an innovative and entirely clean manufacturing technology, allowing Rwanda to be a pioneer in the move away from single use plastics (Ministry of Lands and Forestry, 2017[2]).

The study conducted by Rwanda Water and Forestry Authority in 2017 demonstrated that bamboo may provide a good raw material for toothbrushes and spoons and 50,000 toothbrushes per month are produced by the Northern Province Toothbrush Manufacturing Facility. These have been started to be produced in factory located in Northern Province. Such products fit exactly in Rwanda's vision of stopping using plastics and reducing the use of metallic spoons. It would also allow Rwandan platform to gain significant global attention, likely driving further interest in private sector investment (Ministry of Lands and Forestry, 2017).

Rwandan bamboo was tested to be a good raw material of high quality for roof sheeting with significant environmental and social benefits and a test was done in roof sheeting factory located in Eastern Province. This particular product would replace corrugated iron roofing across the

[1] Bizimana, I. (2015). Evaluation Finale du Projet BamBu. ARECO and EU

[2] Ministry of Land and Forestry, (2017). A feasibility study for a bamboo based bio-economy for Rwanda.

country and have further potential as an export product. The study undertaken by RWFA in 2017, demonstrated also that the production and use of clean bamboo as source of cooking energy in Rwanda would serve as demonstration projects to show the potential for a well-managed bamboo resource to be an interim solution for cleaner energy, as Rwanda moves towards its development goals for renewable and clean energy.

The promotion of the above mentioned bamboo derived products should be in line with Rwandan's vision to promote "made in Rwanda" products. Moreover, a full mapping of the available bamboo in Rwanda along with its value chain analysis and key players would be a winning step towards national, regional and global development commitments (e.g. Vision 2050 aspirations, National Strategy for Transformation (NST1), Green Growth and Climate Resilience Strategy (GGCRS), Nationally Determined Contributions (NDCs), Sustainable Development Goals (SDGs), Agenda 2063, East African Community-EAC Vision 2050, etc.).

It is in this regard, NIRDA in collaboration with ENABEL made a call to engage an experienced consultant to undertake technology audit of bamboo value chain including access to technology, existing technological capabilities, and existing green technologies and to identify possible opportunities for value chain upgrading, extending and optimizing. It is in this regard that Sustain Consortium was hired to undertake technology audit of bamboo value.

1.2. The rationale of undertaking technology audit of bamboo value chain

The Government of Rwanda has approved a Revised National Environment and Climate Change Policy (2019) which was emphasizing on promotion of green economic, enhancing functional natural ecosystems and managing biosafety. The Government further approved the Revised National Land Policy (2019), aiming at strengthening land administration and management to ensure optimal allocation and use of land and promoting climate change adaptation, mitigation and response. More specifically, the revised land policy addresses existing gaps in the land use planning and mapping, land utilization by various sectors, and land administration and management.

In the same line, the improvement of environmental quality comprising rational land use, conserving soil, protecting ecosystems and preserving biological diversity and rehabilitation of degraded zones was listed as a cross-cutting theme in the National Human Settlement Policy. Policy also talks about creating a dynamic continuum between towns and the countryside. The objectives include regrouping settlements, improving the quality of individual houses and building high-quality new houses and facilitating housing through appropriate financing mechanisms. The redesigned villages are to be provided with clean energy and water, and where feasible, connected to a national power network. The Settlement Policy seeks to encourage the promotion and trading of locally available construction materials.

A preliminary study identified several value chains as potentially key in the development of MiR construction materials. Besides clay and natural stones as the materials with the largest potential, the study also highlighted bamboo (straws, fibres, etc…) as innovative material to be used in construction, which could be domestically and internationally competitive because they have a positive impact on climate change and the environment if combined with appropriate green production technologies.

However, the implementation of a bamboo value chain programme would involve different governmental and non-governmental institutions. In terms of the development of bamboo value chain a prior technology audit is highly needed to make the sector fully exploited and fall in NIRDA's objectives of (i) Improving the competitiveness of existing industries in order to increase their export potential or their potential to undertake import substitution and (ii) identifying new sub-sectors or value chains where investment by the private sector would likely lead to export growth or import substitution.

1.3. Bamboo value chain in Rwanda

A study published by the former Ministry of Forestry and Mines (2010) describes Rwanda's wood based industry as having two components. These include primary processors (informal pit sawers) and secondary processors (furniture and joinery). The fist is purely informal in nature while the second includes both formal and informal sector organized into cooperatives, self-formed associations and individuals. Moreover, there is no tertiary processing industries (plywood unit mills, particleboards) has been found in Rwanda (MINIRENA, 2010[3]).

The same study revealed that 96%, 3% and 1% of bamboo production are used for fuel, rural construction and sawn planks respectively. It is worth noting that in 2009, GTZ has reported that the quality of sawn wood in Rwanda is relatively low due to a combination of factors including poor treatment of the sawn wood, poor equipment and lack of technical knowledge (GTZ, 2009[4]). These may be considered as the main cause of the current situation where there is no formalized manufacturing facility for engineered bamboo products for construction within Rwanda despite the introduction of the United Kingdom based New Forests Company (NFC).

Therefore, Rwanda currently is still relying heavily on the importation of finished wood products for both of furniture and construction. This scenario contributes to a large spending on imports,

[3] MINIRENA, (2010). Draft Proposal for Wood Industry Policy
[4] GTZ, (2009). Wood use in Rwanda's construction industry. Report on Identification Mission

provides an attractive market for a bamboo product to enter and gain increasing popularity, particularly within the growing sector for higher quality construction and furniture.

1.4. The main actors in bamboo sector in Rwanda

The bamboo sector in Rwanda to date has been heavily focused on three main aspects: (1) Planting of bamboo for environmental conservation; (2) Promoting livelihood improvement with low value processing, mainly targeting handicrafts and using bamboo as construction material without any engineering technology applied on it and (3) Research purposes. The main actors in the sector along with their relevant roles are:

(i) ***Nursery operators:*** sell bamboo plants;
(ii) ***Growers:*** sell bamboo culms;
(iii) ***Middlemen:*** purchase products from nursery plants, to raw culms, to processed goods and connect them with the next market;
(iv) ***Processors:*** Applying various technologies on bamboo materials for construction purpose;
(v) ***Retailers:*** provide markets for goods to be sold to consumers;
(vi) ***End-users:*** interact with the growers, processors or retailers;
(vii) ***Non-profits:*** provide projects and technical support;
(viii) ***Governmental agencies:*** provides funding, technical research and legislative support, including promoting the Made in Rwanda initiative.
(ix) **Researchers:** Different scholars who have undertaken studies on bamboo.

The primary manufacturers in Rwanda (middlemen) are dominantly involved in informal bamboo value chains where they use traditional and local technologies without an added value on raw material.

The secondary manufacturers for furniture and decoration include for instance Coaba cooperative based in Rutsiro, Mataru industries, Ameki Muebles, Manumetal Ltd, Economats, and Gisozi Timber Market (e.g. Dash Dash Ltd, ADARWA Cooperative, West Home Furniture, Comemok Cooperative, Atelier Isimbi, Koksa Ltd, Melx Ltd, etc) while Roco Construction, Real Contractors Ltd and Fair Construction are among the active secondary manufacturers who use the imported bamboo products especially MDF. A pilot scale manufacturing unit, focusing on the production of engineered bamboo sheets for the production of corrugated roofing has been identified as the ideal bamboo manufacturing unit in Rwanda (Ministry of Lands and Forestry, 2017). Moreover, these companies and firms serve as example, the final list will be provided after field data collection in which local leaders especially at district level will help to enrich the list of key actors in bamboo value chain to be visited in course of bamboo value chain analysis and technology audit.

1.5. Comprehensive strategy to promote bamboo sector in Rwanda

A technology audit of the bamboo value chain should analyze the following key strategies that have been recommended by Rwanda Water and Forestry Authority to support the implementation of bamboo based bio-economy (Ministry of Lands and Forestry, 2017):

Promotion of agroforestry in bamboo production: Promotion of agroforestry with smallholders should be prioritized for smallholder bamboo plantings. Therefore, guidelines should be changed to accommodate bamboo for boundary plantings with an emphasis of planting on terraced slops. Bamboo can also be intercropped with food crops during the first 2-3 years after planting.

Promotion of environmental protection by planting bamboo on degraded land and for erosion control, organic soil restoration, canopy cover, stabilizing water tables and biodiversity conservation.

Promotion of sustainable intensification of agriculture: the principles of sustainable intensification of small-scale agriculture can be applied to bamboo to achieve better environmental sanitation and disaster risk reduction (slope stabilization / flood mitigation), contributing to climate compatible development.

Bamboo plantings in buffer zones: Priority should be given to completing planting of buffer zones along rivers, lake shores and roads for environmental protection such as reducing soil erosion and siltation of river and water bodies.

Inclusion of Women and Youth: the aim is to sensitize populations and achieve its objections of conserving Rwanda's biodiversity through gender integra tion and youth engagement.

Increasing stocking densities: Forestry policy should consider planting bamboo in understocked or degraded forests with an emphasis on areas targeted for reforestation, particularly for those areas targeting the production of fuelwood and charcoal.

Green manufacturing for bamboo products: Establishing a bamboo based bio-economy through the development of resource efficient industries and promotion of green technologies is essential and supports The Green Growth and Climate Resilience Strategy (

Climate Innovation Centers: synergy with these centres for training and financing of bamboo projects should be explored.

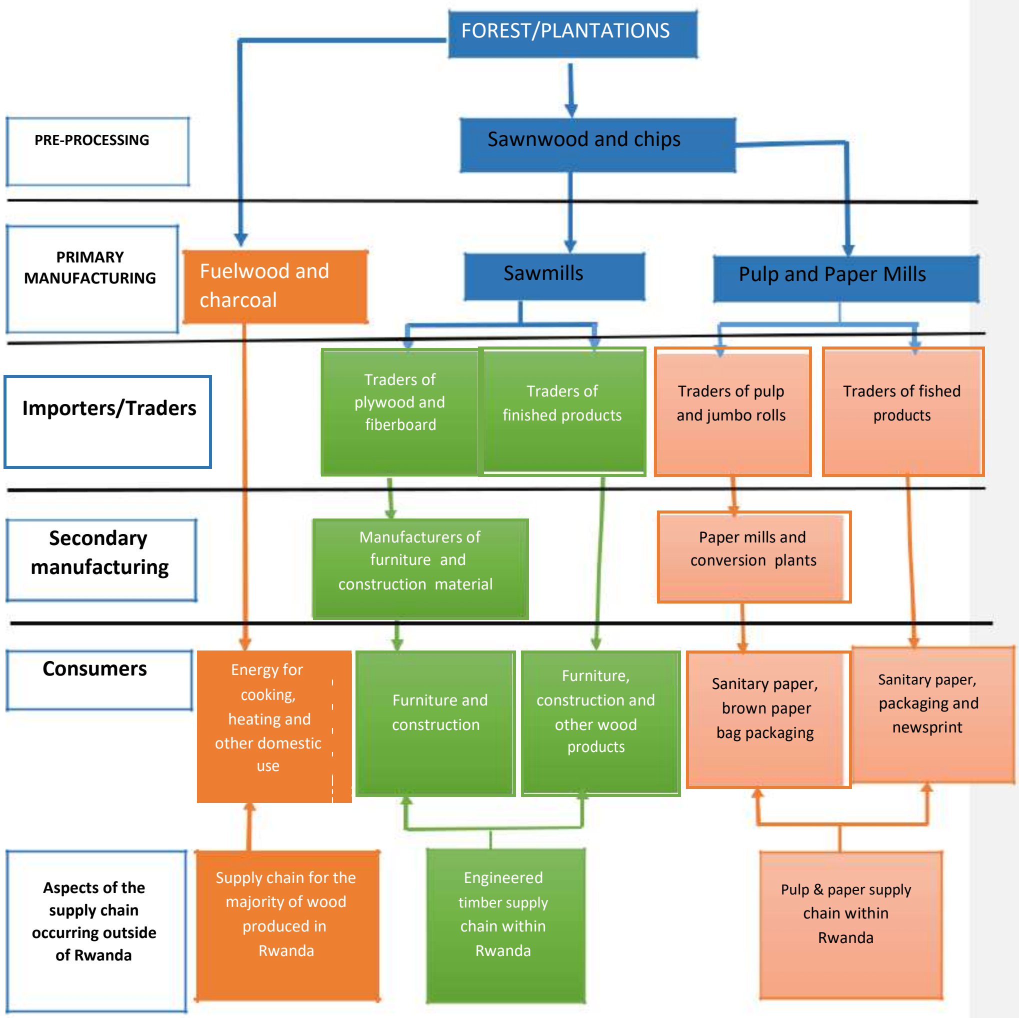
Promotion of Green Building Materials: in carrying out Programme of the Green Growth and Climate Resilience Strategy on Low Carbon Urban Systems, this can be expanded to include green building materials in the development with the use of bamboo engineered timber.

Therefore, all these options will be explored while conducting technology audit of bamboo value chain.

1.6. Production process of bamboo industry in Rwanda

The technology audit of bamboo value chain analysis will depart from the following Rwanda's current timber supply chains.

Figure I: Illustration of production process of bamboo industry in Rwanda



Source: Ministry of Lands and Forestry, 2017

1.7. The objectives of the study

The main objective of this consultancy is to conduct a value chain analysis of the bamboo value chain (countrywide) that should answer the following questions:

1. Assess each value chain in terms of efficiency:
   a) Identify the products offered in the value chain and its producers;
   b) Determine the degree to which supply meets demand for each product identified;
   c) Identify production efficiency in terms of the ratio of costs versus benefits (inputs versus outputs);
   d) Assess available technology and technological capabilities that is used for the development of products; is this suitable for production processes? What are gaps, challenges?
   e) Research other kind of technologies from other countries that can be implemented (or not) in Rwanda. Which technology can be imported in Rwanda? What would be its advantage?
2. Assess each value chain in terms of existing quality:
   a) Are customers satisfied with the quality of the product including design?
   b) Are customers satisfied with the value for money?
   c) Do the products meet market requirements?
   d) Is the product presentation (e.g. marketing, packaging) up to standard?
   e) How to improve existing quality? How to improve the perception of the existing quality?
   f) Which are best practice examples in other countries?
3. Assess each value chain in terms of product differentiation:
   a) How to improve the (local) competitive advantage/disadvantage of the products?
   b) Which are the main competitors and what is the price and cost comparison?
   c) For each product, do producers conduct any research and development (also in terms of new technology, green, climate resilient)?
4. Assess each value chain in terms of social and environmental standards:
   a) Do producers take any social (including workplace security) and environmental standards into account? If so which ones (RSB, RHA, ILO, MIFOTRA, other)
   b) What are the labour costs/standards?
   c) Are any trainings offered to employees?
   d) Do producers work together with TVET schools? Do they take interns or apprentices?
   e) Which are the main impact in the environment of this value chain? Which synergies can be implemented?
   f) How each technique will be valuable in the Green Building Minimum Compliance system developed by RHA with GGGI?

g) Which standards have still to be developed?

5. Assess each value chain in terms of business environment:
   a) Immediate business environment: what are market conditions, regulations and administrative procedures that keep companies in the value chains from doing business?
   b) Wider business environment: what are other issues that keep companies in the value chains from doing business (e.g. interest, infrastructure, access to labour)
   c) Which are the potential synergies in the business environment?
6. Assess the carbon impact (CO^2) of these materials:
   a) What is the expected total CO^2 emission of the production and transport processes these construction materials?
   b) What is the expected total CO^2 emission of the production and transport processes of the usual materials?
   c) What is the difference in CO^2 emissions between the proposed MiR construction materials and the usual construction materials?
   d) What is the expected carbon sequestration of the use of these materials in comparison to the usual construction materials? (if any)
   e) Analysis on the existing technology and technological capabilities that are available in the value chains versus what is available outside of Rwanda to increase the efficiency of products developed in the value chain including indicating new products that could be developed if the relevant technology/technological capability would be available;
   f) SWOT analysis of the two value chains and individual players and recommendations on which strengths and weaknesses to focus on;
   g) Analysis on upgrading (collaboration between different producers to move to a higher value added component of the chain), extending (actions to broaden existing value chain to increase its job creation and value impact potential) and optimizing (actions to improve operation of certain links of the value chain to achieve greater value added) the value chains;
   h) Recommendations on the above

2. DESCRIPTION OF APPROACHES AND METHODOLOGY

An integrated methodology combining the literature review, quantitative and qualitative methods will be employed in this study. While the quantitative methods are free from personal biases and thus help ensure objectivity of findings, the qualitative methods reflect better the interviewees' perceptions and experiences and they uphold humanistic values essential to understand perceptions. The main components of the methodology are the following.

2.1. Desk review

A desk review of all relevant documents related to the aspects of the study, including but not limited to national development plans and strategies, value chain, Tech Audit, legislation, market data and other studies related to bamboo were reviewed prior to the field data collection. Through the initial desk review, key stakeholders and the bamboo key actors were identified. Furthermore, bamboo markets were assessed as well as end-user to have general view of Rwandan bamboo value chain. Key documents were sourced from NIRDA, Enabel, MINAGRI, the National Institute of Statistics of Rwanda (NISR) and other relevant governmental and non-governmental institutions which host a comprehensive and complete dataset needed to perform this assignment.

2.2. Field data collection tools

Both quantitative and qualitative approaches were used. The quantitative approach involved the use of individual digital questionnaire and photo taking while the qualitative approach combined desk review, Focus Group Discussions (FGD) and Key Informant Interviews (KII). It was revealed that mixed methods studies promote an understanding of chosen phenomena in a manner that would not be possible using a single approach and identified 4 main aspects that must be taken into consideration when planning a mixed method research study: time distribution, weight attribution, combination and theorization (Dos Santos, et al., 2017).

2.2.1 Quantitative research and sample size

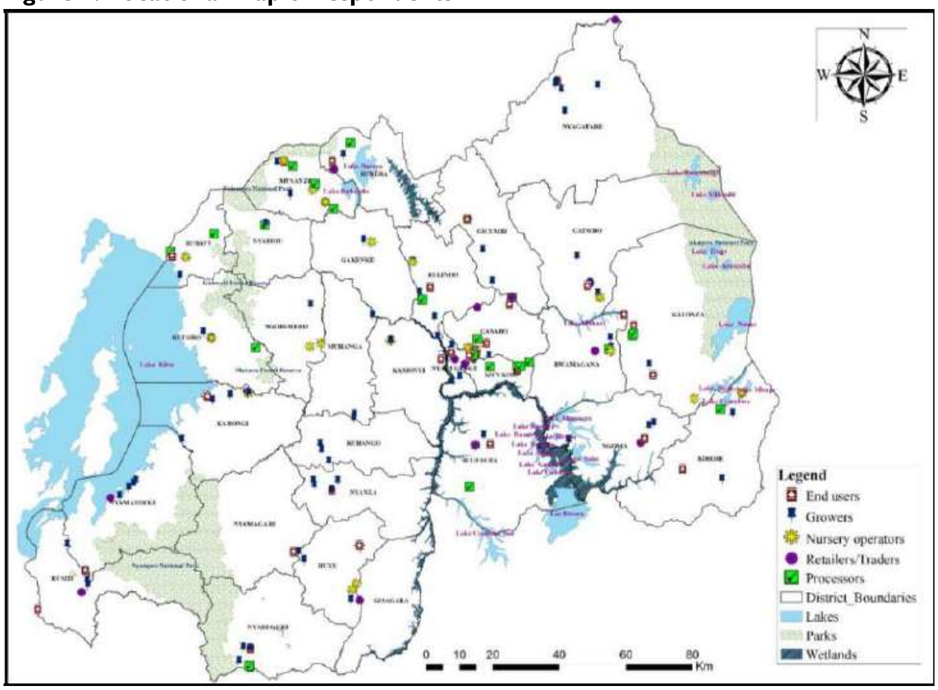
The value chain analysis including technology audit of clay value chain for bamboo construction materials were undertaken in all 30 districts of the country. Purposive/judgmental sampling and random sampling techniques were used to determine the sample size. The sample were selected in two stages: The first stage focused on the key stakeholders who will respond to the individual questionnaire. The list included all actors involved in the clay value chain from the producers up to the end-users: (i) nursery operators, (ii) growers, (iii) middlemen, (iv) processors, (v) retailers. and (vi) end-users.

Table 1: List of respondents by district

Districts	End users	Growers	Nursery operators	Processors	Retailers/traders	Total
Bugesera	1	2	1	1	1	6
Burera	1	2	1	1	1	6
Gakenke	0	1	1	1	0	3
Gasabo	2	3	4	2	0	11
Gatsibo	2	5	0	0	2	9
Gicumbi	2	2	1	1	1	7
Huye	2	6	3	0	1	12
Kamonyi	0	3	1	0	0	4
Karongi	1	3	2	0	0	6
Kayonza	3	1	1	2	1	8
Kicukiro	1	2	0	3	0	6
Kirehe	1	2	1	1	1	6
Muhanga	0	2	0	0	0	2
Musanze	1	1	3	2	1	8
Ngoma	1	3	0	0	1	5
Ngororero	0	2	2	0	0	4
Nyabihu	0	1	0	1	1	3
Nyagatare	1	5	0	0	1	7
Nyamasheke	0	6	0	0	1	7
Nyanza	1	6	0	0	0	7
Nyarugenge	4	9	1	1	3	18
Nyaruguru	3	4	0	2	0	9
Rubavu	2	1	1	3	0	7
Ruhango	0	4	0	0	0	4
Rulindo	1	3	1	1	1	7
Rusizi	2	3	0	0	1	6
Rutsiro	0	3	1	1	2	7
Rwamagana	1	3	2	1	1	8
Total	33	88	27	24	21	193

At this stage, the respondents were selected using snow ball and systematic sampling methods to include different actors (end users, nursery operators, bamboo growers, processors and retailers/traders distributed across 30 districts of the country. The sampling technique allowed to identify the main actors to the satisfaction or information saturation of the researcher/consultant. The consultant ensured that the coverage all potential actors especially processing units. These respondents were given an individual digital questionnaire. The following table provides more detailed information on sample size in each group of actors by district. Based on the information provided by Ministry of Lands and Forestry, in 2017, the formalized manufacturing facility for engineered bamboo products for construction are very limited in Rwanda. Therefore, the sampled processors included also firms which apply the secondary manufacturing on the imported products. It is with noting that the research used Open Data tool kit (ODK) which helped capturing the GPS data and visualizing location of the respondents as per the following map.

Figure 1: Locational map of respondents



The Computer-Assisted Personal Interviewing (CAPI) comprising of tablets with appropriate software were used to collect necessary data which was finally submitted to the client. This system has proved to be more effective and efficient than the usual Paper and Pencil Interviewing (PAP) system. The process involved uploading of the final questionnaire in both languages (English and Kinyarwanda) on the tablets using Open Data Kit software (ODK). The latter helps to collect field data on a mobile device (tablet) and transmit it to a server from where they are later extracted for analysis. In addition, the GPS incorporated in ODK helped to regularly monitor geographical location and progress of the interviews.

2.2.2. Qualitative research and sample size

At the second stage, qualitative data were collected using interview guides during the Focus Group Discussions (FGD) and Key Informant Interviews (KII). The latter include non-profit and governmental agencies along with researchers and academia who are interested to studies related to clay. The following stakeholders were involved in the study through interviews as Key Informants when conducting technology audit of clay value chain in Rwanda.

Table 2: List of Key Informants

N°	District/Institution	Position
1	Kayonza	District Environment Officer
2	Kirehe	District Forest and Natural Resources Officer
3	Ngoma	District Forest and Natural Resources Officer
4	Bugesera	District Environment Officer
5	Gicumbi	District Environment Officer
6	Gatsibo	District Forest and Natural Resources Officer
7	Nyagatare	District Forest and Natural Resources Officer
8	Rwamagana	District Forest and Natural Resources Officer
9	Nyarugenge	District Environment Officer
10	Kamonyi	Environment officer
11	Nyaruguru	Forestry and Naturel resource officer
12	Kicukiro	Forestry and Naturel resource officer
13	Muhanga	Acting Director of Agriculture
14	Huye	Environmental officer
15	Ministry of Agriculture and animal resources	Director General of Agriculture Development
16	Ministry of Infrastructure	Affordable and Social Housing Engineer
17	Ministry of Environment	Director General of Land, Water and Forestry
18	Ministry of Trade and Industry	Director of Industrial Development Unit
19	Rwanda Development Board	-
20	Rwanda Polytechnics, IPRC Kigali	Head of Civil Engineering Department
21	Rwanda Land Management and Use Authority	Head of department
22	National Industrial Research and Development Agency	Technical support specialist
23	Rwanda Housing Authority	Property valuation specialist, ag. director of government assets management
24	Rwanda Agriculture Board	DDG/RAB RUBIRIZI

25	MINALOC	DG
26	RWAFA	Seed Processing and Storage Officer
27	ENABEL	Coordinator
28	REMA	Ag Director of Environmental Regulation and Pollution Control Unit

Notwithstanding that the above mentioned stakeholders were planned to be interviewed across the country; in total, 10 FGDs were undertaken with bamboo nursery operators and growers respectively were conducted as collective views of the key stakeholders, while 21 KIIs were met to inform the study. The list was expanded in order to capture views of different stakeholders involved in bamboo sector.

2.3. Secondary data collection

The secondary data were collected to complement the primary field data. Key documents were sourced from NIRDA, Enabel, Ministry of Environment, MINAGRI, Rwanda Environment Management Authority, Ministry of Industry and Commerce, Ministry of Infrastructure, Ministry of Local Government, the National Institute of Statistics of Rwanda (NISR) and other relevant governmental and non-governmental institutions which host a comprehensive and complete dataset needed to perform this assignment. Furthermore, the secondary data were obtained from published articles, books, reports and official gazettes of the Republic of Rwanda. This review will be done by the consultant.

2.4. Research quality assurance and ethics

The research was subject to ethical approval. The research underpinned by a commitment to integrity, honesty and competence. Participation to the research was voluntary; all informants were asked to give informed consent to their participation. All interviews were carried out in private and confidentiality as well as anonymity were assured. All survey data were stored to ensure that there was no possibility of data leakage. Participants in KII and FGDs were asked to respect the confidentiality of what members of the group said. The Enumerators were trained on ethics, questionnaire contents and well as handling the gadgets. A pre-test was conducted to ensure the appropriateness of the data collecting tools as well as the statistical outputs.

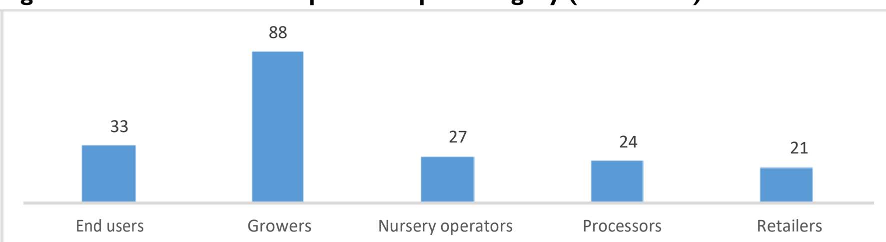
2.5. Data analysis and report writing

During analysis, descriptive statistics using SPSS were employed to analyse the findings of the survey and a comprehensive analysis of each stratum of value chain was undertaken. ArcMap software was used to prepare a geo-locating map of visited sites per actor. Triangulation of data was made with focus on the existing technology and technological capabilities that are available in the value chain versus what is available outside of Rwanda to increase the efficiency of products developed in the value chain including new products that could be developed if the relevant technology/technological capability would be available. Furthermore, the analytical and comparative approaches were used to assess the local value chain technology audit versus what is available outside the country as well as the internationally competitive value chain. SWOT was employed to assess bamboo value chain and technology audit strengths, weaknesses, opportunities and threats towards of what is done outside the country.

3. ANALYSIS OF DATA AND PRESENTATION OF RESULTS

The section below provides the findings of the survey from the field on a number of indicators, which include demographic characteristics of respondents, description of bamboo operators, working conditions of employees, productivity and financial assets, infrastructure and technology in place, quality control and standards status assessment and environmental issues resulting from the bamboo uses. It is important to mention that all districts (30) were covered by the study.

Figure 2: Distribution of respondents per category (in number)



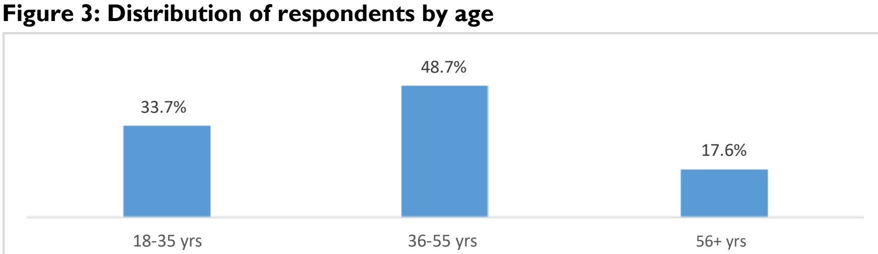
Source: Bamboo Tech Audit survey, 2020

The figure above reveals that 193 respondents in total were interviewed, more bamboo growers (88) contributed to this study by responding to the individual questionnaire followed by end-users (33). Furthermore, nursery operators (27), processors (24) and retailers (21) gave also their point of view by responding the questions addressed individually to them. This shows that processors and retailers proportion is very low while the growers are the most available in this sector. Thus, it can be deducted that processing bamboo products is still at early stage as it was discussed also in section related to the technology of this study.

3.1. Demographic characteristics of respondents

It is worth noting that all interviewed respondents are included in nursery operators, processors, bamboo growers and traders for both female and male. Therefore, the distribution of respondents by age has been presented below.

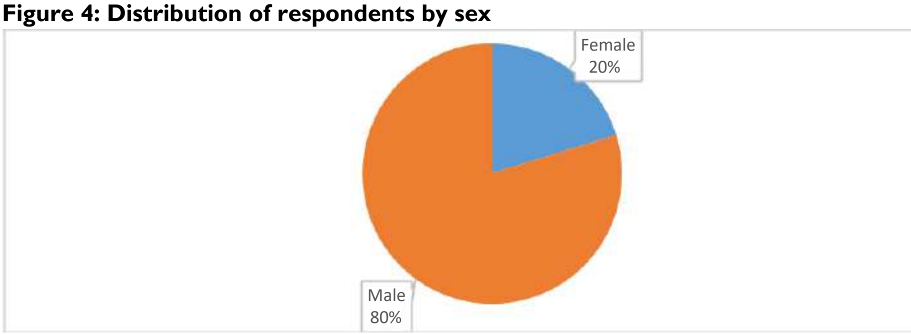
Figure 3: Distribution of respondents by age



Source: Bamboo Tech Audit survey, 2020

It was revealed that 48.7% of bamboo operators are aged between 36 and 55 years old with 33.7% have between 18 and 35 years of age. The bamboo value chain actors with more than 56 years old are representing less than 17.6%. This implies that more than 80% of bamboo value chain actors are in the age group varying between 18 and 55 years. The distribution of respondents by sex is reported in figure below.

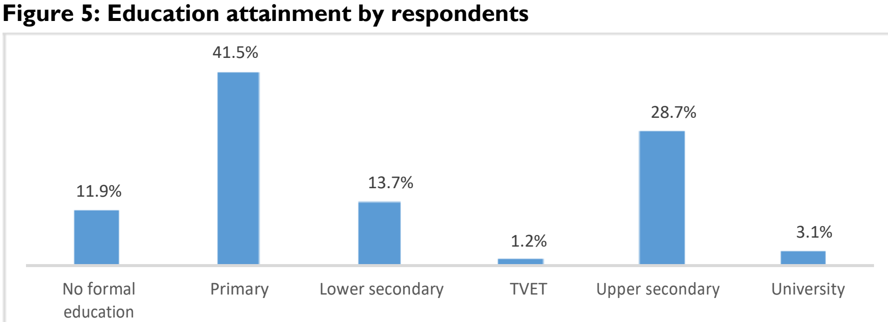
Figure 4: Distribution of respondents by sex



Source: Clay Tech Audit survey, 2020

The figure above shows that more males (80%) were interviewed compared to the females (20%). The highest number of interviewed males belongs to bamboo growers. This depicts that males are much more engaged in activities linked to bamboo value chain oriented to the production of materials.

Figure 5: Education attainment by respondents



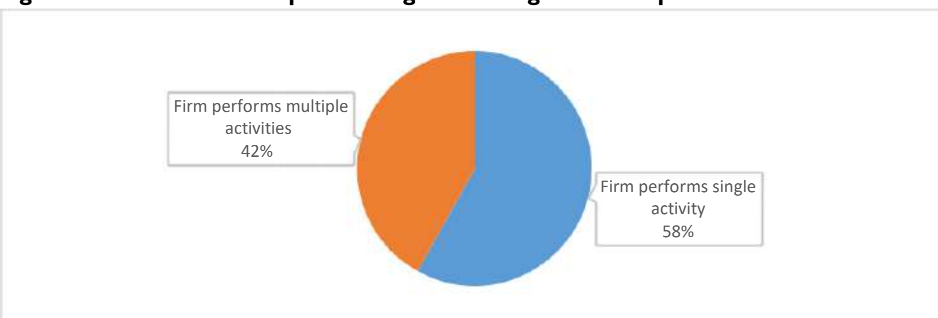
Source: Bamboo Tech Audit survey, 2020

Among the interviewees, the highest percentage (41.5%) have at least primary education while 11.9% did not go for formal education. That is to say that the data were collected from knowledgeable people in the sector who were able to provide relevant information in accordance to the asked questions. The high number of staff who completed lower (13.7%) and upper secondary schools (28.7%) are much more seen as processors and retailers as reported by the members of FGDs and KII across visited districts. This shows that bamboo sector is still using unqualified staff at seedlings nursery and tree growing stages.

3.2. Description of firms

The information on the main activity of a firm/individual engaged in bamboo value chain for construction materials informs on the expected products from such firm. Therefore, the information on whether visited firmed are performing either single or multiple activities are presented in figure below.

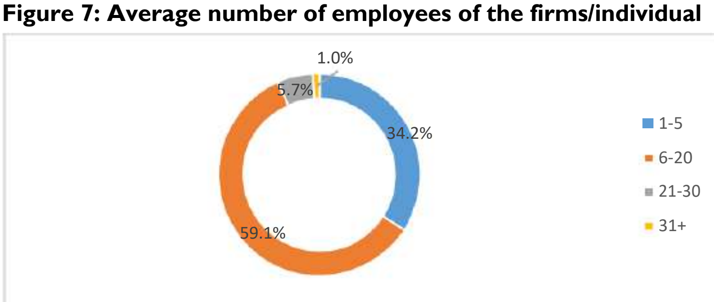
Figure 6: Firms/individual performing either single or multiple activities



Source: Bamboo Tech Audit survey, 2020

The figure above reveals that 42% of respondents are performing multiple activity. The majority of them are engaged in nursery operating and growing bamboo trees. 58% of respondents are engaged in a single activity of value chain.

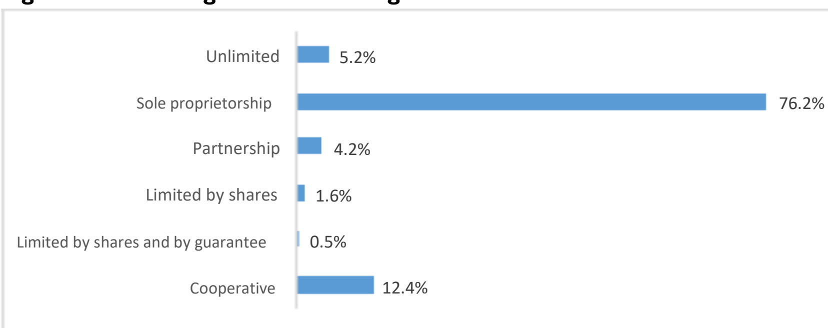
Figure 7: Average number of employees of the firms/individual



Source: Bamboo Tech Audit survey, 2020

The figure above shows that the majority of firms/individuals (59.1%) engaged in bamboo value chain employ between 6 and 20 employees while 34.2% gave the employment to 1-5 employees. There are also 5% and 1% of firms/individuals who have employees ranged between 21 and 30, and above 31respectively. The latter two groups are especially engaged in growing bamboo trees as it was confirmed during FGDs and KIIs. The firm's legal status and registration have been also studied and the findings were presented in figure below.

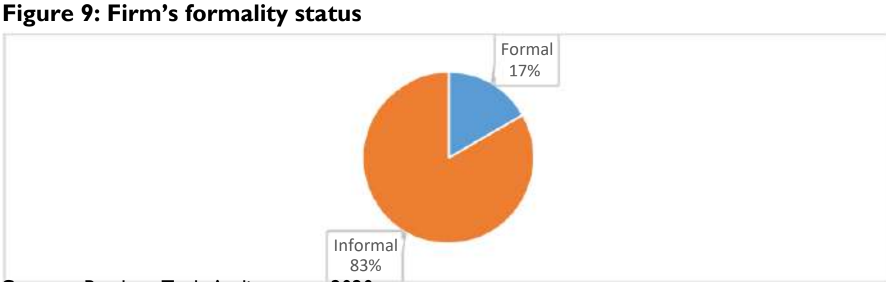
Figure 8: Firm's legal status and registration



Source: Bamboo Tech Audit survey, 2020

It has been revealed that 76.2% of the visited firms belongs to sole proprietorship with 12.4% belonging to cooperatives while 4.2% are owned by different people working in partnership. Moreover, 5.2% of firms belong to different stakeholders in form of unlimited by shares and a negligible equal percentage of 1.6% and 0.5% of firms are registered as limited by shares and limited by shares and guarantee respectively. This shows that there is still a need to sensitize the investors in bamboo products on the importance of investing by putting together shares to improve the competitiveness of Rwandan clay products. Additional data on origin of the firm's owners was presented in figure below.

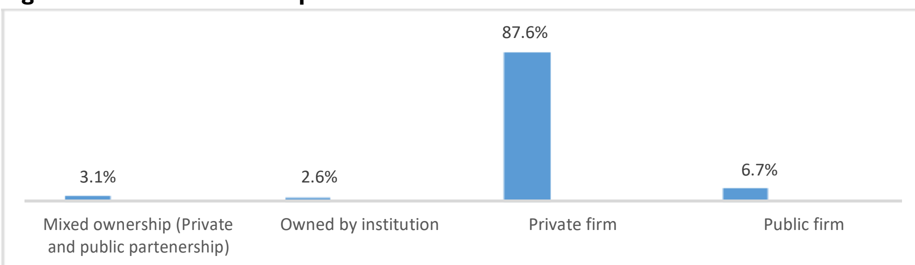
Figure 9: Firm's formality status



Source: Bamboo Tech Audit survey, 2020

The study revealed that majority (83%) of firms are informally operating across the country with only 17% are operating formally. The members of FGDs said that growing individually bamboo seedlings and trees did not require to have trading licenses as it is included in agriculture. Furthermore, it was seen that use of bamboo in construction is not yet generalized across the country which discouraged many people to be much involved in commercialization of bamboo products. Thus, the majority of activities applied on bamboo do not require to possess a trading license. The origin of firm's owners are shown in figure below.

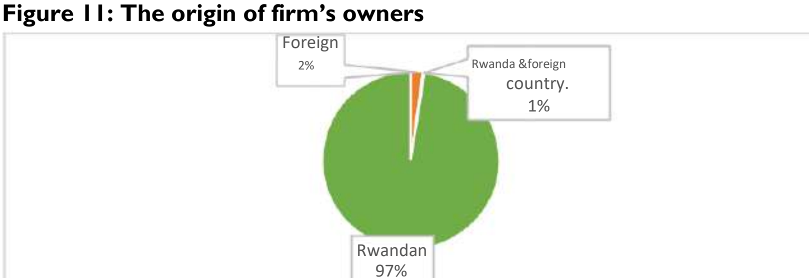
Figure 10: Firm's ownership status



Source: Bamboo Tech Audit survey, 2020

Though the majority of bamboo trees are owned by the government of Rwanda, the investigation focused on the other types of ownership. In this case, the study revealed that 87.6% of visited firms are in hand of private owners, with 6.7% owned by the government. Moreover, 3.1% and 2.6% are in control of mixed ownership and institutions respectively. It is worth to mention that, it has been hard to get someone who should give detailed information on planted bamboo which are under control of the government of Rwanda but general information on such plantation was sourced from Ministry of Environment and Rwanda Water and Forestry Authority during KIIs. The origin of firm's owners was also analyzed and reported in figure below.

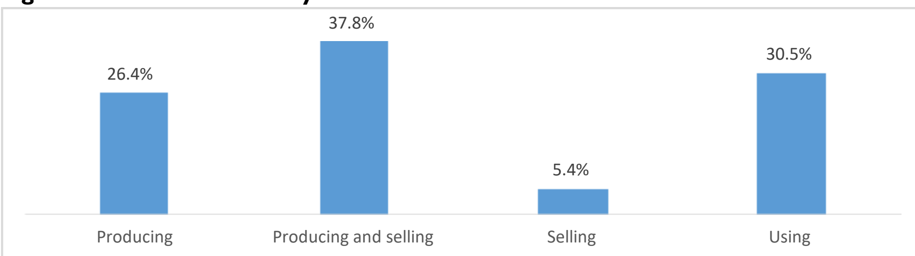
Figure 11: The origin of firm's owners



Source: Bamboo Tech Audit survey, 2020

It has been reported that the majority (97%) of visited firms/bamboo plantation are owned by Rwandans with only 2% owned by the foreigners and 1% under control of both foreigners and Rwandan. However, in this year 2020, the government of Rwanda has started negotiation with Chinese who will exploit bamboo trees owned by the government of Rwanda.

Figure 12: The main activity of the firms



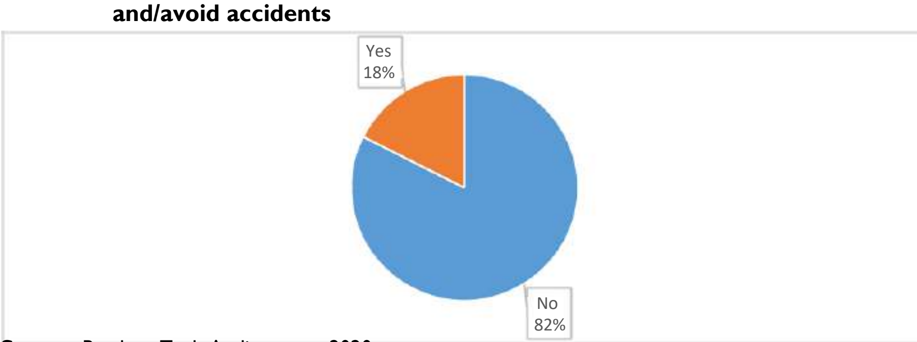
Source: Bamboo Tech Audit survey, 2020

The highest number of visited firms/individuals (37.8%) confirmed to have been engaged in producing and selling either bamboo seedlings or trees with 26.4% and 5.4% who said that they produce and sell either bamboo seedlings or trees respectively. Moreover 30.5% highlighted that they have used bamboo products for construction purpose.

3.3. Working conditions of employees

Working conditions of the employees contribute to his/her productivity in the firm. Motivated employees contribute much more compared to the discouraged ones but there are different ways of motivating the employees. Therefore, this aspect was explored to assess whether the working conditions in place may facilitate the employees to be very productive or not.

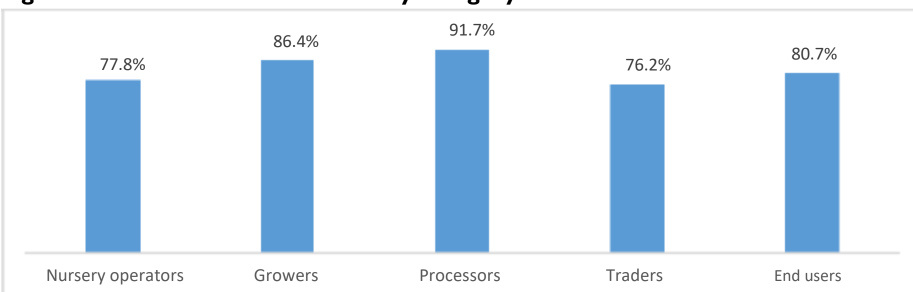
Figure 13: Possession of clothes and other form of protection to reduce or and/avoid accidents



Source: Bamboo Tech Audit survey, 2020

It has been revealed that only 18. % of firms' employees have appropriate clothes and other protection tools to reduce or/and avoid accidents at the work place. This percentage is still very low. However, as the majority of respondents (88/193) are bamboo growers who are the same time farmers; Moreover, findings are not surprising normally farmers in Rwanda do not possess specific clothes or boots to be used while undertaking farming activities. The information on the possession of insurance has been reported in figure below.

Figure 14: Possession of insurance by category of actors



Source: Bamboo Tech Audit survey, 2020

The study revealed that more than 75% of investigated bamboo value chain actors possess an activated insurance known as "Mutuelle de Santé" with very few (less than 5%) having access to another health insurance scheme (e.g., RSSB, MMI, CORAR, MEDIPLAN). The bamboo value chain actors are very happy with health facilities linked with this health insurance scheme as since 2015, it was scaled up to cover any type of needed medical treatment including accidents at the work place (EICV 5, 2018). The working schedule in bamboo related activities was investigated and findings were reported in the following table.

Table 3: Working schedule by category

	Nursery operators	Growers	Processors	Traders	Users	Average
Full time	53.3%	61.3%	59.0%	66.8%	88.9%	63.1%
Part-time	27.4%	18.4%	16.3%	19.3%	0.0%	17.9%
Occasional workers	19.3%	20.3%	17.3%	13.9%	11.1%	17.7%
Professional Intern	0.0%	0.0%	7.5%	0.0%	0.0%	1.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Bamboo Tech Audit survey, 2020

The table above shows that the highest number of firm's employees by category are full time employees working as either users (88.9%), traders (66.8%), bamboo growers (61.3%) or nursery operators (53.3%). Moreover, it was highlighted in FGD that the constructors are only fully engaged to complete specific houses and at specific stage. A good percentage of nursery operators (27.4%), bamboo growers (18.4%), traders (19.3%) and processors (16.3%) are working as part-time employees. Moreover, the professional interns are almost absent in this sector with only 7.5% seen in processing firms. Therefore, the suggestion comes to integrate teaching and learning programs related to the processing of clay based construction materials in TVET and technical schools to improve the sector. The feedback on the working hours per day are presented here below.

Table 4: Working hours of firm's staff per day

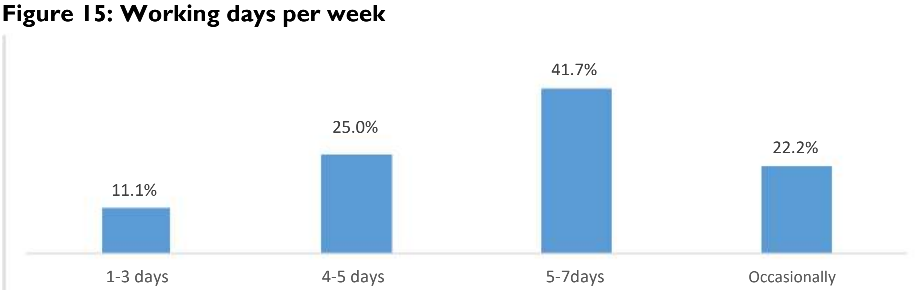
	Nursery operators	Growers	Processors	Traders	End users	Average
Occasionally	3.7%	37.8%	4.2%	5.0%	23.1%	22.4%
Less than 4 hours	3.7%	2.4%	0.0%	0.0%	0.0%	1.7%
4-8 hours	59.3%	45.1%	66.7%	55.0%	26.9%	48.6%
8-12 hours	33.3%	14.6%	29.2%	40.0%	50.0%	27.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Bamboo Tech Audit survey, 2020

The table above informs that the highest number of firm's staff work between 4 and 8 hours per day in each category. This includes processors (66.7%), nursery operators (59.3%), traders (55%), and bamboo growers (45.1%). However, there is a good number of bamboo actors who confirmed to spend between 8 and 12 hours in bamboo related activities. These include the end users (50%), traders (40%), nursery operators (33.3%), Processors (29.2%), bamboo growers (14.6%). This shows that the majority of firms' staff are spending between 4 and 12 hours at work.

This working time is reasonable if the employees are given a good salary and also an annual paid leave. Moreover, there is also a good percentage especially of bamboo growers (37.8%) who are engaged occasionally in bamboo related activities. When respondents were asked about the working days per week, the feedback given was reported in figure below.

Figure 15: Working days per week



Source: Bamboo Tech Audit survey, 2020

The figure above reveals that the highest number (41.7%) of bamboo value chain actors spend between 5 and 7 days a week in bamboo related activities. This means that they spend most of their days of a week at work implying that their livelihood depend on income generated from the bamboo related activities. Moreover 22.2% confirmed to occasionally be engaged in bamboo related activities with 11.1% who declared to use only 1 to 3 days per week for the same purpose.

This implies that the later to groups may have enough time to be engaged in other activities generating the income. The information on the received incentive by employees of the firms is presented in table below.

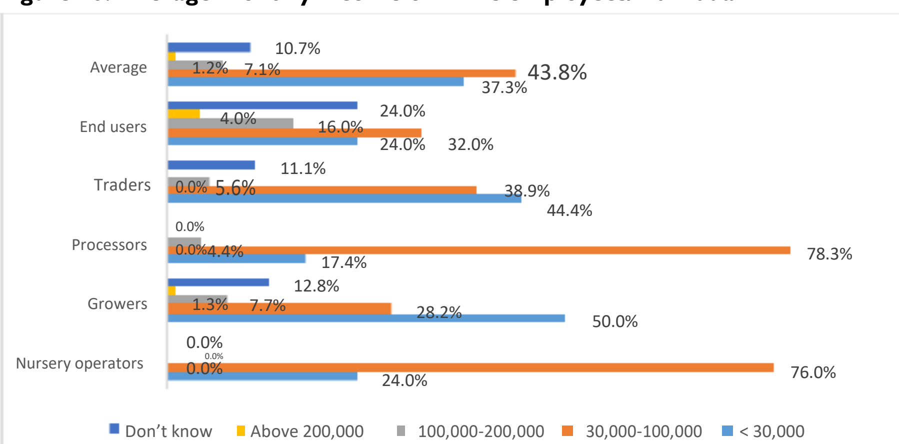
Table 5: Received incentive by employees of the firm in past 12 months

	Nursery operators	Growers	Processors	Traders	End users	Average
Fixed monthly bonus	14.8%	3.4%	16.7%	4.8%	6.1%	7.3%
Bonus on done activity	22.2%	26.1%	25.0%	4.8%	15.2%	21.2%
Trainings	0.0%	4.6%	12.5%	0.0%	6.1%	4.7%
Irregular bonus	0.0%	4.6%	8.3%	4.8%	15.2%	6.2%
No incentive received	63.0%	61.4%	37.5%	85.7%	57.6%	60.6%
Total	100%	100%	100%	100%	100%	100%

Source: Bamboo Tech Audit survey, 2020

This study explored the incentive given to the employees by the firms and it was found that the majority of the bamboo actors did not receive any incentive as declared by the highest number of traders (85.7%), nursery operators (63%), bamboo growers (61.4%), and end users (57.6%) processors (37.5%) respectively. Moreover, there are bamboo growers (26.1%), nursery operators (22.2%), processors (25%) and end users (15.2%) who confirmed to have received bonus on done activity in past 12 months. The percentage of staff who benefited from trainings is very low (Growers: 4.6%, processors: 12.5%, end-users: 6.1%) which implies a poor capacity building strategies in bamboo sector. The average monthly income of firm's employees is presented in figure below.

Figure 16: Average monthly income of firm's employees/individual



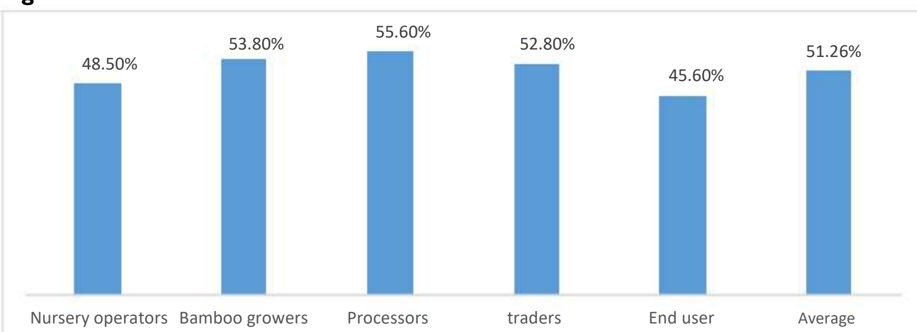
Source: Bamboo Tech Audit survey, 2020

The figure above reveals that more than 75% of nursery operators and processors earn between 30,000 Rwf and 100,000 Rwf on average per month while the most of the totality of remaining proportion in these groups earn monthly less than 30,000 Rwf per month during the past 12 months. The situation is different in traders where 44% and 38.9% earn less than 30,000 Rwf and between 30,000 Rwf and 100,000 Rwf respectively. The same situation was seen in growers where 50% and 28.2% get less than 30,000 Rwf and between 30,000 Rwf and 100,000 Rwf respectively.

These findings show that the majority of bamboo value chain actors are getting a monthly income of less than 100,000 Rwf. Notwithstanding that the majority of bamboo value chain actors revealed that are not satisfied with the amount of money they gain from bamboo-based activities, as summarized in figure below but they recognized that planting bamboo trees created job opportunities across the country.

Commented [JPH1]: Salary or revenue or earnings ?

Figure 17: The level of satisfaction of bamboo value chain actors in terms of income



Source: Bamboo Tech Audit survey, 2020

The study revealed that only between 45% and 56% of bamboo value chain actors are satisfied with the income they gain from bamboo based activities. Reference to the feedbacks from FGDs which took place with nursery growers and processors, the majority of participants in the discussions were not happy with the income they get but they confirmed to have a hand on cash during selling time. They wish to see their income increased as they claimed that Rwandan are not yet at level of processing bamboo to compete with other construction materials used in Rwanda.

3.4. Business relationships network between bamboo value chain actors and other stakeholders

There have been three main projects that have been carried out with the aim of promoting bamboo planting and associated livelihood improvement. These projects represent the primary flow of financing into the bamboo sector to date.

(A) Government Partnership - The China Bamboo Aid Project: it has been the most prominent project in the development of the bamboo sector in Rwanda. The China Bamboo Aid Project started in 2009 and it was a collaborative bilateral project between Rwanda and China. The project's objective was to promote the development of sustainable bamboo resources and production for bamboo products. The intended output of the project was:

- Increased coverage of bamboo forests;
- Establishment of five operational workshops;
- Increased knowledge and awareness on the management and use of bamboo resources and products improved and disseminated;
- Strengthening of capacity, skills and knowledge of stakeholders and communities in bamboo management and utilization; and
- Improved quality of bamboo planting materials and economic opportunities to smallholder famers.

The main accomplishments of this project over the 8 years since its inception have been:

(i) The establishment of a Chinese operated bamboo nursery.
(ii) Conducted training programs in Kigali and rural areas where 840 people have been trained in bamboo propagation or handicrafts, including 400 people in bamboo processing technology and 440 people in bamboo planting technology (Tian and Si, 2016). This includes the establishment of Masaka training centre and trainings conducted there.

A 2016 study done by the China National Bamboo Research Centre states "three phases of the projects have been implemented for six years, 21 experts have been dispatched and the total project funding has reached 15 million yuan" (Tian and Si, 2016). This is the equivalent of $2.2 million. A Rwandan government report has the total in-kind (no cash exchanged) contribution to be 40 million Yuan (or nearly $6 million) from 2010–2017, with an additional 10 million Yuan ($1.5 million) planned for 2017–2019. From 2011–2017, the contribution by the Rwandan Government has been Rwf 198,786,657 ($235,000) (Janviere, 2017).

(B) Non-Profit - ARECO's: The Project Bamboo Burera (BamBu) was a three year European Union (EU) funded project from 2012 to 2015 with the objectives of promoting bamboo for environmental protection, poverty alleviation and climate resilience in the Volcanoes National Park and Rugezi Wetland in Burera District (Bizimana, 2015). This project had a budget of €474,000 (or $560,000 / Rwf 470,000,000) (Bizimana, 2015). ARECO worked with the China Bamboo Aid Project for delivery of their training programs. The project achieved the following key results:

- Planting of 329 ha of bamboo or 174,000 plants;
- Trained 240 people on bamboo propagation and 147 people on bamboo processing;
- Trained 80 technicians on climate mitigation and adaption;

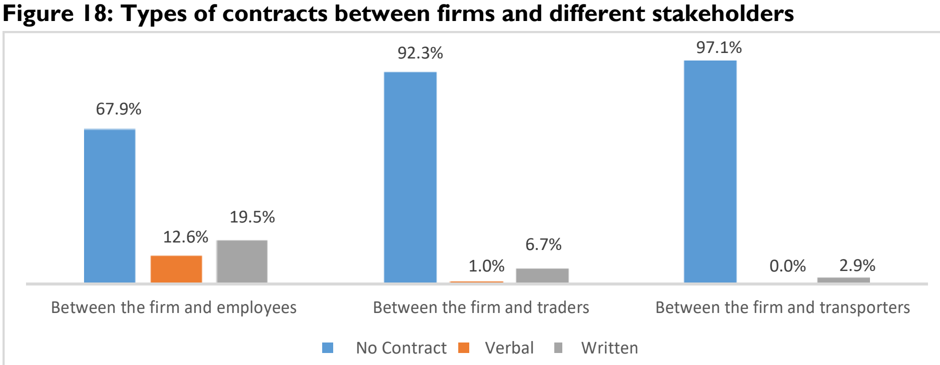
- Sensitized more than 100,000 people on bamboo opportunities.

(C) Conjoint project of International Organization and FAO's Securing Community Livelihoods with Bamboo Program was developed to promote the sustainable management and use of bamboo resources as a means of sustainable development, poverty alleviation and livelihoods support for both rural and urban communities. The projects were implemented in Nyaruguru and Kicukiro districts where trainings were conducted and demonstration plots set up for nursery practices, plantation management and market development. From 2012 – 2015, the project received a total grant of €499,000 (or $590,000 / Rwf 500 million) (Drakenberg and Cesar, 2013).

Additionally, there are a number of environmental projects that have incorporated bamboo plantings on rivers and lakeshores. These projects are mostly run by REMA and include: DEMP I, DEMP II, LVEMP, LAFREC. These plantings were done strictly for environmental management and until recently were not part of the bamboo value chain.

When respondents asked about the types of contracts existing between firms and employees or any other stakeholder, the provided feedback was presented in figure below.

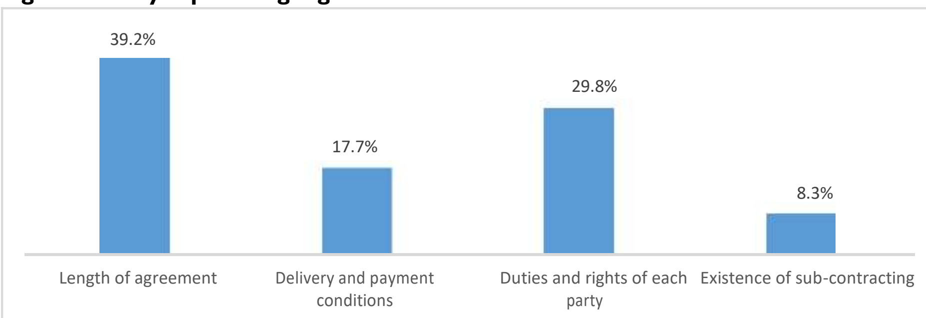
Figure 18: Types of contracts between firms and different stakeholders



Source: Bamboo Tech Audit survey, 2020

The study revealed that the majority of firms do not have any contract between firm and various stakeholders as only 19.5% and 6.7% of firms have confirmed to have written contracts with employee and with traders respectively while only 2.9% of firms have contract with transporters. Furthermore 12.6 % of employees and 1% of traders have contracts with the firms which perform activities related to bamboo. The absence of written contracts may become an obstacle for an employee or a trader to get a loan from a bank to extend his/her business or develop new projects.

Figure 19: Key aspects highlighted in contract



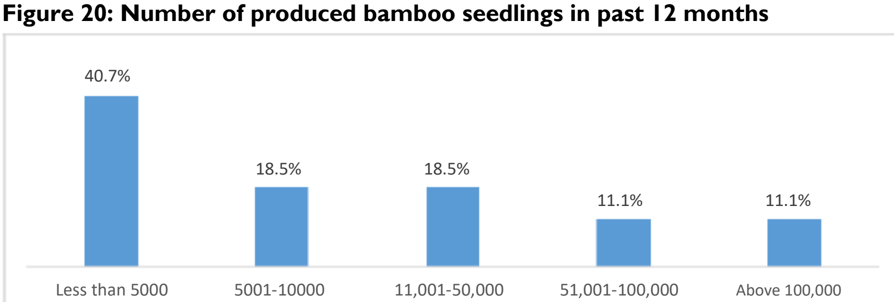
Source: Bamboo Tech Audit survey, 2020

The study revealed that the written contracts between firms involved in bamboo value chain for construction materials and employee/trader/transporter highlight the length of agreement, duties and rights of each party as confirmed by (39.2%), and 29.8% of respondents respectively while 17.7% and 8.3% of respondents declared that their contracts mention delivery and payment modalities, duties and rights of each party respectively. When the respondents were asked whether they have consulted the lawyers about signing the contracts, the answer was 'no' for the majority of the respondents. This means that the contracts are not prepared by professionals in the domain which might results into inconsistence in different articles of the contract.

3.5. Productivity and financial assets

The production of each firm informs on the potential financial profit which can be made by specific firms. It is in this regard that the average number of produced bamboo seedlings and trees was analyzed and presented in figure below.

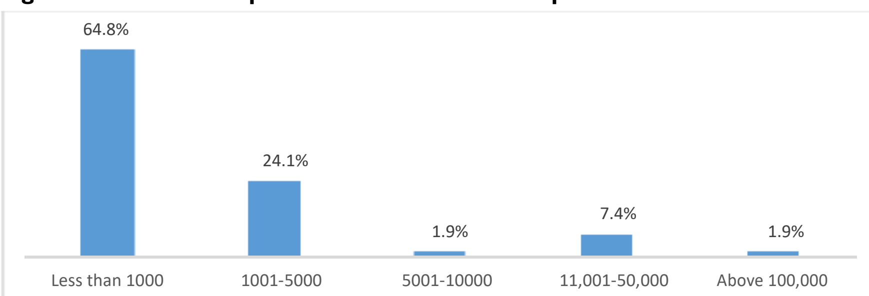
Figure 20: Number of produced bamboo seedlings in past 12 months



Source: Bamboo Tech Audit survey, 2020

The highest number of respondents (40.7%) declared to have produced less than 5000 bamboo seedlings in a year with 18.5% who produced between 5001-10000, between 11,001 and 50,000 respectively. 11.1% of respondents said to have produced between 51,000 and 100,000 and above 100,000 respectively. This produced seedlings are still very few to grow bamboo in different parts of the country (Tian and Si, 2016). It is worth noting that growers harvest bamboo plants as the need arises. Therefore, there is no regular market for the bamboo so one month they may cut 10 culms and then next month 100 culms and then none the following month, which threatens sustainability and productive management of the bamboo plants. Demand is driven by the users further up the value chain and the price depend on the sporadic nature of the market as declared by growers. The same was reported in feasibility study conducted by Rwanda Water and Forestry Authority in 2017. The total annual estimated bamboo production in past 12 months was summarized in figure below.

Figure 21: Number of produced bamboo trees in past 12 months



Source: Bamboo Tech Audit survey, 2020

The highest number of respondents (64.8%) declared to have produced less than 5000 bamboo trees with 24.1% and 1.9% of respondents who produced between 5001-10000, between 11,001 and 50,000 respectively. 7.4% and 1.9% of respondents said to have produced between 51,000 and 100,000 and above 100,000 respectively. The table below shows the total areas covered by bamboo trees across the country.

Table 6: Rwanda's existing bamboo resource

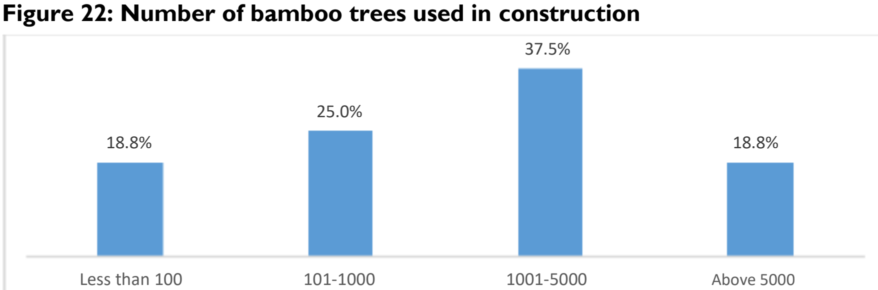
District	Age	Area (ha)
Karongi	6	9.5
Rutsiro	6	2.9
	8	1.1
Rubavu	6	1.0
Nyabihu	4	0.4
Musanze	7	20.6
	4	5.9
Burera	-	-
Rulindo	8	24.8
	8	2.5

	5	1.4
	4	1.4
Gakenke	8	12.2
	8	5.5
	1	1.2
Bugesera	1	45.6
Ngoma	4	66
	4	5.1
Gasabo	5	26.4
	4	8.2
	3	0.5
Nyarugenge	5	4.6
	5	11
Kicukiro	5	07
	2	0.8
	4	3.9
	4	3.5
	5	0.3
Total bamboo stock (hectares		523.5

Source: Ministry of Lands and Forestry, 2017

This study conducted by Ministry of Lands and Forestry showed that a total of 523.5 hectares were covered by bamboo in 2017. Of this total area, 192.7 hectares are highlighted as having suffered from high damages and are at high risk of survival. Furthermore the bamboo is spread over a wide age distribution, as indicated in table above, which limits the available bamboo for commercialization. All these produced bamboo trees are not used for construction purpose as it can been seen in figure below.

Figure 22: Number of bamboo trees used in construction

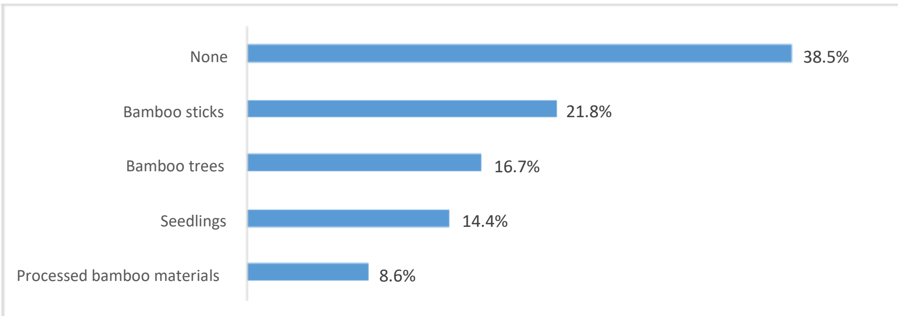


Source: Bamboo Tech Audit survey, 2020

The highest number of respondents (37.5%) confirmed to have used between 1000-5000 bamboo trees for construction purpose while 18.8% and 25% of respondents said to have used above

5000 bamboo trees and between 100 and 900 bamboo trees. This produced bamboo trees are still very few to compete with other types of trees used in construction.

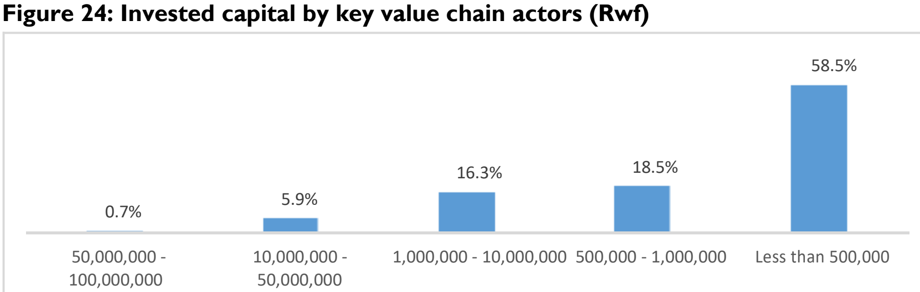
Figure 23: Packed bamboo based materials



Source: Bamboo Tech Audit survey, 2020

The study revealed that the highest number of bamboo based construction materials (38.5%) are not packed while 21.8% and 16.7% of respondents confirmed to have packed bamboo sticks and tees respectively. Furthermore, 14.4% and 8.6% of respondents declared to have packed seedlings and processed bamboo materials respectively. When asked the respondents about the reason behind of the low rate of packing bamboo based products, they said that normally trees are not packed unless are taken to the long distance or when they want to keep their origin nature before processing them.

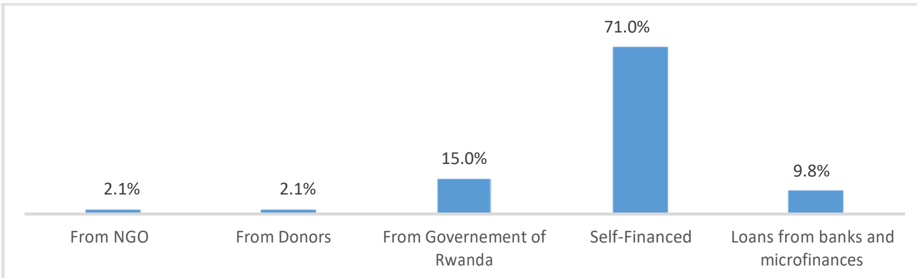
Figure 24: Invested capital by key value chain actors (Rwf)



Source: Bamboo Tech Audit survey, 2020

The figure above reveals that the majority (58.5%) actors in bamboo sector have invested less than 500,000 with only 0.7% of respondents who confirmed to have invested between 50 million and 100 million. These include the end-users who have hotels in Musanze district in Kinigi sector. The remaining percentage of respondents have invested between 500,000 and 50 million in bamboo related activities.

Figure 25: Source of finances to start a business linked with bamboo based construction materials



Source: Bamboo Tech Audit survey, 2020

Financial resources act as enablers of any business. The figure above shows that 71% of bamboo value chain actors financed themselves the start of the business while 9.8% took loan from banks and micro-finances despite of they reported to have been challenged by the high interest rates to pay on taken loans. The information on the firm's annual turnover was captured in figure below.

Table 7: Firm's annual turn over

Rage of turnover	Nursery operators	Growers	Processors	Traders	End users
Less than one million	43.5%	14.6%	33.3%	18.8%	0.0%
Between one million and ten	8.7%	0.0%	0.0%	6.3%	0.0%
Between 10 million and fifty million	0.0%	1.8%	0.0%	0.0%	0.0%
Between fifty million andone hundred million	21.7%	10.9%	28.6%	25.0%	0.0%
Above one hundred million	26.1%	72.7%	38.1%	50.0%	0.0%

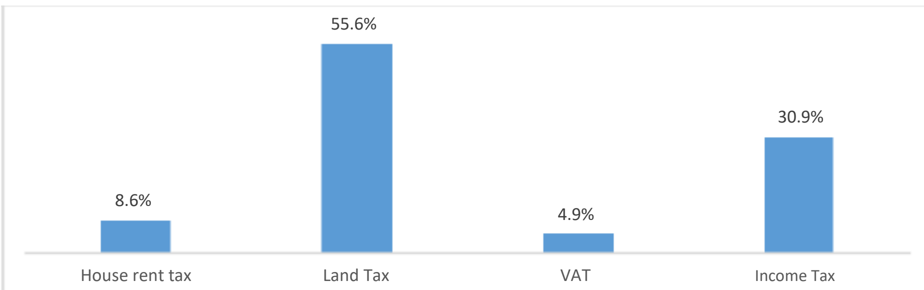
Source: Bamboo Tech Audit survey, 2020

Regardless the profit made by firms in past 12 months, 43.5% of nursery operators reported to have an annual turnover of less than one million with 33.3% of processors having the turnover of the same range. Moreover, 72.7% and 50% of bamboo growers and traders confirmed to have an annual turnover of above one hundred million while 26.1% of nursery operators reported to have the same turnover. It is worth noting that Rwanda is committed to achieving its development goals and has put in place robust national strategies and policies. A strong focus on landscape restoration, promoting green industries and poverty reduction create a positive framework for the advancement of a green economy. Furthermore, the Green Growth and Climate Resilience Strategy also builds on Vision 2020's goals (Ministry of Land and Forestry, 2017). It foresees big wins for low carbon development / mitigation and climate resilience and adaptation if the strategy is implemented, as well as quick wins where the strategy is implemented within development initiatives that were already underway. The following strategies in place for a low carbon economy would help to increase the annual turnover of bamboo value chain actors:

Promotion of made in Rwanda products for a low carbon and increase of exports ;
Exploration of import substitution through domestic low carbon industrial growth;
Supporting Small industries that supplies domestic needs.

When bamboo firms asked about the payment of taxes, the feedbacks provided by respondents was compiled in the following figure.

Figure 26: Payment of taxes by bamboo based companies



Source: Bamboo Tech Audit survey, 2020

The majority of respondents (55.6%) report to have paid the land tax with 30.9% who said to have paid income tax while reports of payment of house rent tax (8.6%) and VAT (4.9%) are less prevalent. The highest number of respondents who paid land tax may be linked to the fact that the majority of them are engaged in growing bamboo seedlings and trees while the number of bamboo processors is very limited.

3.6. Competitiveness of bamboo based construction materials on internal and external market

According to the Porter's theory[5] the competitiveness of bamboo sector can be assessed by analysing the interaction of the following aspects; firstly, the availability of labour and skills they possess and raw materials. Secondly, the status of domestic demand in pressuring companies into making their products more competitive. Thirdly, the received supports from various stakeholders and inputs that are advantageous for internationalization and innovation and lastly, the factors regards how companies are managed and organized.

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[5] Porter, M. E, Argyres, N. & McGahan, A. M. (2002). p. 43

(i) Labour availability and skills: With regard to the labour engaged in clay sector, it was seen that the majority of bamboo actors have at least completed primary school education level where they have not been taught about bamboo processing or technology application on bamboo trees. This shows that the majority of bamboo actors are using especially working experience rather than skills gained from the schools. Thus, it becomes harder to Rwanda to see the adoption of the new technologies in processing bamboo trees. The majority of interviewees especially the end-users confirmed that they use bamboo trees as there are without applying on them any machinery or technology.

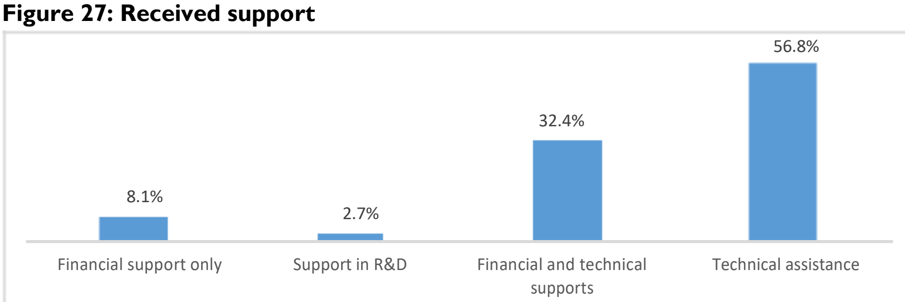
(ii) **Domestic demand in pressuring on production stage:** The lack of economic realization of raw bamboo and processed products puts pressure on the sustainability of plantings, many of which were planted for environmental protection. Despite efforts to sensitize farmers with bamboo on or near their properties, many remove these to make room for other crops or allow domestic animals to graze on them stunting their growth. Following interviews with bamboo value chain actors, the following observations were found:

- ✓ Those directly trained by the above mentioned programs (The China Bamboo Aid Project, ARECO's The Project Bamboo Burera (BamBu) showed excitement about the potential livelihood improvements from growing bamboo trees.
- ✓ The lack of the skills to apply machinery on bamboo trees to have more valuable was mentioned as one of factor hindering the competitiveness of bamboo on the market.
- ✓ High competition from other trees in use in construction sector (e.g. *Eucalyptus, Pinus, Grevillea rubusta*, etc) was mentioned in FGDs as limiting factor to grow bamboo.
- ✓ The other bamboo growers confirmed that bamboo trees are much more sold to make handicrafts and furniture rather than being used in construction sector. Moreover, manufacturing for toothpicks and skewers fails to compete with imported product from China, both from production costs and the cost of bamboo feedstock as declared by different key informants.
- ✓ The respondents confirmed that if an opportunity presents itself for higher earning, they would grow much more bamboo trees.
- ✓ However, there is hope that the bamboo businesses will expand to create new employment opportunities as few investors has started to use bamboo trees to construct big houses as two hotels were constructed using bamboo in Kinigi.

(iii) Stakeholders support for innovation: Notwithstanding that The China Bamboo Aid Project, ARECO's The Project Bamboo Burera (BamBu)), REMA through DEMPI, DEMP II, LVEMP, LAFREC projects contributed in growing bamboo trees especially for environmental protection purpose, there is still less involvement of investors in producing the manufactured products from bamboo such as MDF, roofing materials, etc. Moreover, there are good news that one Chinese company is going to start producing MDF very soon in Rwamagana district, Muyumbu sector as confirmed by the Key informant from Ministry of Environment.

The respondents were also asked about the received support and the provided feedbacks were summarized in figure below.

Figure 27: Received support



Source: Bamboo Tech Audit survey, 2020

The study revealed that bamboo value chain have technically assisted at the rate of 56.8% while those who have been supported both financially and technically represent 32.4%. Furthermore, 8.1% and 2.7% have received financial support only and support in R&D respectively. When asked the type of technical support received they said that they have been advised technically by Farmer's Promoters and sector agronomists in agricultural practices to be applied on bamboo seedlings and trees. Moreover, there is still room to provide more support especially in processing bamboo for construction materials to be more competitive not only locally but also internationally. Specialist training and promoting access to the required finance and technologies, equipment, knowledge and technical support will be crucial to implementing long-term, innovative and far-reaching competitive bamboo products.

(iv) Competition on market from other trees used in construction sector

The unit price and quality of bamboo trees were mentioned in KIIs and FGDs as the main factors determining the competitiveness on the market. Moreover, the value of a bamboo tree can not only estimated based only its price on the market, it can also valuated based on its maturing period as presented in table below.

Figure 28: Comparative maturing period of different trees used as construction materials

Description	Bamboo	Grevillea rubusta	Eucalyptus	Cypres	Pinus	Markhamia lutea
Maturing period from Seedlings to Harvest (Years)	3-5	8	6-7	9-10	9-10	9-10

Source: *Bamboo Tech Audit survey, 2020*

The harvesting of trees used in construction sector takes place at different ages depending on product requirements. For example, the recommended age to harvest bamboo to use in the construction industry is 3-6 years yet for some craft uses they may be harvested at a younger age depending on the species while other hardwood like Eucalyptus, Pinus, grevillea take more than 7 years to be harvested. Furthermore, when harvesting bamboo, it is cut just above the node at the base to carry out the harvest immediately after new shoots have started to grow, at this time the plant will be harvested in few years than before. Additionally, after the first harvest many trees (more than 20) are harvested from the original tree while the tree like Grevillea will be harvested once only.

Table 8: Comparing bamboos with other selected competitors on market

Description	**Period**	**Bamboo**	**Grevillea rubusta**	**Eucalyptus**	**Cypres**	**Pinus**	**Markhamia lutea (Umusave)**
Unit cost of a mature tree		2500	15000	6000	20000	20000	25000
Number of trees to be sold in 10 years	1 - 3 Years	5	0	0	0	0	0
	4 - 6 Years	40	0	1	0	0	0
	7-10 Years	100	1	3	1	1	3
	Total	145	1	4	1	1	3
Sales for mature trees in 10 years	1 - 3 Years	12500	0	0	0	0	0
	4 - 6 Years	100000	0	6000	0	0	0
	7-10 Years	250000	15000	18000	20000	20000	75000
	Total	362500	15000	24000	20000	20000	75000

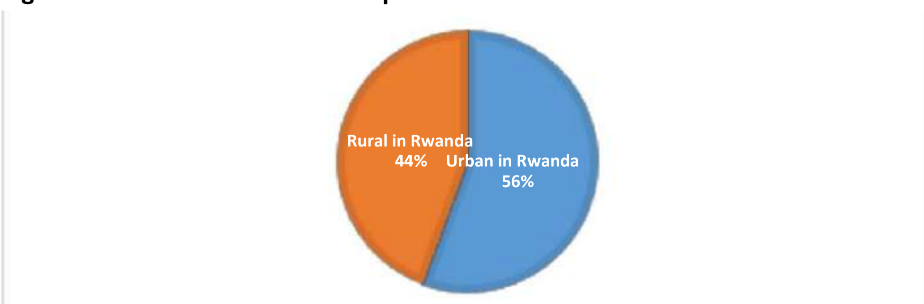
Source: Bamboo Tech Audit survey, 2020

The figure above shows that bamboo is more competitive in term of generated income (362,500 Rwf) in 10 years compared to other construction materials of the same category. Therefore, bamboo is more profitable in terms of vegetative cycle length compared to other trees.

Despite the above mentioned value for money to the bamboo trees, they are less preferred especially compared to many other trees used in construction sector. Regardless the significant potential market for manufactured bamboo based products like MDF and roofing materials in Rwanda, it currently relies extremely heavily on foreign imports for both raw materials for manufacturing and the importation of finished end products. Currently the majority of this supply chain is fulfilled through the direct imports of finished products. These finished products are imported especially from Kenya and China and they reach in Rwanda being expensive due to added cost for transport. Therefore, only the first steps of the value chain that do not require manufacturing are carried out in-country currently.

The following are additional solutions to improve the competitiveness on the market as suggested by the respondents.

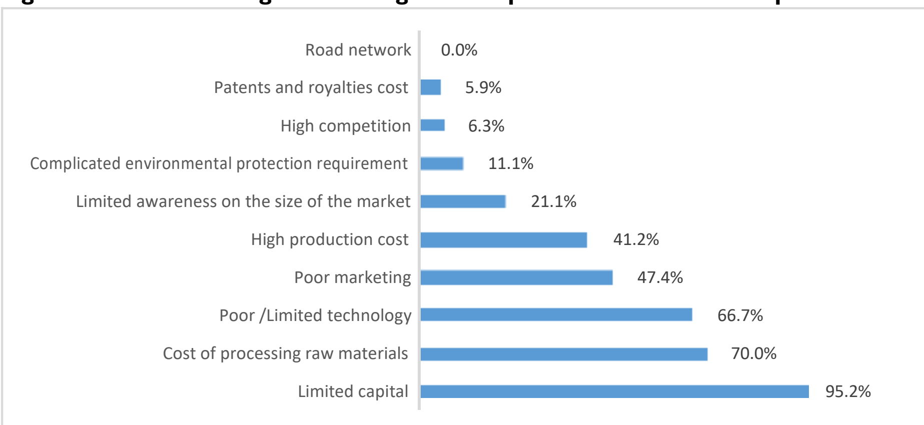
Figure 29: Destination of bamboo products



Source: *Ba mb oo Tech Audit survey, 2020*

The study revealed that the highest percentage of bamboo products are used in urban areas as declared by 56% of respondents compared to rural areas (44%). The bamboo trees growers confirmed that the highest percentage of their products are sold in urban centers even though they are not sure whether all of them are used in construction sector. This shows that there is possibility to market bamboo based products as the urban centers gather people from different part of the country even those from abroad. Furthermore, the Key Informants said that the bamboo trees are especially used in construction of bars and restaurants as shown in Figure 35 and 36 where many people meet regularly to eat and drink. Hence, there is a hope of more use of bamboo trees in future. Therefore, the growers should be ready to plant much more bamboo to respond to respond to the needs of the market.

Figure 30: Main challenges hindering the competitiveness of bamboo products

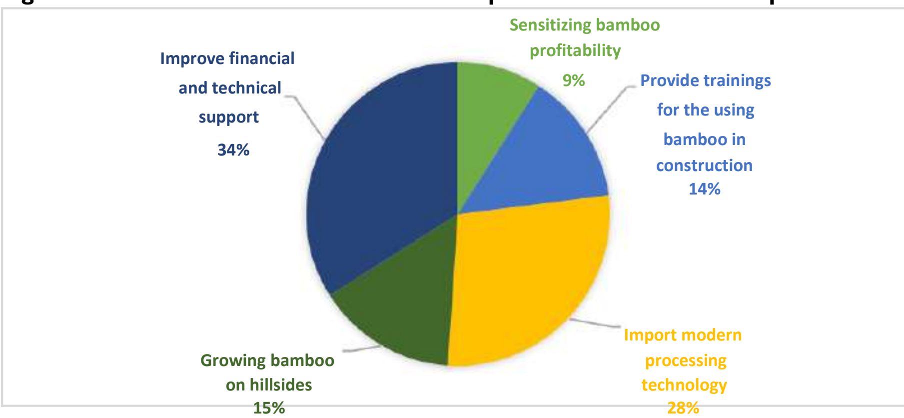


Source: Bamboo Tech Audit survey, 2020

The majority of respondents (95.2% and 70%) highlighted limited capital and high cost of processing raw materials as the main problems hindering the competitiveness of bamboo products. The respondents in FGDs furthermore said that they avoid to take loans from the banks to grow bamboo which will be harvested after three years and above while the loan is paid back monthly. Therefore, they need supporters who can wait to get back their money at the harvest period.

The poor/limited technology for bamboo processing comes to the third position among the others main challenges facing bamboo sector. Therefore, the relevant governmental and non-government authorities should intervene to get sustainable solutions to the above mentioned challenges hindering the smooth operation of bamboo value chain actors and making substantial profit from this sector as the biggest portion of bamboo trees across the country are owned by the Government of Rwanda. When bamboo value chain actors were asked about use of invested capital, the feedback they gave was compiled and reported in the following figure.

Figure 31: Solutions to the low market competition of local bamboo products



Source: Bamboo Tech Audit survey, 2020

The improvement of financial and technical support (34%) and importation of modern processing technologies (28%) were suggested to be the best solutions to the market competition. Growing bamboos on hillsides (15%) and the provision of trainings in the use of construction sector (14%) along sensitization bamboo profitability (9%) were also mentioned as appropriate solutions to deal with market competitions. The processors emphasized on the improvement of importing modern processing technology which may help to manufacturer products like MDF which are normally imported from Kenya and China.

3.7. Infrastructure and technology in place

3.7.1. Assessing the bamboo technology in Rwanda

(i) Agricultural practices applied to grow bamboo seedlings

Normally, the bamboos are propagated through the culms cuttings or rhizomes. But they can also be propagated through the seeds, which are very rarely available. Bamboo seedlings are basically raised on nursery beds and for a year or so they are allowed to grow on poly pots. Later the seedling is transferred into the main field. In the rhizome planting method, a little care is needed. Here, culms of 1 year along with roots should be dug and cut into 1 meter size and be planted in the rainy season.

Usually bamboo planting is done in the rainy season. The pits size of 60*60 must be digged and nursery-raised seedlings should be planted at a space of 5*4 meter.
An average, the amount of time bamboo seedlings have to remain in the nursery ranges from 8 to 12 months. In general, at least 5000 m² should be allotted for every 10,000 seedlings or young

plants that will be raised annually. Adequate space is needed to maintain a stock of growing plants. A crowded nursery will only result in the production of poor stock quality.

Figure 32: Different methods in use in Rwanda to grow bamboo seedlings

Kirehe, Mpanga Huye, Tumba sector, Ruhande cell Rulindo, Mukoto sector sector, Mushongi cell

Source: Bamboo Tech Audit survey, 2020

The study revealed that there are different methods in use across the country for growing bamboo seedlings. Some are grown in open areas, others are grown in green houses depending on the types of grown seedlings and the expected quality of mature bamboo trees.

(ii) Agricultural practices applied to grow bamboo trees

The gestation period in bamboo planting is between 3 and 5 years. Hence the inter space can be used during first 3 years for earning some extra income by growing inter crops such as ginger, chillies or turmeric. For high quality and best yield, fertilizers are used. Manure and fertilization are important when the seedling is transplanted in the main field. As the bamboo plants are heavy feeders, even the richest soil will get washed-out after few years, if fertilizers are not applied on them. But it is always suggested to apply fertilizer after harvesting and previous to irrigating the plants. Potassium and Nitrogen are vital components of the fertilizer due to which the bamboo trees respond and grow well. Also you must apply green manures, organic compost, wood ash and chemical fertigation. Leaf biting and sucking insects are common in young bamboo plants. Hence appropriate pesticides should be applied to control these pests.

Figure 33: Different types of bamboo trees grown in Rwanda

Ngoma, Ngoma sector, Karengere cell | Rulindo, Mukoto sector | Kamonyi, Kayenzi sector, Kirwa cell

Source: Bamboo Tech Audit survey, 2020

The above show different status of grown bamboo in Rwanda. They look like mature bamboo trees which may be harvested. Moreover, it is advisable to start harvesting them from the fifth year onwards for the first time but there are also species in Rwanda which may be harvested after three years as declared by a number of Key Informants.

(iii) Engineered bamboo

Though the engineering of bamboo timber in Rwanda is not yet at advanced stage. The following three categories were subjected by the Ministry of Lands and Forestry, 2017 to be developed in Rwanda: (a) Oriented strand board, (b) Plywood and (c) Medium Density fibre board (MDF) as also reported by the Ministry of Lands and Forestry, 2017. All of these products involve the deconstruction of the woody fibre and then the re-constitution through the binding of different forms of fibre strands, chips, particles or other forms along with suitable adhesives to create a composite board. Therefore, a call is made to various stakeholders to intervene in order to develop the above mentioned recommended three categories of bamboo engineering.

(a) Oriented strand board (OSB)

Oriented strand board (OSB) is a form of engineered timber in which a woody fibre is flaked into individual wood strands, and then compressed with the flakes or strands oriented into specific directions. These strands are then compressed along with a resin to create a wooden panel of varying dimensions. The mechanism of compression along with the orientation of the strands results in a product that has high strength. OSB is used as the raw material for items such as wall and roof sheathing.

(b) Medium density fibre board (MDF)

Fibre board is a form of engineered timber in which a woody fibre is broken down into chips, particles or shavings and then compressed along with a resin. The individual woody pieces are arranged at random within the panel. Fibre board can be further defined as particle board, medium density fibre board and hardboard. MiR MDF are not yet available to the market though the company which was committed to manufacturer them have already installed the industry and it is ready to open soon.

(c) Plywood

Plywood differs from OSB and MDF in that the woody material is not flaked or chipped but instead is cut into thin strips. Multiple strips are joined together to form a veneer panel, and multiple panels are then compressed with resin. Each individual panel is layered at 90 degree alternating directions which provides the engineered material’s strength. Bamboo plywood represents one of the easiest entry point for bamboo to gain market share.

(iv) Common technologies in construction with bamboo trees

Bamboo trees are used in construction activities either on the walls or in roofing activities. There are also used to make doors as the examples are illustrated below.

Figure 34: Examples of uses of bamboo trees on the walls

Gicumbi, Byumba sector, Gacurabwenge cell, Rubyiniro village

Source: Bamboo Tech Audit survey, 2020

The figure above shows different ways Rwandans have been able to manage to construct walls of houses with help of bamboo trees. Below there are some examples of the use of bamboo in Rwanda roofing activities. Moreover, the bamboo trees are used without applying on them any of suggested above engineering technology (Oriented strand board, Plywood and Medium Density Fibre board (MDF)) to improve their values and attract the users.

Figure 35: The uses of bamboo trees in roofing houses

Source: Bamboo Tech Audit survey, 2020

The figure above depicts that Rwandans have been managed to use bamboo trees in roofing activities, Moreover, there is a way of improving the quality of existing roofs by applied machinery on bamboo trees as presented in following section.

Figure 36: Making doors and windows in bamboo trees

Kicukiro District, Masaka Sector, Cyimo Cell, Biryogo Village, At Masaka Incubution center

Source: Bamboo Tech Audit survey, 2020

The figure above shows that bamboo trees have been in use to make doors. The KII and FGD members confirmed that they are also used to make windows of the houses, they said further that bamboo trees are either used as there are without applying any machinery or they are used after applying on them a machine to make them smoother. Below there is an example of a machine used at Masaka incubation center.

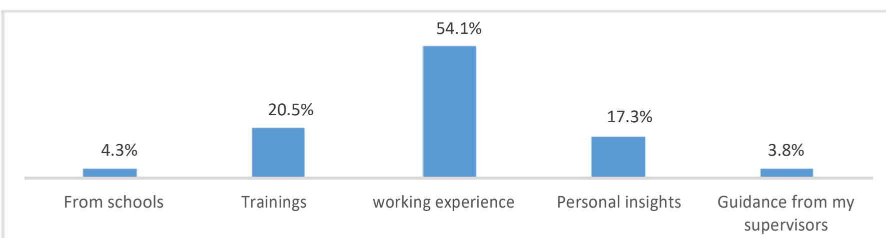
Figure 37: Machine in use at Masaka Incubution center

Source: Bamboo Tech Audit survey, 2020

Though this machine seen at Masaka Incubution center is used for manufacturing various bamboo based products, few of them are used in construction sector as most of them are used to make furniture.

It is worth noting that this study revealed that most of the bamboo value chain actors use bamboo trees directly without applying on them any machinery. There is no deconstruction of the woody fibre and then the re-constitution through the binding of different forms of fibre strands, chips, particles or other forms along with suitable adhesives to create a composite board like MDF, Plywood or OSB. The information on the skills and knowledge in use in performing bamboo related activities were investigated and results were reported in figure below.

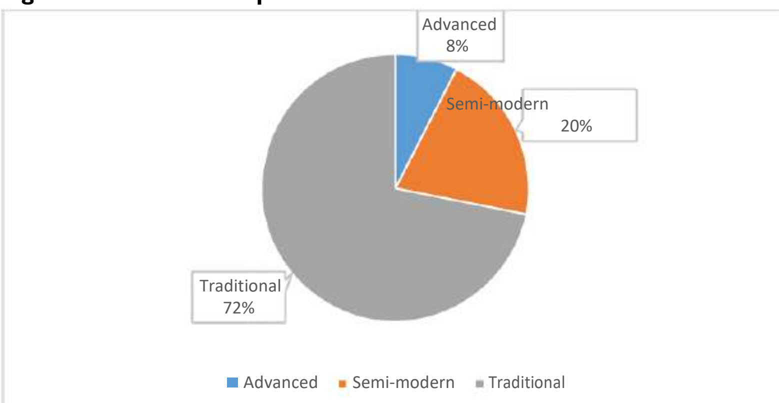
Figure 38: Source of skills and knowledge used in performing bamboo related activities



Source: Bamboo Tech Audit survey, 2020

Based on the information gathered from respondents, the majority of the bamboo value chain actors (54.1%) make use of their working experience to perform daily duties. Only 20.5% and 4.3% are applying what they have learnt from trainings and schools respectively while 17.3% and 3.8% use personal insights and guidance form their supervisors. These percentages are still very low to make bamboo value chain for construction materials skills and knowledge based sector. Therefore, there is a call to develop short course programs and trainings which would be delivered in collaboration with Technical and vocational education and training (TVETs) and other stakeholders to help various bamboo value chain actors to gain required practical skills to be used in bamboo related activities. Additionally, The Integrated Polytechnic Regional College (IPRC) schools should integrate in their programs a component regarding bamboo value chain activities. These will help to apply modern technologies in each stage of bamboo value chain and make sector more competitive.

Figure 39: The level of professionalism of firms



Source: Bamboo Tech Audit survey, 2020

The study revealed that 72% of firms are still traditional in nature with only 20% and 8% which were classified as semi-modern and advanced firms respectively. The level of professionalism was analyzed based applied agricultural practices for nursery seedlings, growing bamboo and applied technology on bamboo by the processors and end users. For instance, the actors who are growing bamboos in green houses and respect all agricultural requirements have been classified in actors who use advanced technology while those who grow bamboos in green houses without respecting the agricultural requirements have been classified in actors who use semi-modern technology. Furthermore, the processors who applied the machinery for re-constitution through the binding of different forms of fibre strands, chips, particles or other forms along with suitable adhesives to create a composite board like MDF, Plywood or OSB are also classified in actors who use advanced technology.

With this regard, a call is made to different investors and stakeholders to invest in modern technology for bamboo related materials to contribute to the national ambitions of having households with suitable and environmentally sustainable houses by 2050.

3.7.2. Best practice from other countries

(i) Promotion of Green building Technologies

It is commonly acknowledged that green building is an effective approach through which the need for implementing sustainability and sustainable development within the construction industry can be addressed[6]. Green building was defined as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's lifecycle"[7].

Thus, the development of green buildings would result in substantial minimization of negative environmental effects and efficient utilization of resources. It should have a Minimum Compliance system developed by RHA with GGGI by promoting energy efficiency, use of renewable energy, ensuring water efficiency, using environmentally preferable building materials and specifications, using local materials, promoting waste reduction, promoting toxics reduction, ensuring indoor air quality, promoting smart growth and promoting sustainable development. Therefore, bamboo based construction materials are suitable to respond to the above mentioned requirement. Below there some examples taken from Mynmar where bamboo trees were used to construct bridges, houses, a variety for various of the use

Figure 40: Examples of the use of bamboo products in touristic areas

Source: https://www.google.com/modern+house+constructed+in+bamboo+trees

Figure 41: Example of modern house constructed in bamboo trees

6 Sev, A. How can the construction industry contribute to sustainable development? A conceptual framework. Sustain. Dev. 2009, 17, 161–173.

7 Son, H.; Kim, C.; Chong, W.K.; Chou, J.S. Implementing sustainable development in the construction industry: Constructors' perspectives in the US and Korea. Sustain. Dev. 2011, 19, 337–347.

Source: https://www.google.com/modern+house+constructed+in+bamboo+trees

The figure above shows that there is a possibility to use bamboo trees in construction of bridges and houses which are eco-friendly.

(ii) Making modern roofing sheets from bamboo trees

The following are the possible technology which may be imported in Rwanda in making roofs from bamboo trees:

- The bamboo culms are split into strips, which are first woven into a mat and then pressed along with suitable resins;
- The bamboo is chipped and fiberized, then mixed with resin and pressed.

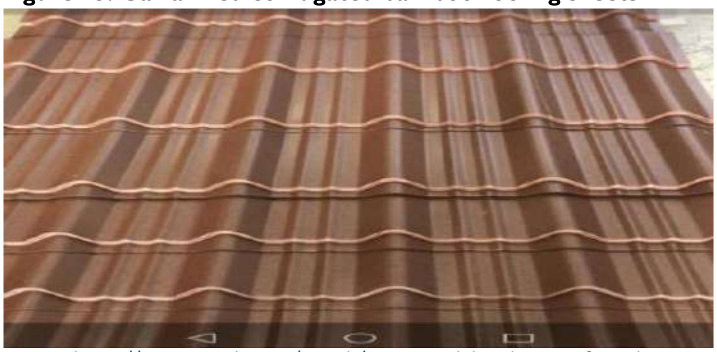
The first technology is more widely available, and relies on significant manual labor to carry out the weaving. While this has advantages it also results in higher quality control requirements and higher levels of waste.

Figure 42: Corrugated bamboo roofing sheets

Source: https://www.google.com/search/corrugated+bamboo+roofing+sheets

The second option allows for a more mechanized industrial system. An R&D period will be necessary to fine-tune the product and in turn develop the specific manufacturing line.

Figure 43: Galvanized corrugated bamboo roofing sheets



Source: https://www.google.com/search/corrugated+bamboo+roofing+sheets

- The specifications of either bamboo strips, or a chipped bamboo feedstock;
- The associated density and strength of the resulting fibres;
- The availability of appropriate, environmentally and socially friendly resins.

Trials are not required to determine the equipment and manufacturing line itself, which will be custom designed however once this equipment has been secured, it is recommended that a 3 -6 month trial period is undertaken to refine the specifications of the equipment. Working with the above factors, it is feasible to design such a facility to meet the highest levels of sustainability, while reducing waste and creating a closed loop manufacturing unit.

Figure 44: Kenyan Bamboo corrugated roofing machine

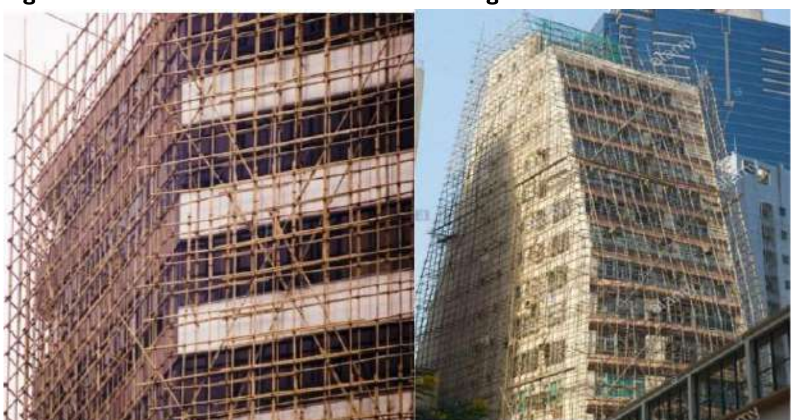
Source: https://www.google.com/search?q=Kenyan+Bamboo+corrugated+roofing+machine&tbm

The figure above shows that some East Africa country like Kenya developed advanced technology to produce galvanized corrugated bamboo roofing sheets.

(iii) Use of bamboo trees for scaffolding

Bamboo trees have been proved to be the best substitute of metals, and other types of timber in construction of scaffolding on tall houses

Figure 45: The use of bamboo for scaffolding in construction of tall houses



Source: https://www.google.com/ =The+use+of+bamboo+for+scaffolding+in+construction+of+tall+houses&tbm

Bamboo trees are very efficient in construction of scaffolding because there are very light compare to other types of timbers and are environmental friendly.

(iv) The use of bamboo for manufacturing MDF

MDF (Medium Density Fiberboard) is the third generation wood substitute, after plywood and particleboard. MDF exceeds wood, plywood and particleboard in terms of quality and applications. The properties of edge cutting, post- forming, nail holding, bonding & moisture resistance are far better in MDF. We cannot think of modern wood decorations in houses & offices without MDF.

MDF is an engineered wood. Excellent machinery & application properties make MDF an economic & future-oriented substitute of solid timber. MDF is flawless, smooth & uniformly strong, easy to cut, machine & joint. It can be carved like natural timber. MDF can be made available for interior & exterior grades, plain or laminated.

Figure 46: Manufacturing MDF from bamboo trees

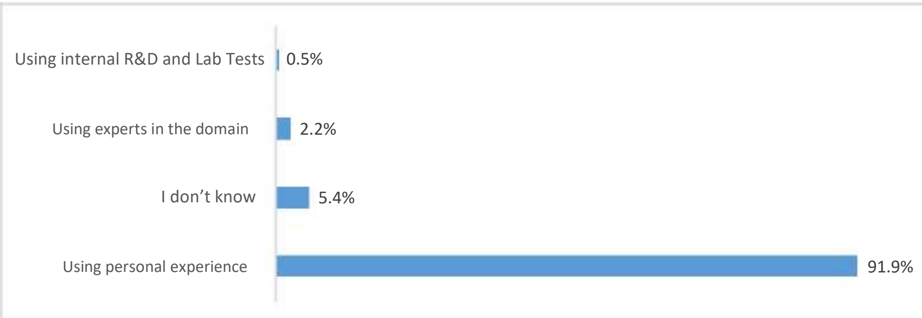
Source: https://www.google.com/search?q=Manufacturing+MDF+from+bamboo+trees&tbm

MDF is used for doors, windows, kitchen & office cabinets, indoor stadiums, auditoriums, and entertainment halls among others. It is also used for interior decorations for offices, houses, hotels & restaurants. The importation of this technology in Rwanda will help the majority of traders to stop relying on imported Kenya and Chinese MDF commonly used across the country. There is a good news that one Chinese company is going to start operating very soon in Rwamagana district, Muyumbu sector.

3.8. Quality control and standards status assessment

Rwanda's building and construction industry has rapidly grown in the past couple of years with both government and private sector engaged in the construction of buildings and roads triggering what is now dubbed as a "construction boom in Rwanda". With this regard investigation was made to assess the methods in use to identify clay with a good quality and findings were shown in figure below.

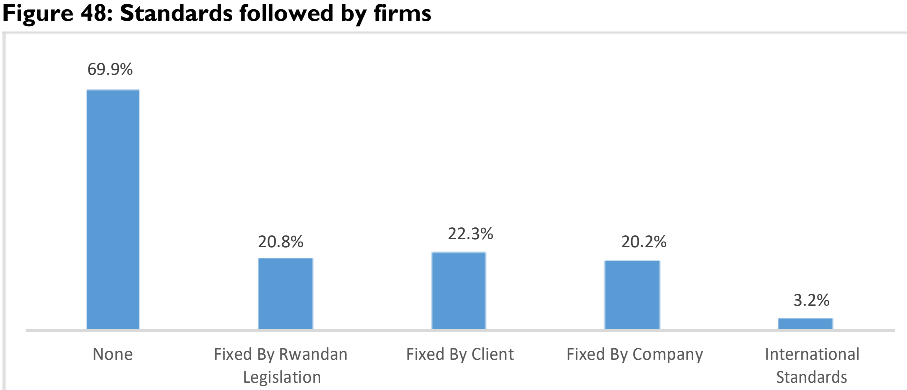
Figure 47: Identification of bamboo with a good quality



Source: Bamboo Tech Audit survey, 2020

The study revealed that the identification of a bamboo as raw material with good quality is done using personal experience as declared by 91.9.% of respondents with 2.2% who use expertise they have in the domain. Only 0.5% of respondents confirmed to use internal R&D and lab tests. The standards followed by firms are presented in figure below.

Figure 48: Standards followed by firms

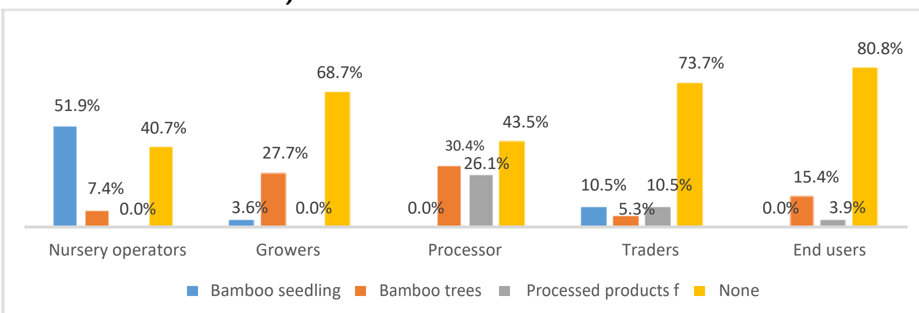


Source: Bamboo Tech Audit survey, 2020

This study explored the standards followed by the firms and 69.9% of respondents revealed that they do not follow any standard in processing stages of bamboo product. 20.8% and 22.3% of respondents confirmed that their firms follow standards which were fixed by Rwandan legislation and by the client respectively with 20.2% that follow those fixed by company itself. This implies that there is a poor follow up and check-up of bamboo products in terms of standards fixed by the government of Rwanda. This makes it difficult for the clients to select the best clay product in terms of durability, resistance to external shocks, and beauty among others. In this respect, a call is made to the governmental, non-governmental institutions (e.g. Rwanda Standards Bureau

- RSB) and other stakeholders to put together their efforts to fix the standards which would be followed to produce competitive bamboo products delivered as construction materials.

Figure 49: Available standards control system by firm's category (not understandable)



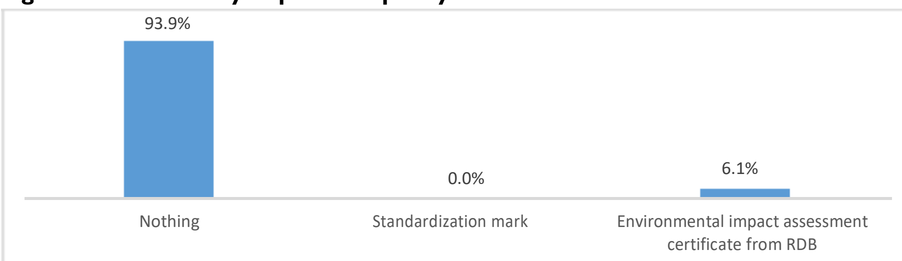
Source: Bamboo Tech Audit survey, 2020

It was reported by majority (80.8% of end-users, 73.7% of traders and 68.7% of growers) that they have no standard control system of their products. Only 51.9% of nursery operators and 30.4% of processors confirmed to have standard control system on bamboo seedling and bamboo trees. This shows that bamboo value chain operators use generally personal experience and personal insights to control the quality of bamboo products. Below figure shows bamboo nursery .

Figure 50: Nursery of bamboo seedlings

When bamboo operators were asked about possession of product/quality certificates of their products the feedback provided was compiled in the following figure.

Figure 51: Availability of product/quality certificates



Source: Bamboo Tech Audit survey, 2020

It was declared by 93.9% % of respondents that they do not possess any quality document/certificate with only 6.1% who have environmental impact assessment certificate from RDB. There is no bamboo value chain actor who have certificate for standardization mark. Based on these findings it can be deducted that bamboo value chain actors do not have an approved methods/techniques to assess the quality of their products.

3.9. Potential environmental benefits and climate change of bamboo

3.9.1. Potential environmental benefits of bamboo

Bamboo as a tool for landscape restoration has the potential to provide a wide range of social, environmental and economic benefits. However such benefits depend upon a stringent framework being adhered to with all bamboo planted and maintained in a sustainable manner:

1. Only degraded and marginal land should be targeted as areas for bamboo planting;
2. Management and harvesting plans follow sustainability guidelines (requiring significant training of smallholders and a strong monitoring and evaluation aspect to the project), ensuring that no over harvesting occurs and thereby ensuring that the bamboo can provide annual incomes as well as be a secure annual source of feedstock to manufacturing industries.

With the above mentioned management bamboo may provide the following environmental benefits:

Grows on degraded land: tropical clumping bamboos are tree like plants that, although requiring active management, are tough, hardy and can thrive on highly degraded soils.

Erosion control: the intricate but shallow underground rhizome system of clumping bamboo provides soil binding properties while the above ground plant reduces run off and leaching of remaining soil nutrients.

Restores organic soils: significant leaf fall within the first few years of growth results in the generation of organic humus, feeding nutrients back into the soil and restoring the top layers of the soil.

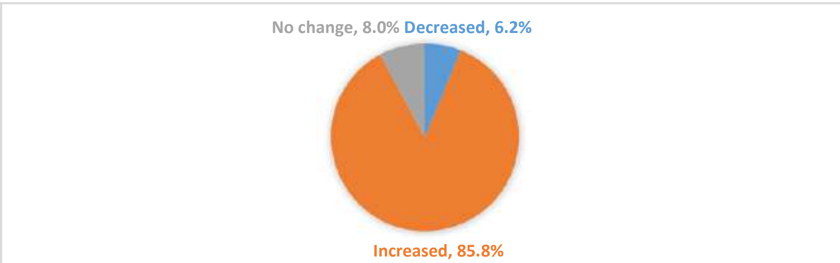
Canopy cover: fast growth creates a dense canopy cover within 4 -5 years of planting, intercepting rainfall and protecting understory species and soils from intense sun.

Stabilizes water tables: the dense canopy cover causes a controlled flow of rainfall down to the forest floor, where the leaf litter and underground rhizome system result in reduced run off and slower filtration of water, regenerating and maintaining water tables.

Biodiversity: connecting remnant forest patches with bamboo enables a diverse ecosystem, facilitating the protection and long term restoration of biodiversity within all levels of the forest ecosystem.

Clumping bamboos have a unique environmental attribute and benefit in comparison to trees. Due to their status as a grass, the sustainable harvesting of bamboo, meaning the removal of individual mature culms from each plant, allows for the annual harvesting of a woody fibre, while maintaining all of the above environmental benefits. In this manner well managed bamboo has the potential to provide a truly sustainable and long term resource to feed industrial timber markets (Ministry of Lands and Forestry, 2017).

Figure 52: Observed change in bamboo woodland areas for the past 2 years



Source: Bamboo Tech Audit survey, 2020

The study shows that majority of respondents (85.8%) confirmed that bamboo woodland has increased in past two years with 8% who did not see any change and 6.2% who saw bamboo woodland. The area covered by bamboo trees can be seen in Table 6.

Table 9: Comparative advantage of bamboo with other plants in protecting environment

	Don't know	Not effective	Effective to some extend	Effective	Highly effective
Maintenance of degraded land	3.7%	16.3%	3.0%	8.9%	68.1%
Erosion control	0.7%	5.2%	7.5%	11.9%	74.6%
Restores organic soils	34.4%	11.5%	10.7%	10.7%	32.8%
Canopy cover	4.5%	6.0%	13.4%	24.6%	51.5%
Stabilizes stream/river banks	9.0%	5.3%	8.3%	23.3%	54.1%
Safeguard the biodiversity	12.6%	9.6%	20.0%	25.2%	32.6%
It protect rivers and water channels from siltation and sedimentation	3.0%	11.9%	4.5%	14.9%	65.7%

Source: Bamboo Tech Audit survey, 2020

Reference to the feedbacks provided by respondents across the country, bamboo was seen to be highly effective in maintenance of degraded land (68.1%), erosion control (74.6%), protection of rivers and water channels from siltation and sedimentation compared to other plants. Additionally, 54.1% and 51.5% considered bamboo highly effective in stabilizing stream/river banks and it plays a role of being a canopy cover respectively. Furthermore, bamboo contribute much in restoring organic soils (32.8%) and safeguarding the biodiversity.

3.9.2. Climate Change Benefits

Landscape restoration utilizing carefully chosen species of bamboo has the potential to contribute significantly towards the fight against global climate change. Eco-Planet Bamboo has pioneered the application of international carbon methodologies to bamboo, and is the first and only entity globally to have received fully verified carbon credits from planted and managed bamboo. Clumping bamboo has a number of unique properties contributing to its effectiveness in positively contributing towards carbon sequestration and storage:

Fast growth means that the removal of atmospheric carbon dioxide occurs within a relatively short time frame after planting compare to other plants.

Due to the unique and selective annual harvesting mechanism the plant is not killed but instead the removal of individual culms only serves to stimulate further growth, resulting in a permanent carbon store.

The below ground root system holds significant amounts of carbon, and the long life of the plant means that this represents long term carbon capture and storage.

The dense leaf little contributes to increasing levels of soil organic carbon. These benefits contribute to the positive impact of bamboo for fighting climate change. The below graph demonstrates these differences in comparison with a hectare of planted trees, such as eucalyptus.

In 2012, Rainforest Alliance successfully validated and verified the first bamboo carbon project globally. Under this methodology one hectare of land under a bamboo reforestation program had a long term average, or maximum carbon benefit of 660tCO2e (Rainforest Alliance, 2012). Utilizing this framework, but allowing for a 25% reduction in total carbon benefits due to climatic differences the loss of bamboo due to mortality and smallholder involvement:

1 hectare of planted bamboo in Rwanda = 495 tCO2e

This translates into the following climate change benefits for Rwanda, if the proposed bamboo based bio-economy at the scale of the initial sites is achieved:

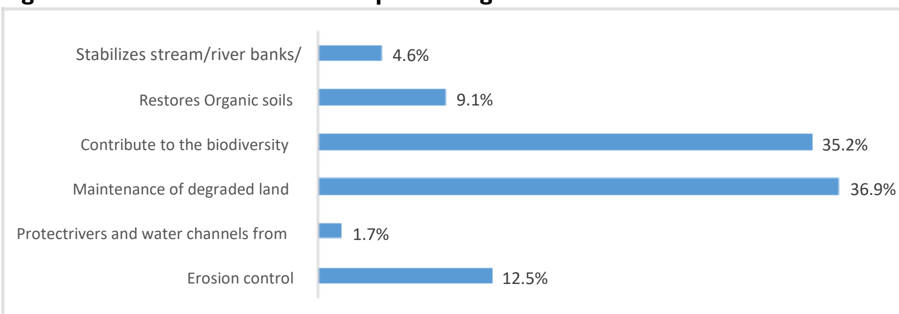
(1) Southern Province: 1,000 ha planting will absorb 495,000 tCO2e

(2) Eastern Province: 1,000ha planting will absorb 495,000 tCO2e

Total Benefit: 990,000 tCO2e (Ministry of Lands and Forestry, 2017).

When the respondents were asked about their understanding on the role of bamboo in dealing with impacts of climate change the feedback they provided was summarized in figure below.

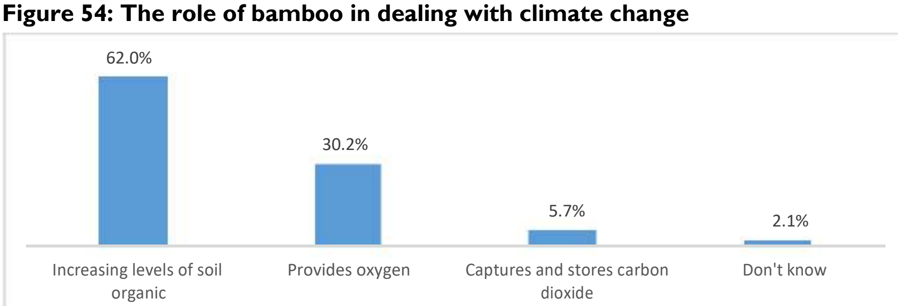
Figure 53: The role of bamboo in protecting environment



Source: Bamboo Tech Audit survey, 2020

It has been declared by 39.9% and 35.2% that bamboo trees contribute to the maintenance of degraded land and protection of biodiversity respectively while 12.5% said that it also play a determinant role in erosion control with 9.1% who confirmed its role in restoration of organic soils. Furthermore, 4.6% and 1.7% highlighted the role of bamboo trees in stabilizing stream/river banks and protecting rivers and water channels. This shows a determinate role of bamboo woodland in dealing with adverse impacts of climate change and variability. Additional roles of bamboo towards climate change impacts were analysed and reported in following figure.

Figure 54: The role of bamboo in dealing with climate change



Source: Bamboo Tech Audit survey, 2020

It was reported by 62% of respondents that bamboo contribute to the increasing the levels of soil organic with 30.2% confirming its role in provision of oxygen and while 5.7% of respondents mentioned its role in capturing and storing carbon dioxide. By doing so, it plays both mitigation and adaptation roles to climate change and variability. This findings show that the respondents are aware of the role of bamboo in absorption of CO_2 and provision of Oxygen to living things.

3.10. SWOT analysis of clay value chain for construction materials in Rwanda

Bamboo value chain for construction materials in Rwanda has not evolved to become a productive industry especially at processing stage. Additionally, small pots of bamboo plantations are very scattered across the country. This therefore sets the tone for the SWOT analysis presented below.

Table 10: SWORT analysis of clay value chain for construction materials

Strength: High potential for environmental impact due to protection of the lake's catchment; Existence of water near bamboo plantation ease its faster growing; Short maturing period of bamboo trees make them to be available throughout the year; High climate resilient crop; Availability of investors who are willing to develop processing of bamboo trees; Existence of hotels constructed partially by bamboo trees can serve as examples in using bamboo products in construction sector; Existence of houses and other basic infrastructures constructed in bamboo trees outside the country which may serve as examples to improve the use of bamboo trees as construction material.	**Opportunities**: Existence of national forestry strategic plan which include lakeshore buffer zone plantings; Potential to take part inregional environmental projects for the plantings (i.e. Nile Basin Initiative); High income crop for the farmers Existence of market not only in Rwanda but also in the region like East Africa. A good raw material to make competitive MDF; Potential to positively contribute to the annual income of smallholder farmers. n 2011 a draft National Bamboo Policy was proposed that highlighted the planting of bamboo as a riparian buffer in order to reduce soil erosion, siltation of rivers and water bodies by growing bamboo on slopes and buffer zones along riverbanks and lakeshores and these also highlight in revised environmental and climate change policy of 2019.
Weaknesses: Communities are not sensitized on the use of bamboo in construction sector; It is very hard to have very extensive lands which may be used to grow bamboo trees; Planting bamboo trees on hillside is very limited while most of marshland are owned by the Government of Rwanda; Processing bamboo products it is still at low stage. Limited diversification of bamboo MIR products; Limited use of advanced technology in processing bamboo products;	**Threats:** Less ideal rainfall, longer dry period especially in eastern and central parts of the country; Bamboo plantation are frequently flooded especially during rainy season and they are covered by sediments and/or silting as the majority of them are planted around lakes, rivers and streams; Some landowners with very extensive lands are not willing to avail their land to grow bamboo as they are not yet sensitized on the profitability of growing bamboo trees High competition of other species of trees used in construction sector;

Non-contiguous planting: many of the planted areas comprise of extremely small patches (less than 5 hectares), with each patch being located without any relationship to other planted areas. *Poor species choice:* low consideration has been given to site-species selection, and no consideration to species-product selection. The choice of species results in lower yields than could be achieved if the suitability of each specie was undertaken. Poor investment in the sector.	

Source: Clay Tech Audit survey, 2020

The above SWORT analysis is not exhaustive but indicative in nature as bamboo value chain is a very large business involving various stages. Therefore, it is open to further analysis at each stage of bamboo value chain for construction materials.

4. GENERAL CONCLUSION AND RECOMMENDATIONS

4.1. General conclusion

Bamboo remains an important and promising resource for construction materials in Rwanda. It has immense potential added value for development compared to many other forest resources. Moreover, as a plantation crop, bamboo has great prospects for advancing social forestry.

The focus should be on livelihood improvement and diversifying market opportunities. Rwandan are called to be very creativity and clearly have the ability to design, develop, and produce new bamboo applications for local markets and for export at each stage of bamboo value chain. The main actors include nursery operators, growers, processors, retailers (traders) and end-users. Additionally, the governmental agencies are also included in bamboo value chain actors as well as the researchers as they create conducive working environment in bamboo sector.

To be able to tap the existing potentials for development of the bamboo sector, it will be necessary for public and private sectors to recognize that bamboo is an important and valuable commodity and not merely a minor non-wood forest product to may be used to manufacturer a variety of products for construction purpose
It is evident that bamboo has an important role to play for Rwanda in the creation of employment opportunities, and enhancing construction industries. Bamboo can also contribute to environmental conservation by reducing pressure on dwindling natural forests. It is therefore critical that Rwandans embrace the development of bamboo as a natural resource and industrial commodity.

Moreover, there is a significant lack of understanding on bamboo's current classification and how to apply it under forestry law. The only information available is from the draft 2011 draft National Bamboo Policy, which was never approved. Few, if any, officers have dealt with bamboo for licensing so when presented with how to handle it, many are left guessing or apply standard forest harvesting licenses and fees. This is further demonstrated with some documents calling it a bamboo tree and others referring to bamboo forests, and yet bamboo in Rwanda still having an NTFP classification. Furthermore, the areas classified as state land in the public domain and state forests along rivers, lakes and roadsides are not regularly harvested while the income from them would help for their auto-maintenance.

Therefore, Rwanda's existing planted bamboo resource should urgently be put under a sustainable management regime if further mortality is to be prevented. If done so and commercialized targeting industrial products, this existing and available resource has the potential to kick start industrial manufacturing for the country and generate support and interest in bamboo. Commercialization of this resource should target manufacturing technology that is innovative, clean, and can launch Rwanda globally as a green economy.

Though a strong focus by the Government of Rwanda was put on landscape restoration, promoting green industries and poverty reduction by creating a positive framework for the advancement of a green economy, these would be supported by promotion of made in Rwanda products for a low carbon and increase of exports including bamboo products, exploration of import substitution through domestic low carbon industrial growth and supporting small industries that supplies domestic needs. These will help to develop in Rwanda the advanced technologies allowing the destruction of woody fibre and then the re-constitution through the binding of different forms of fibre strands, chips, particles or other forms along with suitable adhesives to create a composite board like MDF, Plywood or OSB. Moreover, this will require to conduct a systematic market analysis of bamboo-based construction materials at each stage of bamboo value chain.

4.2. General recommendations

It is against our recommendation to keep treating the bamboo industry for construction materials along its existing terms, which will only continue to lead to a focus on low value products. Therefore the following are recommended:

Improvement of designs, innovative use of bamboo should be the focus to upgrade the value of bamboo.

The industrial manufacturing units are recommended to be developed in Rwanda.

To move from using bamboo as trees only towards to production of more competitive products like MDF, roofing sheets, among others.

The Government of Rwanda make available attractive financing options and incentive schemes for private sector involvement in the sector. The proposed projects are unlikely to be attractive for private sector for foreign direct investment without a blended public and private finance strategy. If such financing is made available, the impact towards a green economy for Rwanda and the stimulation of domestic manufacturing is considerable.

Rwanda's existing bamboo resources to be enacted, clear clarification and policies on harvesting and other licenses for this resource, taking into account the unique attributes of bamboo not only to the environmental protection by also its commercial roles, are recommended.

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5. APPENDIX 1: QUESTIONNAIRE

5.1. Individual Questionnaire for the key actors

Introduction of interviewer to the respondent(s)

Greetings

My name is …………………………………We are here to collect information related to undertake technology audit of bamboo value chain for construction materials on behalf of ENABEL and NIRDA. The information you provide will help in better knowing the technologies in use in bamboo value chain for construction materials for better improving the sector. Moreover, the information provided will be kept confidential and only used for the purpose of this study. Thus, honest cooperation in this process is solicited for this purpose.

1. Identification of respondent

1.1. Province / City of Kigali:
1.2. District:
1.3. Sector:
1.4. Cell:
1.5. Village:
1.6. Name of enumerator:
1.7. Name of respondent:
1.8. Age of respondent:
1.9. Sex of respondent:
1.10. Marital status:
1.11. Education level:
1.12. Position of respondent:
1.13. Respondent's phone number:
1.14. Date of the survey:
1.15. Starting Time:
1.16. GPS coordinates:
1.17. Name of site/firm:

2. Identification of the firm

Question 2.1: Category of respondent

Choose	Yes	No
Nursery operators		
Growers		
Middlemen		
Processors		

Retailers/traders		
End users		

Question 2.2: Firm's category

Choose	Yes	No
Individual		
Micro scale firm (1 – 5 employees)		
Small scale firm (6 – 30 employees)		
Medium scale firm (31-100 employees)		
Large scale firm (above 100 employees)		

Question 2.3: Firm's legal status and registration

Choose	Yes	No
Sole proprietorship		
Cooperative		
Limited by shares		
Limited by shares and by guarantee		
Unlimited		
Partnership		

Question 2.4: Firm's ownership status

Choose	Yes	No
Private firm		
Public firm		
Mixed ownership (Private and public partnership)		
Owned by institution		
Any other (specify)		

Question 2.5: The origin of firm's owners

Choose	Yes	No
Rwandan		
Foreign		
Joint (Rwandan + foreign country)		
Others (specify)		

Question 2.6: Stage of the use of bamboo in the company/cooperative

Answers	Yes	No

Growing seedlings		
Transport& selling seedling		
Production of bamboo sticks		
Selling bamboo sticks		
Processing bamboo		
Transport products of bamboo materials		
Selling bamboo based cons. Materials		
Transport of bamboo based materials		
Use of bamboo materials		
Any other (specify)		

Question 2.7: The quantity of bamboo value chain products

Answers	Number/Quantity in tons
Grow seedlings	
Sold Seedlings	
Sold bamboo	
Produced bamboo sticks	
Sold bamboo sticks	
Processed bamboo	
Sold bamboo based cons. Materials	
Transported of bamboo based materials	
Used bamboo materials	
Any other (specify)	

Question 2.8: The main activities undertaken on bamboo by the firm (tick the right answer)

Name products	**Producing**	**Selling**	**Transporting**	**Using**
1.				
2.				
3.				
4.				
5. etc				

Question 2.9: The main raw materials used in past 12 months in processing

	Estimated quantity
1.	
2.	
3.	
4.	
5.	

Question 2.10: The source of raw materials

Choose	Yes	No	If yes specify the country
Rwandan			
Foreign			
Joint (Rwandan + foreign country)			
Others (specify)			

Question 2.11: Quantity of raw materials used in past 12 months (write in appropriate place)

Name products	**Tones**	**Number**
1.		
2.		
3.		
4.		
5. etc		

3. Working conditions

	Yes	No
3.1. Do you have an appropriate cloths and protection to reduce/avoid accidents		
3.2. Do you have any insurance?		
If yes name it		

Question 3.3: Working schedule

	Number of working hours	Number of males	Number of females
Full time			
Part-time			
Occasionally			
Professional internship			
If any other (specify)			

Question 3.4: Number of workers

	Number of females	Number of males
Man-power		
Technicians		
Engineers		
Administration staff		
Sellers		
Drivers		

3.5. Qualification of staff

Choose	**Number of males**	**Number of females**
No schooling and do not know either to read or to write		
No schooling but know to read and write		
Primary school		
Lower secondary		
Upper secondary		
TVET		
University		
Interns from different schools/university		

Question 3.6: Working hours per day

Choose	**Yes**	**No**
Occasionally		
Less than 4 hours		
4 – 8 hours		
8 – 12 hours		
More than 12 hours		

Question 3.7: Working days per week

Choose	**Yes**	**No**
Occasionally		
1 – 3 days		
4 – 5 days		
5 – 7 days		

Question 3.8: Received incentive (possibility of more than one answer)

Choose	**Yes**	**No**
Fixed monthly salary		
Salary on done activities		
Trainings		
Getting insurance from firm's owner		
Bonus		
Any other (specify)		

Question 3.9: Employee monthly income for value chain actors

Choose	Yes	No
< 30,000		
30,000-100,000		
100,000-200,000		
Above 200,000		
Don't know		

Question 3.10: What is type of contract existing between the following in your company?

Choose	No contract	Verbal	Written	Other (specify)
Between the firm and employee				
Between the firm and trader/seller				
Between the firm and transporter				
If any other (specify)				

Question 3.11: If yes does the contract specify any of the following?

Choose	Yes	No	If yes mention number of employees with such contract
Length of agreement			
Delivery and payment conditions			
Duties and rights of each party			
Existence of sub-contracting			
Conflict resolution methods			
If any other (specify)			

Question 3.12: Number of Partners we work with in the value chains (Upstream and downstream)

Choose	Number
None	
My firm and nursery growers	
My firm and stakeholders	
My firm and processors	
My firm and trader/seller	
My firm and transporter	
If any other (specify)	

4. Available technology

4.1. Name the key activities are you undertaking during bamboo nurseling

Activities	Frequency
None	
1.	
2.	
3. etc	

4.2. Name the key activities are you undertaking during bamboo growing stage

Activities	Frequency
None	
1.	
2.	
3. etc	

4.3. Name the key activities are you undertaking during bamboo processing stage

Activities	Frequency of manual activities	Frequency of automated activities	Frequency of semi-automated activities
None			
1.			
2.			
3. etc			

4.4. Name the key materials used during the following bamboo value chain stages

	Key materials used
None	
Bamboo nurseling	
Bamboo growing stage	
Bamboo processing stage	
Trading bamboo products	
Transporting bamboo products	
Using the end products of bamboo	

5. Productivity and financial data

5.1. (a) Quantity of production per year (Nursery operators)

Name the product	Quantity
1.	
2.	
3.	
4. etc	

5.1. (b) Quantity of production per year (bamboo growers)

Name the product	Quantity
1.	
2.	
3.	
4. etc	

5.1. (c) Quantity of production per month (processors)

Name the product	Quantity
1.	
2.	
3.	
4. etc	

5.1. (d) Quantity of sold per month (retailers)

Name the product	Quantity
1.	
2.	
3.	
4. etc	

5.2. Matching needs and demand in construction materials

	% of my production/ delivery capacity compare to demand
Bamboo seedlings	
Bamboo trees	
Raw materials	
Processed products	

5.3. Types of standards followed

Choose	**Yes**	**No**
None		

Fixed by Rwandan legislation		
Fixed by client		
Fixed by company		
International standards		
If any other (specify)		

5.4. Sources of bamboo based manufactured construction products (traders)

Choose	**Yes**	**No**
Rwanda		
In EAC countries		
In African countries outside EAC		
Outside Africa		
Any other (specify)		

5.5. What are the main problems hindering the competitiveness of the products

Choose	**Yes**	**No**
Limited capital		
Cost of processing raw materials		
Patents and royalties cost		
Poor marketing		
Limited awareness on the size of the market		
Accessibility to the working area/road network		
Complicated environmental protection requirement		
Poor /limited technology		
High production cost		
High cost of manufacturing experts		
High competition		
If any other specify		

5.7. Invested capital by bamboo value chain actors

Choose	**Tick the right answer**
Less than 500,000	
Between 500,000 and 1,000,000	
Between 1,000,000 and 10,000,000	
Between 10,000,000 and 50,000,000	
Between 50,000,000 and 100,000,000	
More than 100,000,000	

5.8. Annual total firm's turn over (income)

Choose	**Tick the right answer**

Less than 500,000	
Between 500,000 and 1,000,000	
Between 1,000,000 and 10,000,000	
Between 10,000,000 and 50,000,000	
Between 50,000,000 and 100,000,000	
More than 100,000,000	

5.9. Does your company pay for any of the following expenses?

Choose	**Yes**	**No**
Land taxes		
Taxes for districts		
Taxes for Rwanda Revenue Authority		
House rent		
If any other (specify)		

6. Infrastructure and technologies in place
6.1. Infrastructure in place

Choose	**Yes**	**No**
Water		
Electricity		
Roads		
Warehouses		
Modern technology/machines (specify)		
Traditional equipment (specify)		
If any other (specify)		

6.2. Source of skills and knowledge used in performing daily duties

Choose	**Yes**	**No**
From working experience		
From trainings		
From schools		
Personal insights		
Guidance from my supervisors		
If any (specify)		

6.3: Assistance received by the following

Choose	**Yes**	**No**
Nursery operators		
Growers		
Middlemen		
Processors		
Retailers/traders		

End users		

6.4: Type of assistance received

Choose	Yes	No
Technical assistance		
Financial support		
Support for market access		
Support in research and development		
Any other (specify)		

6.5: Source of assistance received

Choose	Yes	No
From the Government of Rwanda		
From NGO		
From external partners in business		
From internal partners in business		
From donors		
Any other (specify)		

6.6. How are you identifying a bamboo product of good quality?

Choose	Yes	No
Using personal experience		
Laboratory test		
Using experts in the domain		
Using external consultants		
Using appropriate machine		
Internal R &D		
I don't know		
If any other (specify)		

6.7. Do you have any quality/ standards control system for the following

Choose	Yes	No	If yes specify
Bamboo seedling			
Bamboo trees			
Raw materials to be mixed with bamboo			
Processed products from bamboo			
Packaging materials			
Transport means			
Roads			

Houseware			
If any other (specify)			

6.8. What are quality/safety certificates or product certificates do you have?

Choose	**Yes**	**No**
Nothing		
Standardization mark (S mark)		
Environmental impact assessment certificate from RDB		
If any other (specify)		

6.9. What strategies did you take among the following to upgrade your business?

Choose	**Yes**	**No**
Nothing to do		
Comply with fixed standards		
Improving research and exploration component		
Improving the quality of our products		
Technology modernisation		
Capacity building of the staff		
Increase capital		
Regular quality control by competent experts		
Automation		
Invest in the new bamboo products		
Improving supervision in the firm		
Appointing technical staff		
Engaging in all process of value chain		
If any other (specify)		

6.10. Comparing the local products with external (imported ones) on quality and preference

Local products quality and preference by local customers compared with imported ones	More preferred	Equal	Less	Don't know
1.				
2.				
3.				
4.				

6.11. Comparing competitor of production Technology

Products	In Rwanda (local firm)			Outside Rwanda &Foreigner in Rwanda		
	Yes	No	Don't know	Yes	No	Don't know

Green technology						
Modern/efficient technology						
Bigger investments						
Any other specify						

6.12. Comparison of production cost and selling cost

List of commercialized bamboo products	Estimated production cost by unit	Selling price by unit	Selling price from outside product (on market)	Don't know
1.				
2.				
3.				
4.				

6.13. Make a list bamboo products do you pack.

Seedlings	Yes	No
Bamboo trees		
Bamboo sticks		
Processed bamboo materials		
Transported bamboo based cons. Materials		
Imported bamboo materials to be used for construction purpose		
Any other (specify)		

7. Environmental issues and ways to deal with them (For nursery operators only)

	Decreased	**No change**	**Increased**
7.1. Did you see any change in bamboo woodland areas for the past 12 months?			

	Yes	**No**
7.2. Are you aware of roles played by bamboo trees in environmental protection in this area?		
If yes mention them		

7.3. If yes choose among the following?

Choose	Yes	No
Maintenance of degraded land		
Erosion control		
Restores Organic soils		
Canopy cover		
Stabilizes stream/river banks		
Contribute to the biodiversity		
It protect rivers and water channels from siltation and sedimentation		
If any other (specify)		

7.4. How effective is the bamboo in the following compared to other plants playing the same role:

Choose	Not effective	Effective to some extend	effective	Highly effective
Maintenance of degraded land				
Erosion control				
Restores Organic soils				
Canopy cover				
Stabilizes stream/river banks				
Contribute to the biodiversity				
It protect rivers and water channels from siltation and sedimentation				
If any other (specify)				

7.5. Bamboo may be used to deal with climate change for the following reasons:

Choose	Yes	No
Increasing levels of soil organic carbon		
It captures and stores carbon dioxide		
It provides oxygen		
Don’t know		
Others (specify)		

5.2. FGD Guides for Processors

1. (a) Describe the main products do you get from bamboo……………………………….
…………………………………………………………………………………………
(b) Describe production process/technologies of each product?...
(c) How competitive local bamboo based products compared to imported ones?
…………………………………………………………………………………………
2. (a) What are the main challenges are you facing during production process?.......................
……………………………………………………………………………………….
(b) How are you proceeding to overcome them?..
………………………………………………………………………………………..
1. (a) What are the main raw materials are you using in your firm/industry?
………………………………………………………………………………………......
(b) What are the main challenges are you facing in getting raw materials and other supplies?
………………………………………………………………………………………..
(c) What are the strategies are you using to overcome them?
………………………………………………………………………………………..
2. What are recommendations are you giving to make your products competitive internationally?
…………………………………………………………………………………………...
3. (a) What are the environmental issues are you facing in production process?...............
…………………………………………………………………………………………..
(b) What are you doing to mitigate them……………………………………………
…………………………………………………………………………………………..

5.3. FGD Guides for nursery operators and bamboo growers

1. (a) How are you getting bamboo seeds of good quality?………………………………
…………………………………………………………………………………………….
(b) What are the main activities are you undertaking on bamboo until it is sold?……………
…………………………………………………………………………………………….
2. (a) Describe your main stakeholders …………………………………………………..
…………………………………………………………………………………………….
(b) What are the potential synergy with other actors to optimize the profit?
……………………………………………………………………………………………
3. (a) What are the main challenges are you facing in growing bamboo.....................................
………………………………………………………………………………………..
(b) What are you doing to mitigate them?...
………………………………………………………………………………………
4. (a) What are the environmental issues are you facing in growing bamboo................
………………………………………………………………………………………..
(b) What are you doing to mitigate them?…………………………………………………
………………………………………………………………………………………………..

5.4. KII Guides

1. What are the main bamboo products manufactured in Rwanda?……………………………..
2. How competitive are the national bamboo products on local and international market?…………………
3. What are the main technologies in use for processing bamboo in Rwanda?..............................
4. What are the sittings in place in Rwanda to promote bamboo products? ……………………….
5. (a) What are the technologies to import in Rwanda to enhance the sector
   (b) What are the advantages of each of those technologies? ……………………..
6. Describe the environmental and health issues caused by growing and processing bamboo in Rwanda if any?...
7. (a) What are strategies in place for environmental protection while growing and processing bamboo?...
   (b) How each strategy will be valuable in the Green Building Minimum Compliance system developed by RHA with GGGI vis a vis to CO_2 emission?..
8. How bamboo based construction products can be promoted in Rwanda?
9. Could you compare bamboo based products in terms of preference with other products which performing the same function?

5.5. List of Key Informants

Nº	NAMES	DISTRICT/Institution	POSITION	CONTACTS
1	BAVUGE Bernardin	KAYONZA	District Environment Officer	0788413796
2	KALINDA Vital	KIREHE	District Forest and Natural Resources Officer	0788454456
3	NSHIMIYIMANA Jean Claude	NGOMA	District Forest and Natural Resources Officer	0782042745
4	MUKUNZI Emile	BUGESERA	District Environment Officer	0788513177
5	HACINEZA Eugene	GICUMBI	District Environment Officer	0789766046
6	NAMUHORANYE Sylver	GATSIBO	District Forest and Natural Resources Officer	0783181571
7	MBONIGABA Claude	NYAGATARE	District Forest and Natural Resources Officer	0788586146
8	MUKAGISAGARA Eugenie	RWAMAGANA	District Forest and Natural Resources Officer	0788806224
9	NISHIMWE Rosine	NYARUGENGE	District Environment Officer	0788475973
10	Kabalisa Valens	Kamonyi	Environment officer	0788826134
11	Raj Fidele Habiyakare	Nyaruguru	Forestry and Naturel resource officer	0783118630
12	Ngizwenayo Annaclet	Kicukiro	Forestry and Naturel resource officer	0788250962
13	Mukamana Mupenzi M.Goretti	Muhanga	Acting Director of Agriculture	0788558945
14	Butera Martin	Huye	Environmental officer	0788579585
15	Dr. MUREKEZI Charles	Ministry of Agriculture and animal resources	Director General of Agriculture Development	0783008453
16	AHABWE Emmanuel	Ministry of Infrastructure	Affordable and Social Housing Engineer	0783466825
17	MANYIFIKA Marc	Ministry of Environment	Director General of Land, Water and Forestry	0788216588
18	MUGWIZA Telesphore	Ministry of Trade and Industry	Director of Industrial Development Unit	0782494406
19	KAGOYIRE Christine	Rwanda Development Board	-	-
20	Eng. Theodore DUSABIMANA	Rwanda Polytechnics, IPRC Kigali	Head of Civil Engineering Department	0788441130
21	ISHIMWE Grace	Rwanda Land Management and Use Authority	Head of department	0788874562

22	NGENDABANGA Jean Pierre	NIRDA	Technical support specialist	078853079
23	BIMENYIMANA Eraste	Rwanda Housing Authority	Property valuation specialist, ag. director of government assets management	0788439600
24	BUCAGU Charles	Rwanda Agriculture Board	DDG/RAB RUBIRIZI	0788305182
25	NINGABIRE Yves Bernard	MINALOC	DG	0788387998
26	MUHAYIMANA Janvière	RWAFA	Seed Processing and Storage Officer	0788682491
27	Mathias Spaliviero Edward Kyazza	ENABEL	Coordinator	
28	NSENGIYUMVA Jacques	REMA	Ag Director of Environmental Regulation and Pollution Control Unit	0786624431