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Sawnwood Substitution in Dar es Salaam, Tanzania and its Linkage to Environmental Conservation

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Abstract

There is an increased trend of global awareness and discussions on the contribution of building designs and materials in global warming and greenhouses gases emissions. The use of wood materials in the construction sector is also increasing hence linked to forest industries and conservation, building sector, global warming and global climate change. The construction sector contributes directly and indirectly to environmental degradation and greenhouses gases emissions. With the current global awareness on climate change and adaptation, the substitution of wood products in the construction sector in Tanzania is inevitable. Despite its significant growth, the substitution of sawnwood by different alternatives in Tanzania is not well examined. Therefore, this study forecasted the substitution of sawnwood for year 2016, 2021 and 2026 for Dar es Salaam using income elasticity of demand to explain the effects of these substitutions to the environment. The consumption of sawnwood in none storey buildings, medium category and high category buildings were 2.69 m^3, 3.1 m^3 and 5.3 m^3 respectively. In 2012, Dar es Salaam consumed a total of 8,706.9 m^3 of sawnwood for doors and window frames in about 2878 new buildings. Kinondoni district consumed 42.2%, Ilala district 34.8% and Temeke district 23% of the total sawnwood. The per capita sawnwood consumption for building in Dar es Salaam in 2012 was 2.7 m^3 while for aluminium was 46.2 m^2. Windows showed high substitution of sawnwood compared to doors with aluminium being the main substitute material. The forecasted per capita consumption of sawnwood and aluminium materials for buildings in 2026 was 3.4 m^3 and 86.8 m^2 respectively. Sawnwood consumption in none storey buildings is increasing as a results of high rate of urbanization and economic growth hence increased number of middle-income population which causes an increased demand and construction of houses for residential purposes. The increased demand for construction materials have negative impacts to the environment where these materials are harvested. We recommend further research on the effects of substitution of sawnwood and the promotion of lesser-known and underutilized sawnwood species to strengthen wood industry in Tanzania due to the current high demand of sawnwood and high substitution rates.

Keywords: Substitution effects; Sawnwood consumption; Income elasticity; Elasticity of demand; Construction sector; Building industry; Forest sector; Environmental conservation

Introduction

There is an increasing global awareness and discourses on the contribution of building designs and materials in global warming and greenhouses gases emissions [1,2]. The tastes, preferences and choices of building material should therefore consider these global interests, resource bases and the environmental effects for extracting and processing these resources [3]. Wood is one of the world's main construction materials which are widely used in housing and construction activities. It can be sawn longitudinally, with or without its natural rounded surface but also with or without bark to produce sawnwood [4]. The use of wood-based panels and other wood products in construction and building works have shown an increasing trend [5]. The increase use of these materials therefore gives a clear relationship between forest industries, building sector, global warming and climate change globally. The effects of wood products and alternative construction materials to the changing global climates are not well studied and examined. It is therefore important to understand the rates of substitution between wood and alternative materials and the amount of greenhouse gases that can be avoided as results of such a substitution [2]. Among other things, the main concern about the alternative construction materials is on how the wastes are being handled [3].

In Tanzania, the construction industry contributes significantly to the national economy. More than 10% of GDP comes from the construction sector and its contribution to employment is more than 9% of the total population [6,7]. Studies indicates that, the contribution of the construction industry in Tanzania for three consecutive years 2006, 2007 and 2008 were estimated to be 1,399,609/-, 1,641,741/- and 1,904,420/- TAS respectively [8]. The construction sector is one of the fastest growing sectors in the economy with an annual turnover of between 1.8 - 1.9 billion USD (Dailynews, 2011). The same study indicates that, the construction projects with a total value of 2.8 trillion TAS were registered in 2010, with building works accounting for half of the total value of the projects. The value of the registered building works amounted to 1.4 trillion TAS, civil works was 884 billion, specialists in electrical 231 billion TAS and electrical works 187 billion TAS (CRB, 2011). These studies also estimated that more than 60% of the government budget is expended on the construction sector. The growth rate of the construction sector increased between 12 - 15% in 2009/2010 compared to that of about 9% in 2008/2009. These changes in growth rate were attributed by an increase in the construction of

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residential and none residential buildings, roads, bridges and land improvement activities.

The rapid expansion of towns as results of high rate of urbanization and commercial activities indicate an imbalance between the amount of wood products supplied to consumers and the actual requirements [9]. Similarly, the emerging competition between wood products in the building and construction works with substitute materials like concrete, steel, plastic and aluminium may result into dwindling of wood markets [10]. High quality reconstituted wood based panels such as particle board, Medium Density Fiberboard (MDF) and Oriented Strand Board (OSB) are predicted to reduce the consumption of locally made wood materials from traditional forest industries due to differences in tastes, preferences and quality [10]. Forecasting the consumption of wood products under different driving forces is inevitable since many decisions for future development of the forestry sector will depend on the forces that influence the demand and supply of these wood products. The substitution of wood with none wood materials or with different species causes a shifting demand of these building materials. Replacement of wood framed ground floor system by concrete stab foundation and applications of roof trusses replacing sawnwood, plywood substituting sawnwood in roof sheathing and sub flooring are currently becoming common practices [11,12]. On the other hands, metal poles are replacing premature poles used in the formwork while aluminium is replacing timber in door and window frames. Consumers are also shifting into diverse species comprising of soft wood and lesser-known hardwood species that were previously underutilized and ignored [13-15].

The increase in demand for sawnwood in building industry depends on the efficiency of the wood industry and its ability to face competition from substitute materials. Despite the importance of the building sector in Tanzania, scanty information is available on future demand for wood products and its associated environmental consequences resulting from substitution by other materials. This information is useful to different stakeholders such as tree growers, timber traders, policy and decision makers at national and international levels. On the other hand, the understanding of substitute building materials may stimulate trades, promote local industries, contribute to environmental and forest conservation in the country. Therefore, the general objective of the study was to investigate substitution of wood products and forecast its consumption in the building industry in Dar es Salaam city, Tanzania. Specifically it aimed to estimate the present consumption of sawnwood products by the building industry, identify the types of sawnwood products and areas being substituted and the level of substitution in the building industry, identify factors underlying substitution of sawnwood products by other materials in the building industry, forecast future consumption of wood products by the building industry. The findings are expected to serve as a basis for promoting the use of wood products by construction companies, architects, designers and builders.

Methodology

Study area

Dar es Salaam Region is located between latitudes 6°36’ and 7° South and longitudes 33°33’ and 39° East. It is bordered by the Indian Ocean on the East and by the Coast Region on the other sides. Administratively, Dar es Salaam is divided into 3 municipalities, Ilala, Kinondoni and Temeke with 73 wards altogether. It has the total surface area of 1800 square kilometers of which 1393 square kilometers is land mass with eight offshore islands, which is about 0.19% of the entire area in Mainland Tanzania. Temeke (786.5 km^2) Municipality has the largest land surface area followed by Kinondoni (531 km^2) while Ilala (273 km^2) has the smallest area [16]. According to 2012 national census, Dar es Salaam had a population of 4,364,541 people. The Tanzania National Bureau of Statistics reported that the population was expected to rise to more than 6 million people by 2015 [16]. Dar es Salaam city accommodates about 40% of the total manufacturing industrial units in the country contributing to about 45% of Tanzania’s gross industrial manufacturing output [17,18]. The city is endowed with a major harbour and is considered to be an epicenter for manufacturing industry. The city attracts commercial and transportation activities from both formal and informal sectors. Increasing rates of unemployment and underemployment plays a great role in the growth of the informal sector and settlements.

Data collection

Data for this study were collected using questionnaires, one to one interviews as well as direct observation. Buildings from both residential and none residential areas were sampled to assess the amount of sawnwood and none wood building materials used for construction and the extent of substitution. Sampling was done with replacement depending on the availability of respondents and their willingness to respond. From each municipality, records of registered timber traders and furniture makers were obtained. Building contractors and architects were identified through registers obtained from their respective registration boards, while residential house constructors were identified at the building sites. The sample sizes were determined differently depending on the population of the target groups in these municipalities and the easy of accessibility. For small population comprising of building contractors and public sector organizations, sample sizes of 100% were considered to increase precision. In the large population comprising traders in building materials a sample size of not less than 30%. In each municipality a list of wards was prepared and 50% of wards from each municipality were sampled to ensure adequate representation of building categories. Buildings were sampled depending on their categories and the sample size ranged from 20-50% starting from lower to higher categories to increase reliability and precision.

Primary data were collected using questionnaires, data sheets, checklists and direct observation. Sawnwood and substitute materials used in building activities were assessed and the amount was estimated. Factors underlying sawnwood substitution were identified from non residential and none residential categories. Buildings into higher category, middle category and the lower category depending on the number of storeys. Semi structured questionnaires with open and closed ended questions were used to acquire quantitative and qualitative information. In these questionnaires data on estimates of sawnwood products and building substitution materials, factors underlying sawnwood substitution, species, uses, availability, sources, preferences and prices of sawnwood products and substitute materials were collected. Direct observation was employed during the survey and it enabled the researcher to see the extent in which the substitution of building materials was taking place. Information on consumption of sawnwood products, species used, and substitute building materials were captured and recorded in special data sheet. Key informants in this study were construction engineers, building contractors, house builders, forest officers, town planners, quantity surveyors, site inspectors and land officers. Personal interviews were conducted to acquire more information on quantities, type of permits, size of plots, and building permits issued for previous years. Secondary data on consumption of wood products, substitute building materials and factors underlying wood substitutions and consumption in the building sector were collected from the three municipalities of Ilala, Temeke and Kinondoni. Other secondary information was accessed from different documents available in the municipalities, official publications, reports and journals.

Data analysis

Both quantitative and qualitative data were, coded, checked and analyzed using Statistical Package for Social Sciences (SPSS) and MS-excel computer programme. Verbal responses from key informants were analyzed using content analysis to get the meaningful information. The output were summarized in a descriptive statistics such as frequency, mean and sums especially on the uses, availability, sources, preferences, of wood products and substitute building materials. The mean and sums of quantities of sawnwood products and substituted building materials consumed and prices were also obtained. Forecasting consumption of sawnwood and the substituted materials in the building industry were done. Forecasting for years 2016, 2021 and 2026 were performed using the model that fitted the collected data. Before using any model the forecasting techniques were evaluated to get the appropriate forecasting model. Basing on the previous consumption of sawnwood products in the building industry single moving average and single exponential smoothing models were used. Single moving average technique was chosen to compute forecast for future periods because it fits with the limited amount of data obtained from the study. Data requirement for application of single moving average are minimal. The accuracy of this method in computing forecast for future periods is low compared to single exponential smoothing which gives more weight to the recent observations. Forecasting using Income Elasticity of Demand model (IED) were performed to relate consumption of sawnwood to the population size, income (per capita GDP) and the rate of urbanization of Dar es Salaam city. Income elasticity of demand model was established first before obtaining the future consumption of sawnwood for Dar es Salaam city. The basic relationship included population sizes, incomes and rates of urbanization which were extrapolated to the targeted years. Population changes over targeted years were extrapolated by the formula below.

$P_t = P_o e^{rt}$ (1)

Where:

P_o = Previous population size

P_t = Population at time t in years

E = Base of natural logarithm (2.71828183)

r = Average annual population growth

t = Time interval in years between two periods

We made and assumption that, all the building permits issued by the three Municipalities in Dar es Salaam were implemented and no changes were made in those building plans.

Results and Discussions

Consumption of building materials for doors and windows

A total of 2,078.6m^3 of sawnwood and 23,965.3m^2 of aluminium materials were consumed by window frames and doors in 732 buildings (Table 1). On average, the lower category (none storey) buildings consumed about 2.7 m^3 of sawnwood per building while medium buildings (1-3 storeys) consumed about 3.1 m^3 per building. The higher building category with 4 or more storeys consumed about 5.3 m^3 of sawn wood per building. The difference in sawnwood consumption between lower building category and medium category is 6.4% while between medium and high building categories is 26.7%. Previous studies show that any amount between 0.5 m^3 and 6 m^3 of sawnwood per building unit would be a justifiable estimate [19]. However, this suggestion is mainly for none wood houses with only roof structures, doors and windows made of wood. On the other hands, the average aluminium consumption in the lower building category was be 24.8 m^2 and in medium building category was 69.0 m^2 while in the high building category averaged to about 134.2 m^2 per building. There are several environmental consequences accompanied to the high consumption of both aluminium and sawnwood. The increased use of sawnwood is linked to over exploitation of forest resources resulting into deforestation and land degradation hence the effects of global warming due to reduction of the carbon sink blanket. Other studies have documented that the high rate of consumption of alternative building materials other than sawnwood is associated with the increased greenhouse gases emissions to the atmosphere [1,3]. It is therefore important to research and understand the quantity consumed in each building and their contribution and into the process of global warming.

The per capita building sawnwood consumption in 2009, 2010 and 2012 were 2.6 m^3, 2.5 m^3 and 2.7 m^3 respectively. Per capita building consumption in 2010 was lower by 6% compared to the previous year and increased by 11% in year 2012 (Table 2). The average per capita consumption of sawnwood and aluminium per year was high in Ilala with 3.7m^3 of sawnwood and 65.2 m^2 aluminium from year 2009 to 2012 followed by Kinondoni with an average per capita consumption of 2.4 m^3 and 36.4 m^2 of sawnwood and aluminium respectively. Temeke consumed 1.9m^3 of sawnwood and 23.3 m^2 aluminium per capita per year. However, Kinondoni had the highest average consumption of total sawnwood consumed per year from year 2009 to 2012 consuming an average of 40.4% of total sawnwood consumed yearly. Ilala district consumed 36.3% of sawnwood and Temeke consumed an average of 23.3% of total sawnwood (Table 3). From year 2009-2012 Kinondoni had an average of 1.6% increase of sawnwood consumption each year while Ilala increased its consumption by 0.7% in the first two years and decreased by 2.6% in 2012. Ilala had the highest consumption of Aluminium from 2009 - 2012 compared to Kinondoni and Temeke. The average increase of Aluminium consumption in Ilala was 1.4% while in Kinondoni it was about 0.9% of aluminium indicating that Ilala had 0.5% more average increase of aluminium consumption each year compared to Kinondoni.

Consumption of building materials depends on the type of material used, architectural designs and size of the building and its associated parts. Among the 8973 assessed doors, 8760 (97.2%) consumed sawnwood and only 223 of the doors (2.8%) consumed aluminium materials (Table 4). The trend of consumption of sawnwood and aluminium materials in windows show that 10869 (65.1%) windows out of 16682 were made of sawnwood while 5813 windows (34.9%) were made of aluminium frames. The number of doors consuming sawnwood was high in the none storey buildings than in high building categories while the number of doors consuming aluminium was high in the high storey buildings. Sawnwood framed windows decreased significantly from none storey buildings to high storey buildings while aluminium framed doors showed a significant increase. The use of substitute building materials in doors increases from none storey buildings to high storey buildings with significant increase in window frames. None storey buildings consumed more sawnwood in doors and windows covering 99.9% and 73.5% respectively. In the

Building Category	Building units surveyed	Sawnwood consumption (m^3)	Sawnwood weighted m^3/building unit	Aluminium consumption(m^2)	Aluminium weighted m^2/ building unit
Lower(none Storey)	653	1756.6	2.7	16 170.1	24.8
Medium(1-3 Storeys)	43	131.6	3.1	2965.1	69.0
High(≥ 4 Storeys)	36	190.2	5.3	4830.0	134.2
Total	**732**	**2078.6**	**2.8**	**23,965.3**	**32.7**

Source: Field Data (2012)

Table 1: Consumption of sawnwood and substitute building materials in different building categories.

Building category	Sawnwood m^3/ unit	2009		2010		2012	
		Building units	Sawn wood m^3/year	Building units	Sawnwood m^3/year	Building units	Sawnwood m^3/year
Lower	2.7	1815	4882.3	1580	4250.3	1439	3870.9
Medium	3.1	790	2417.4	964	2949.8	1245	3809.7
High	5.3	121	640.1	86	454.9	194	1026.3
Total		**2726**	**7939.8**	**2630**	**7655.0**	**2878**	**8706.9**
Population		**3,040,118**		**3,118,132**		**3,194,903**	
Consumption(m^3) per capita (1000)			2.6		2.5		2.7

Source: Field Data (2012)
Note: Municipalities have indicated that between 30% -70% of buildings are in unsurveyed areas therefore no building permits were solicited. A correction factor of 50% was used to get the correct number.

Table 2: Per capita consumption of sawnwood in building units from 2009 - 2012.

DESCRIPTION	BUILDING		2009				2010				2012		
	MATERIAL	ILL	TMK	KNDN	TOTAL	ILL	TMK	KNDN	TOTAL	ILL	TMK	KNDN	TOTAL
Population		775,125	940,167	1,324,826	**3,040,118**	795,209	964,913	1358,004	**3,118,126**	815,313	988,809	1390,781	**3,194,903**
Total consumption	SW(m^3)	2913.5	1918	3108.3	**7939.8**	2860.1	1748.4	3046.5	**7655**	3026.3	2006.3	3674.3	**8706.9**
Percentage (%)		36.7	24.2	39.1	**100.0**	37.4	22.8	39.8	**100.0**	34.8	23.0	42.2	**100.0**
Per1000 capita													
consumption	SW(m^3)	**3.8**	**2.0**	**2.3**		**3.6**	**1.8**	**2.2**		**3.7**	**2.0**	**2.6**	
Total consumption	AL(m^2)	45,194.5	26,512.3	43,945.6	**11,5652**	48,889.3	22,190.6	46,056.9	**117137**	61,686.2	27,220.2	58,607.5	**147,513.9**
Percentage (%)		39.1	22.9	38.0	**100.0**	41.7	18.9	39.3	**100.0**	41.8	18.5	39.7	**100.0**
Per1000 capita													
consumption	AL(m^2)	**58.3**	**28.2**	**33.2**		**61.5**	**23.0**	**33.9**		**75.7**	**27.5**	**42.1**	

Source: Field Data (2012)
Note: ILL = Ilala, **TMK** = Temeke, **KNDN** = Kinondoni, **AL** = Aluminium, **SW** = Sawnwood

Table 3: Consumption of Sawnwood and Aluminium per district from year 2009-2012.

Building category	No of storeys	Sawn wood Doors assessed	Percent (%)	Aluminium framed Doors assessed	Percent (%)	Sawnwood framed windows assessed	Percent (%)	Aluminium framed windows assessed	Percent (%)
Low	0	6800	99.9	6	0.1	10 186	73.5	3676	26.5
Medium	1-3	837	90.1	92	9.9	328	27.4	869	72.6
High	≥ 4	1123	90.0	125	10.0	355	21.8	1273	78.2
Total		**8760**	**97.2**	**223**	**2.8**	**10,869**	**65.1**	**5813**	**34.9**

Source: Field Data (2012)

Table 4: The trend of consumption of sawnwood and aluminium in doors and windows in different building categories.

medium buildings category (1-3 storeys), 90.1% of the doors consumed sawnwood and the rest (9.9%) consumed aluminium materials. Most of the windows (72.6%) in medium category consumed aluminium materials while 27.4% consumed sawnwood. On the other hand sawnwood consumption in the highest building category covered 90.0% of doors with aluminium covering the remaining 10.0%. About 78% of windows consumed aluminium materials while 22% consumed sawnwood materials. Surveys revealed that aluminium materials are currently popular in the building industry compared to Poly Vinyl Chloride (PVC) as most of the substituted sawnwood doors and window frames in new dwellings and renovated buildings were made of aluminium. Steel were also observed during assessment but its abundance and substitution was low compared to aluminium materials. Sawnwood is being replaced by aluminium, steel, PVC and other materials depending on the intended use and location of doors and windows (Figure 1). Aluminium has taken the largest share (61%) in substituting sawnwood materials in the building and construction industry followed by steel -24% (Figure 2). Poly Vinyl Chloride (PVC) materials are described as one of the best and most appropriate materials for windows and doors and is economically cheaper than both sawnwood and aluminium.

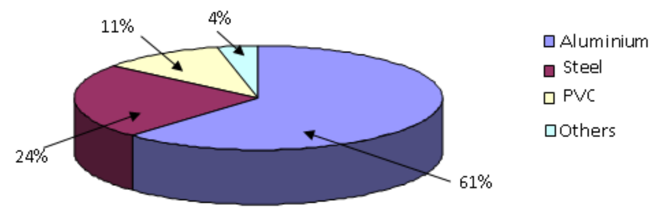

Figure 1: Building materials substituting sawnwood in doors and window frames.

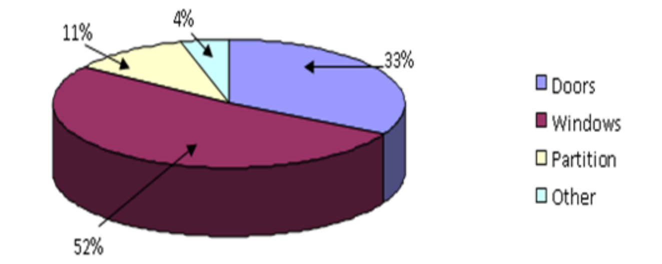

Figure 2: Preferences for aluminium substitution in construction activities.

Building contractors, architects and house builders revealed that aluminium is mostly preferred for windows followed by doors and partitions (Figure 2). Majority of the respondents (52%) mentioned that aluminium is preferred and mostly substituted in windows and some few in doors indicating that aluminium materials are mostly used to replace sawnwood in windows compared to doors and partitioning works. Only 4% of the respondents said that aluminium materials are being used to replace sawnwood sections other than windows, doors and partition. The substitution of these materials is directly linked to many factors including price, quality, availability and durability. It is therefore important for traders to ensure good quality products to guarantee the market for sawnwood products in the country.

About 46% of the respondents revealed that the rate of substitution in doors ranges between 0-25% meaning that aluminium was less preferred in doors while about 38% asserted that substitution ranges from 26-50% and 17% stated gave the highest range (Table 5). The highest substitution percentage range estimates in windows was 52% followed by 26% implying that aluminium was mostly preferred in windows compared to other parts. It is also revealed that, aluminium materials are less preferred for partitioning as few respondents mentioned this during interviews. About 35% of the assessed windows in buildings consumed aluminium while only 3% of the assessed doors consumed aluminium. This support the narration by some key informants that more than 50% of the people prefer aluminium materials for windows compared to doors and partitioning. Furthermore, majority (70%) of the people had the opinion that availability of aluminium was abundant in Ilala, Kinondoni and Temeke municipalities and only 26% mentioned that the materials are scarce.

Experience from the field indicate that the availability of aluminium in Dar es Salaam market is high but the future supply may be uncertain due to high demand and extension of market and number of customers in other regions but is not evident to what extent the upcountry market for aluminium will grow in future. The report provided by construction registration board in 2011 indicated that among 2635 building contractors country wide, about 1040 (nearly 40%) building contractors are based in Dar es Salaam. Moreover, more than 300 commercial and residential construction projects each with a value of more than 2.1 billion TAS (Tanzanian Shillings) were implemented in the same financial year in Dar es Salaam. The largest project in this city was a commercial building by the Public Services Pension Fund (PSPF), worth more than 100 billion TAS (pers. comm). Field observation showed that many projects were implemented at the city center and mostly being commercial multi-storey buildings made by none wood materials including aluminium and glasses.

For residential buildings, 64.3% of the interviewees revealed that the rate of substitution ranged between 0-20% implying that in residential buildings sawnwood are still being used in large quantities compared to commercial and office buildings (Table 6). In commercial buildings, 42% of those interviewed stated that sawnwood substitution range between 61-80% while 27% thought that the rate of substitution was about 41-60%. On the other hand, about 54% of the interviewee showed that sawnwood substitution in office buildings is low compared to commercial buildings but a bit high when compared to residential buildings (range between 21-40%). The extent of sawnwood substitution in commercial, residential and office buildings also differ depending on the regulations and the use of the building. The corresponding responses from building contractors, architects and house builders on what type of buildings will sawnwood substitution likely to occur showed that commercial buildings were leading in sawnwood substitution by high percentage range compared to residential and office buildings. In order to assess sawnwood substitution in different building categories respondents estimated their percentage ranges of substitution to the three categories of buildings which aimed to provide a general picture of what is happening in the building industry with regard to sawnwood substitution by other building materials.

The majority of respondents (93%) revealed that substitution of sawnwood by non-wood building materials in none storey buildings and medium class categories (1-3 storey buildings) were very low (Table 7). In the high-class category about 65.2% of the interviewee asserted that the substitution was high (41–60% range). The percentage estimates from different stakeholders on probable substitution range increased as the number of storeys increased and therefore sawnwood substitution by other building materials is estimated to increase from none storey buildings to high storey buildings. These results similar trend as those reported previously in Table 4.

Type	Doors	Windows	Partitions
Range (%)	Frequency and Percentages		
0 - 25	51 (45.5%)	7 (6.3%)	108 (96.4%)
26 - 50	42 (37.5%)	18 (16.1%)	4 (3.6%)
51 - 75	0 (0.0%)	58 (51.8%)	0 (0.0%)
76 -100	19 (17.0%)	29 (25.8%)	0 (0.0%)
Total	**112 (100%)**	**112 (100%)**	**112 (100%)**
Source: Field Data (2012)			

Table 5: Preferences and application of aluminium materials.

Type	Residential	Commercial	Offices
Range (%) Frequency and Percentages			
0-20	72 (64.3%)	15 (13.4%)	33 (29.5%)
21-40	26 (23.2%)	18 (16.0%)	60 (53.6%)
41-60	7 (6.3%)	30 (26.8%)	18 (16.0%)
61-80	7 (6.2%)	47 (42.0%)	1 (0.9%)
81-100	0 (0.0%)	2 (1.8%)	0 (0.0%)
Total	**112 (100%)**	**112 (100%)**	**112 (100%)**
Source: Field Data (2012)			

Table 6: Sawnwood substitution in the building industry in Dar es Salaam.

The use and availability of sawnwood products in building industry

The building industry uses both hardwood and softwood in different activities. Building contractors, architects and house builders revealed that both sawn hardwood and softwood are being used extensively (Table 8). Among the 112 respondents, only 11% preferred sawn hardwood and 9% preferred sawn softwood while 77% preferred both softwood and hardwood for building and construction activities. Most of the customers use sawn hardwood in window frames and doors while softwood are mostly used for roofing, joinery, rafters and scaffolding. Field observation indicated that all sawnwood window frames and doors were found to be constructed using sawn hardwood. *Afzelia quanzensis* and *Pterocarpus angolensis* were the main species used in window and doors frames because of their strength, durability and resistance to termites.

Most of the sawnwood sold in Dar es Salaam originates from other regions including Lindi, Mtwara, Morogoro, Rukwa and Tabora. About 47% of the interviewed building contractors purchased sawnwood in the city depending on the availability while 36% of building designers and consultants obtains hardwoods locally in Dar es Salaam markets. However, 52.4% of the house builders purchases sawn hardwood from other regions. Previous reports show that the main sources of hardwood timber mostly *Pterocarpus Angolensisis* marketed in Dar es Salaam were the miombo woodland in Tabora and Rukwa regions, coastal forests such as Kilwa and Lindi regions, and some pockets of forests in highland areas of Morogoro and Tanga regions [20]. Other reports show that, almost 90% of hardwood timber in the local market in Dar es Salaam are obtained illegally and the government is losing massive revenues due to the malpractice as a result investors are using imported timber from the Democratic Republic of Congo, Ivory Cost and Mozambique. This illegal harvesting tends to cause detrimental effects to the conserved forests and the environment in general (Table 9).

Sawnwood preference and demand in building industry in Dar es Salaam

The demand for sawnwood in building and construction industry showed an increasing trend (Table 10). This trend was also revealed by building contractors (77 %), architects (56%) and house builders (67%). Increased demand of sawnwood in Dar es Salaam is accelerated by the rapid increase in population currently estimated to be about 5 million people (NBS, 2012). The demand for sawnwood demand is a derived demand because it depends on the demand of other goods and sectors. Therefore, the demand for sawnwood is a function of activities in different sectors that use sawnwood materials. The increased demand for sawnwood tends to increase price which motivate illegal harvesting. Increasing illegal harvesting of timber and sawnwood products have negative effects to the forest resource base. To maintain the forest resource bases needs a strong and clear policy on forest industries, products and trade. Although the substitution of alternative materials may be good to forest conservation but the impacts of the alternative materials to the environment may be unknown but severe. The environmental effect of these materials depends on how the residuals are disposed and the life span of the materials [3].

Building and construction industries are considered as demand drivers of sawnwood in the market because they save as a basis for building and construction activities. In estimating the demand and market power of the firms dealing with sawnwood markets, factors that affect the number of new constructed buildings or houses include economic activities, demographic factors such as birth rate and the rate of immigration in the communities [21]. Anecdotal evidences and field observation indicates that these factors are contributing significantly in the growth and expansion of the construction sector in Dar es Salaam. The positive changes in these factors will continue to cause an increase in demand of both sawnwood and alternative construction materials in Dar es Salaam. The increased consumption of these materials need to be controlled or rather may have negative impact to the environment.

Sawnwood prices in Dar es Salaam

The prices of sawnwood in Dar es Salaam differed depending on the species and quality of wood. Hardwood species were sold at higher prices compared to softwood species (Figure 3). However, during field survey it was observed that there were few species of sawnwood hardwood such as *Pterocarpus angolensis, Afzelia quanzensis, Milicia excelsa, Podocarpus spp* and *brachystegia spiciformis* in the market. In year 2012 *Pterocarpus angolensis* and *Afzelia quanzensis* had the highest real prices compared to *Brachystegia spiciformis* and *Podocarpus spp*. From 2004-2012 the real prices of each sawn hardwood species increased significantly. The real price of *Pterocarpus angolensis* from 2004-2008 rose by 32% (740000–983000 TAS per m^3 equivalent to USD 925-983 per m^3) but in 2008 to 2012, the real prices rose by 43%

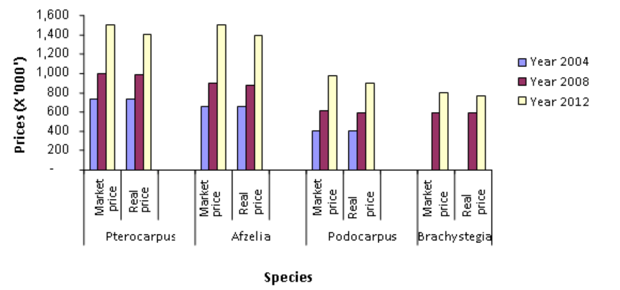

Figure 3: Real and current market prices of hardwood species in Dar es Salaam Market.

Type	None-storey buildings		1-3 Storey buildings	>3 Storey buildings
Substitution (%) Frequency and Percentages				
Very Low (0-20)	104 (92.9%)		5 (4.5%)	0 (0%)
Low (21-40)	8 (7.1%)		82 (73.2%)	5 (4.5%)
Moderate (41-60)	0 (0.0%)		24 (21.4%)	73 (65.2%)
High (61-80)	0 (0.0%)		1 (0.9%)	34 (30.3%)
Very High (81-100)	0 (0.0%)		0 (0.0%)	0 (0.0%)
Total	**112 (100%)**		**112 (100%)**	**112 (100%)**
Source: Field Data (2012)				

Table 7: Percentage estimates for sawnwood substitution in different building categories.

Item	Building contractors		Architects		House Builders	
			Frequency and Percentages			
	Number	%	Number	%	Number	%
Don't know	2	6.7	0	0	2	9.5
Hardwood	3	10.0	8	13.1	1	4.8
Softwood	2	6.7	6	9.8	2	9.5
Both	23	76.7	47	77.0	16	76.2
Total	**30**	**100**	**61**	**100**	**21**	**100**
Source: Field Data (2012)						

Table 8: Sawnwood preferences by different end users.

Item	Building contractors		Architects		House Builders	
	Number	%	Number	%	Number	%
Sawnwood Availability	**Frequency and Percentages**					
Hardwood is abundant	5	16.7	20	32.8	3	14.3
Hardwood scarce	14	46.7	26	42.6	6	28.6
Hardwood is very scarce	11	36.7	15	24.6	12	57.1
Softwood is abundant	24	80.0	38	62.3	17	81
Softwood is scarce	5	16.7	14	23.0	3	14.3
Soft wood is very scarce	1	3.3	9	14.8	1	4.8
Total	**30**	**100.0**	**61**	**100.0**	**21**	**100.0**
Source: Field Data (2012)						

Table 9: Sawnwood availability in Dar es Salaam.

Item	Building contractors		Architects		House Builders	
	Frequency and Percentages					
Sawnwood demand	No	%	No	%	No	%
Increasing	23	76.7	34	55.7	14	66.7
Decreasing	3	10.0	10	16.4	2	9.5
Constant	4	13.3	17	27.9	5	23.8
Total	**30**	**100**	**61**	**100**	**21**	**100**
Source: Field Data (2012)						

Table 10: Sawnwood demand in building and construction industry in Dar es Salaam.

which is an increase of about 11% compared to the previous period. The real prices for *Afzelia quanzensis* rose by 36% from 2004-2008 and by about 58% from 2008-2012 which is about 15% more compared to *Pterocarpus angolensis* in the financial years 2008-2012 indicating that the value and uses of *Afzelia quanzensis* and *Pterocarpus angolensis* in the building industry has risen significantly in recent years. During site visits, it was revealed that most of the building contractors used *Afzelia quanzensis* species for doors compared to *Pterocarpus angolensis* with the reason that the former is often available in the market than the later. According to the data from the Bank of Tanzania, the inflation rates for the year 2004, 2008 and 2012 in the country were 4.1%, 6.7% and 12.7% respectively (pers. comm). The comparison of price index showed a slight difference between real and market prices of the sawnwood species.

The sharp increase of prices of sawn hardwood may be attributed by the increase in the logging costs, transport and the high inflation rates experienced in the country. The interviewed registered timber traders and end users mentioned that the prices of sawnwood are not stable, it may rise or fall within short period of time. Apart from availability, the fluctuation of sawnwood prices in recent years has been accelerated by inflation which raised the transportation costs of goods due to increased prices of fuel and spare parts. Anecdotal evidence shows that, most of the sawn hardwoods are imported from Mozambique. The government royalty fee per m^3 of timber doubled to 256000 TAS thus making it difficult for small scale carpentry factories to invest in timber trading. Some traders revealed that sawnwoods in Mozambique are being charged in dollars therefore the inflation of the Tanzanian shilling resulted into high sawnwood prices in Dar es Salaam.

Both timber traders and end users revealed that the instability in sawnwood prices is mainly due to the rise in prices of fuel and logs since transportation is associated with fuels (Table 11). They also claimed that frequent instability of prices are caused by distances from which sawnwood are being produced especially after banning logs production in Rufiji, Kilwa and Liwale districts. These arguments are in line with those given by other previous research findings [22,23].

Factors underlying sawnwood substitution and Aluminium doors and windows prices in Dar es Salaam

Product preferences are constantly changing due to new product innovation and changing consumer preferences. It also changes due to the global awareness on climate change and global warming issues. Previous studies have suggested to consider the global warming effects when designing the buildings and deciding the types of materials to use [2,3]. Other factors that could result into loss of market share for sawnwood products and the alternative materials included price, production cost, environmental impacts, maintenance cost and the quality of the product. Therefore, these factors and others not mentioned are underlying factors for substitution of sawn products in the building industry. Some of the factors mentioned by the interviewed stakeholders include fluctuating sawnwood prices, availability of sawnwood products especially sawn hardwood compared to substitute materials, emergence of new technologies that provides access to new design structures, appearance of substitute materials, quality and durability of the substitute materials. Increased supply of steel, aluminium, PVC and concrete industrial materials have also taken the market share of timber framing hence causing some market erosion and possibilities of some substitute materials replacing sawnwood. Experience from the field show that, it is not only aluminium materials that are substituting sawnwood in window and door systems but also plastic materials. Plastic frames construction is gradually gaining popularity in Dar es Salaam as some importers and manufactures were located in the city. PVC materials, readymade window and door frames for retail and whole sale are recently becoming common in Dar es Salaam. The marketing officer from one of the trading company explained that PVC material are not new in construction activities because they have been trading for many years and is now penetrating markets in developing countries including Tanzania. This to a large extent has been attributed by the globalization and technology advancement which gives people more choices and preferences for building materials. Several companies are now dealing with PVC products their offices are mainly in Dar es Salaam, Tanga and Arusha. However, the efficiency of PVC material depends on its plasticity and dimensional length. Some of the interviewed technicians revealed that PVC material deteriorates fast when exposed to the air for a long time compared to sawnwood, aluminium and other building materials.

The prices of doors and windows vary depending on the type of materials used, size, design and the amount of materials consumed. Window and door frames are commonly made using sawnwood, steel, aluminium and Poly Vinyl Chloride (PVC). Empirical evidences from the field indicate that doors and windows used in buildings have different prices depending on the sizes, species used, design, quality of sawnwood and location. Complex designs consume large amount of sawnwood compared to normal doors hence higher prices. From 2008 to 2012, outer doors were highly priced compared to inner doors

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because most of the outer doors are double in size and consumes large amount of sawnwood materials in shutters and frames (Figure 4). The doors were priced almost twice compared to window frames because doors constitute both frame and shutter. There was a very slight increase in the price of doors from 2008-2009 but with a significant increase from 2009 - 2012. The price of window frames showed a very small increase until 2012 where the rate of increase was high (38%) compared to 9% in 2010. Aluminium doors and windows have different prices depending on size and raw materials used. Like in sawnwood, aluminium also has both good and poor quality raw materials hence customers choose material that are affordable to them depending on their income and preferences. Aluminium doors and windows have extra charges including labour for fitting the door or window unlike sawnwood doors and window in which the charges are for the finished item. The price of aluminium window frame per square meter (TAS/ m^2) (Tanzania Assistance Strategy) ranges from 125000 to 142000 TAS depending on the quality of aluminium materials. An assessment on the window covering 2.1 m by 0.9 m revealed that windows with vent were charged about 300000 TAS and none vented windows were charged about 270000 TAS. It was further observed that for windows with clear mirror, the charges were 250000 and 270000 TAS for none vented to vented windows respectively. The prices varied from 300000 to 350000 TAS for standard inner doors while outer doors ranged from 550000 to 650000 TAS. The outer doors were mostly found in commercial buildings than office and residential buildings. Most of the doors identified in offices were inner doors covered with clear or tinted glasses. The majority of the visited carpenters in Dar es Salaam said that there is still a potential market for doors and window frames although the market fluctuate over time in terms of the number of customers.

An assessment on various commercial apartments in the city center revealed that many doors and windows are made by aluminium materials. Aluminium materials are preferred because they are more attractive and that it helps them to display their businesses for customers to easily identify what is inside their shops. As you move from the city center to peripherals the situation changes and most people tend to use sawnwood doors and windows strengthened by iron bars. This may be due to the fact that there are many customers in the city center where shops are concentrated and the market is competitive compared to peripheral areas where the population is small and higher risky for burglars. The prices for PVC windows and doors ranged from 98 dollars (150000 TAS) of door or window frame to 105 dollars (170000 TAS) per square metre. These prices include other items that complete the window or a door except fitting charges. Observations show that PVC windows and doors were priced high compared to aluminium. The prices were charged in dollars because businessmen preferred dollars which was stable compared to Tanzanian currency which fluctuated over time.

Forecasted substitution and consumption of sawnwood in Dar es Salaam

Population, economic attributes, urbanization and rural-urban migration are the main factors causing a high demand of forest products in Dar es Salaam. By using historical information of these factors, time series models are useful for performing the forecasting. The common time series models are the smoothing models which bases on the principle of averaging (smoothing) past errors by adding a percent of the error to the percent of the former forecast and Linear time series methods which require data with trend and systematic differences between the actual and the forecasted value (Wheelwright). Results obtained from time series model were compared with results obtained using other forecasting methods that fits the data and come up with real estimates of future sawnwood consumption. The results provided by smoothing methods do not show real estimates since the two methods (single average smoothing and exponential smoothing) provide less estimates compared to the current consumption (Table 12).

Income elasticity of demand model depends on the relationship between the present sawnwood consumption, income and population growth using income elasticity of demand. Using a single moving average and single exponential smoothing methods to forecast the consumption we found that 2.6 m^3 and 2.7 m^3 per 1000 capita sawnwood will be consumed in 2026 in Dar es Salaam. Income Elasticity of Demand (IED) model show that sawnwood per capita consumption in 2026 is estimated to be around 3.7m^3 (Table 13). The 2026 consumption

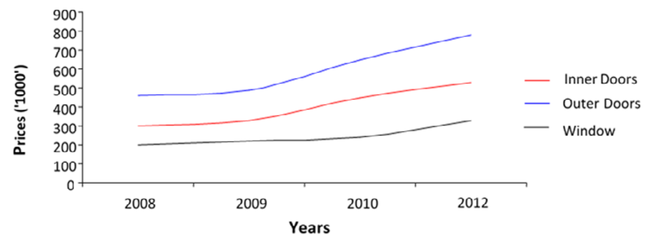

Figure 4: Sawnwood doors and windows prices.

Item	Timber Traders		Timber end users	
	Number	%	Number	%
Price instability	**Frequency and Percentages**			
Transportation	6	13.04	4	9.75
Rise in Fuel price	14	30.43	13	31.70
Distance from source	4	8.70	8	19.51
Rise in price of Logs	13	28.26	11	26.82
Logging ban	9	19.57	5	12.19
Total sample	**46**	**100.00**	**41**	**100.00**
Source: Field Data (2012)				

Table 11: Causes of price instability for sawnwood in Dar es Salaam.

Year	Time period	Observed values (per 1000 capita consumption) m^3	Single moving average (per 1000 capita sawnwood consumption, m^3)	Single exponential smoothing(per 1000 capita sawnwood, m^3) $\alpha = 0.1$
2009	1	2.61		
2010	2	2.46		
2011	3	2.73		
2012	4		2.60	2.61
2016	9		2.62	2.66
2021	14		2.62	2.69
2026	19		2.62	2.69
Source: Field Data (2012)				

Table 12: Forecasted consumption of sawnwood using different time series.

Type of Model	2012	2016	2021	2026
	Per Capita Sawnwood consumption in m^3 (X 1000)			
Single moving Average	2.60	2.62	2.62	2.62
Single exponential smoothing (α =0.1)	2.61	2.66	2.69	2.69
Income elasticity of demand	2.78	3.01	3.33	3.67
Source: Field Data (2012)				

Table 13: A summary of sawnwood consumption forecasts using different models.

estimates by IED future consumption forecast differed by 1.1m^3 per capita with Single moving average and differed by 1.0 m^3 (15.4%) with single exponential smoothing method. The income elasticity of demand of 1.2 indicates that change in income has a positive response on demand of sawnwood. In many developing economies, the building and construction activities, which consume substantial amount of building materials including sawnwood, tend to be inseparable with other sectors. Statistics show that, the economy of Dar es Salaam has been growing fairly fast compared to other regions contributing about 16% in the country's GDP (NBS, 2012). The demand for sawnwood is highly affected by income among other several factors. Previous studies established an Income Elasticity of Demand (IED) of 1.4 and 2.5 for Arusha region in the Northern Tanzania [14,24]. The current study shows that the income elasticity of demand for Dar es Salaam is about 1.2 which is lower than those reported from previous studies. Despite the difference, the obtained income elasticity of demand shows that the consumption of sawnwood and other substitute materials are highly dependent on income. These findings are similar to previous studies by Ngaga [24] and Machumu [14]. The world economic crisis and continued inflation of goods in the country between recent years and substitution could have slowed down the income per capita of the people in Dar es Salaam hence less demand and consumption of sawnwood than expected (Table 14).

It is estimated that at the end of 2026 about 364386 m^2 of aluminium will be consumed in the building activities in Dar es Salaam especially for windows and doors fittings (Table 15). This is an increase of about 216957 m^2 of aluminium building materials consumed between 2011-2026 in doors and window frames. It is an average of about 9.8% increase of building materials substituting sawnwood annually. In the next 15 years, per capita consumption of substitute building materials is estimated to rise from 46.2 m^2 to 86.8 m^2 of aluminium which is an increase of 88% [25]. This substitution considers only aluminium materials but there are other sawnwood substitutes emerging in Dar es Salaam city including PVC which may probably substitute both sawnwood and aluminium in some of the areas. Therefore, if these types of substitute building materials prevail in the market, the substitution of sawnwood may increase causing shifting of demand at different levels. The rate of substitution will depend on types and categories of buildings or the types of activities being undertaken. It is expected that most of the substitution will likely occur in commercial and office buildings with the assumption that the current situation will prevail in future. On the other hand, substitution in residential houses will depend on the income status of the people and other factors like availability and accessibility of the building materials. The current initiative through government agencies and parastatal organization in constructing residential houses will significantly reduce the consumption of sawnwood in general. Houses constructed by these agencies and organizations were observed to have more than 90% aluminium windows and few doors were made of aluminium unlike in the individual constructed houses especially non-storey buildings which most of their doors and windows were made of sawnwood.

The three models gave different results where by income elasticity of demand (IED) estimated the highest estimate (15406 m^3) compared to single exponential smoothing which amounted to 11293 m^3 while single moving average estimates were 10999 m^3 (Table 16). The IED has been argued to be the best model in forecasting the future consumption of sawnwood because it considers the population, income and current consumption which definitely changes over time. The consumption forecast of sawnwood for 2026 will therefore be 15406 m^3 showing that sawnwood consumption in windows and doors will increase by more than 75% from the current consumption of about 8707 m^3. The mushrooming commercial storey buildings in urban areas including Dar es Salaam will moderately increase sawnwood consumption in building industry in future. This therefore necessitates proper policies for the pricing and trading of both soft and hard sawnwood as well as the alternative construction materials.

2011 per 1000 capita sawnwood consumption	Population growth per year (%)	GDP growth per year (%)	GDP growth rate per year (per capita) %	Income elasticity (EID)	Per 1000 capita increase in consumption	Estimator	2012 (per 1000 capita) m^3	2016 (per 1000 capita) m^3	2021 (per 1000 capita) m^3	2026 (per 1000 capita) m^3
2.73	4.3	6.0	1.7	1.2	2.04	(1.02)	2.78	3.01	3.33	3.67
Source: Field Data (2012)										

Table 14: Sawnwood consumption forecast in building and construction industry for Dar es Salaam from 2012 - 2026.

2011 (Per capita consumption m^2)	Population growth per year (%)	GDP growth per year (%)	GDP growth rate per year (per capita) %	Income elasticity	Per 1000 capita increase in consumption	Estimator	2012 (per 1000 capita) m^2	2016 (per 1000 capita) m^2	2021 (per 1000 capita) m^2	2026 (per 1000 capita) m^2
46.17	4.30	6.00	1.70	2.50	4.25	1.043	48.2	57.0	70.3	86.8
Total consumption forecast (m^2)										
							1,47,513	**2,02,635**	**2,72,553**	**3,64,386**
Source: Field Data (2012)										

Table 15: The Forecasted consumption of aluminum using Income Elasticity of Demand (IED).

Forecasting model	2016			2021			2026		
	Per 1000 s/w consumption, m^3	Population (000)	Total s/w consumption m^3	Per 1000 s/w consumption, m^3	Population (000)	Total s/w consumption m^3	Per 1000 s/w consumption, m^3	Population (000)	Total s/w consumption m^3
Single moving average	2.62	3555	9314.10	2.6	3877	10157.7	2.6	4198	10998.8
Single exponential smoothing α = 0.1	2.66	3555	9456.30	2.7	3877	10429.1	2.7	4198	11292.6
Income elasticity of demand	3.01	3555	10700.5	3.3	3877	12910.4	3.7	4198	15406.7
Source: Field Data (2012)									

Table 16: Forecasted total sawnwood consumption using different forecasting models.

Conclusions and Recommendations

Sawnwood is considered environmentally friendly and better alternative for construction purposes in Tanzania. Its extraction however is directly linked to environmental damages and degradation due to increased pressure to forest resources. In the construction and building industry, sawnwood is much consumed in none storey buildings and its consumption per building unit is minimal in the high storey buildings. For both none storey and storey buildings, sawnwood consumption is high in doors than in window frames. Sawnwood substitution is greatly taking place in storey buildings compared to none storey buildings with more substitution in window frames than doors. Durable sawnwood species are becoming more scarce hence predicting high substitution rates in the future. The fluctuation of sawnwood prices, dwindling availability of sawnwood products especially for hardwood species, emergence of new technologies, quality and durability of the substitute materials are among the factors enhancing the substitution of these materials. The consumption of sawnwood in Dar es Salaam will keep increasing with aluminium being a dominant substitute building materials. However, the environmental effects of these aluminium materials have not been established especially at this era where the impact of global warming and climate changes are enormous.

Durable timber species takes long to mature, the promotion of commercially unknown and underutilized sawnwood species in order to meet the existing demand of sawnwood in the country is recommended. More research on strength properties, resistance to weather and durability on lesser-known species are required. Researchers should also provide this information to architects, building contractors and other consumers for future consumption. Promoting substitute-building materials is important for conservation purposes and reducing pressure on the existing forests as results of a high demand of sawnwood. This study covered sawnwood consumption and substitution in windows and doors and its link to environmental conservation in Dar es Salaam city only, more researches on sawnwood consumption, substitution and the effect to the environment in the entire building and construction sector is necessary for future development of forest sector in Tanzania.

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