

論	文
Article	

Adoption of Woody-biomass Briquettes for Forest Conservation in Northern Tanzania

By

Christian Paul KOLONEL*, Satoshi YOSHINO**[†] and Takayoshi SATO**

(Received May 16, 2024/ Accepted September 13, 2024)

Summary : In response to the continued loss of forests in Tanzania, two strategies are mainly applicable: enhancing the conservation of forest resources and developing ways to efficiently utilize the scarce resources. We carried out a study to establish the status of briquettes production and utilization, and analysed the conditions under which briquette projects have been implemented in the northern part of Tanzania. A field survey was implemented in Arusha and Kilimanjaro regions whereby data were collected using a questionnaire with open and close-ended questions. Our results indicate that production and utilization of briquettes is implemented by various adopters, ranging from sole individuals to corporate organizations both from private and public sectors. We found that adoption of briquettes is linked to a multitude of factors, all of which are associated with the main objective of adoption and the type of end-use; that is whether firewood or charcoal is being substituted. Such factors are related to enhancing communities' social welfare, economic gains and or environmental concerns. In our study, individual producers, corporate producers (NGOs), and business companies rely heavily on matters related to social welfare, environmental issues, and economic objectives respectively. At utilization level, business companies focus more on economic gains, government agencies (schools and training institutions) on social welfare, while individual and corporate consumers are more driven by environmental issues that are linked with the overdependence on charcoal and firewood. To achieve forest management objectives through development of alternative energy, briquettes in this case, subsidies and funding need to consider and intergrate all three aspects of sustainability to address social needs, economic perspectives and environmental concerns.

Key words : Briquettes, woodfuel substitution, briquetting technologies, deforestation, Tanzania

1. Introduction

About half of the wood extracted from forests worldwide is used to produce energy for cooking and heating, whereas Africa uses ten times as much energy to cook similar amounts of food than other regions which use modern technologies (1). High reliance on woodfuel (charcoal and firewood) in Tanzania continues to put pressure on forest conservation, ultimately affecting social welfare,

economic development and forest conservation measures. While the forested land area accounts for 48.1 million hectares (2), two million tons of charcoal are consumed annually in Tanzania (3). The overdependence on forests accelerated by unsustainable and illegal woodfuel production in the form of charcoal and firewood has been quantitatively found to cause degradation and loss of forests. A study by Kaale (4) found that 100,000 to 400,000 hectares and 20,000 hectares of forests per year are lost

* Department of Forest Science, Graduate School of Agro-Environmental Science, Tokyo University of Agriculture

** Department of Forest Science, Faculty of Regional Environment Sciences, Tokyo University of Agriculture

[†] Corresponding author (E-mail : sy202075@nodai.ac.jp)

due to charcoal and firewood production respectively. Similarly, WWF (5) reported an annual loss of 121,061 hectares of forests due to charcoal production, while on the other hand 100,000 to 125,000 hectares of forests were lost in 2009 (6). Furthermore, an estimated 33% of deforestation caused by charcoal production was reported by (7), while 469,420 hectares of forests were lost in Tanzania between 2002 and 2013 (2). Even though much of the deforestation takes place in the natural forests, man-made forests have a vital role in minimizing such alarming rates of deforestation.

The alarming rate of forest losses in Tanzania calls for urgent and immediate response at all levels from individual, family, schools, companies, corporate and at government levels. Immediate responses need to be in place for the following strategies : i) enhance forest resources conservation ; and ii) efficiently utilize the scarce forest resources. With regard to enhancing forest resources conservation, the protection of natural forests by creating more artificial forests has been steadily developed. Although the problem cannot be resolved immediately, it is being gradually implemented. For example, more commercial forests are being developed in the southern part of the country, where forest resources are abundant and there are few restrictions. In the north, while there are many places to preserve national forests, including national parks, there are few commercial forests in the northern part of Tanzania.

Regarding efficient resource utilization, there is a growing need for efficient use of scarce resources due to a continued loss of forests. For a number of years, dissemination and installation of improved cookstoves (ICSs) through a number of projects have been implemented to promote efficiency in the woodfuel sector (8). Even though it remains as a relative term, improved cookstoves are regarded as having a reasonably high efficiency of woodfuel combustion. In Tanzania, the reference has always been the open fire to ascertain how improved ICSs are. To-date, ICSs projects have been highly focusing on communities living adjacent to natural forests with the aim of attaining minimal woodfuel combustion through improved burning efficiency (9). Despite the fact that ICSs are limited to woodfuel demand side, the adoption of ICSs has not attained wide coverage, the reasons being similar to technical, socio-economic and cultural factors highlighted by Manibog (10). Gladstone et al. urges that developing new methods of fuel production as op-

posed to only new methods of fuel consumption is a more flexible means to enhance efficient and improved energy technologies (8). However, specific locations with regard to the type of woodfuel need to be considered, since much of the charcoal for example is consumed in urban areas, compared to firewood, which is highly consumed in rural areas (11). At least 80% of charcoal in Tanzania is consumed in urban areas while more than 80% of firewood is consumed in rural areas, near forests which obviously are far from the cities and towns.

The Tanzania National Charcoal Strategy and Action Plan (NCSAP) 2021-2031 on the other hand aims to strategically address the issues of limited production and use of alternative charcoal (briquettes in this context) accelerated by over-dependence on woodfuel in the country. In line with the strategy, directives mostly in the form of verbal statements have been issued to the public in efforts to halt the adverse impacts of unsustainable woodfuel exploitation of natural forests. As one of the alternative energy sources, we therefore focus on briquettes made of solidified forest biomass in the form of wood residues. Briquettes are classified into two types : those that harden without carbonization, known as non-carbonized briquettes ; and those that harden after carbonization, known as carbonized briquettes. In other words, carbonized briquettes are called charcoal briquettes.

Production and utilization of briquettes in Tanzania represents a new and emerging technology aimed at providing woodfuel substitutes/alternatives to save trees which would have been deliberately cut for woodfuel production. However, there is lack of evidence of fuel substitution between fuelwood and agricultural fuels (12). Substitution of briquettes for woodfuel entails partial or total transition from traditional fuels (charcoal and firewood) by adopting the use of briquettes for similar applications (cooking and heating in this context). Despite the potentials that may be harnessed from briquettes production/utilization, data and records of briquettes industries are lacking and difficult to establish. Neither official production volumes nor amount of briquettes consumed are known. Among the reasons for the lack of data is the isolated nature of briquetting industries ; short-term project based briquetting interventions ; short-time span of the briquetting activities since established due to financial, technical, and socio-cultural challenges as pointed out by Mwampamba et al. (13).

On a field basis, the positive outcomes of briquettes

production/utilization is dependent on the rate and extent of adoption, which further depends on the sustainability of briquetting technologies, reflected by their environmental acceptability, economic viability and social acceptability. However, less is known in the scientific literature to shed light on the status of briquettes adoption in Tanzania. Neither the determinants for briquettes acceptance nor factors accelerating and incentivizing briquettes adoption are documented, given the underlying status of woodfuel. We focused on four types of fuel : firewood, charcoal, non-carbonized briquettes, and carbonized briquettes. Ascertaining the conditions of briquettes production/utilization is important in order to clarify the direction of forest management for efficient utilization.

2. Methodology

Basic information about Tanzania

Located in the eastern part of Africa between 1° and 12°S latitude and between 29° and 41°E longitude at an altitude between 358 metres and 5,950 metres above sea level, Tanzania has a total area of 945,087 square kilometers. It has 888,600 square kilometers (94%) of total land area ; of which agricultural land covers 44.62% ; arable land accounts for 15.24% ; and forested area accounts for 51.64% as percentage of total land area.

The total forested land covers 48.1 million hectares, of which protected and production forest covers 28.09 and 20 million hectares, (58.04% and 41.6% of all forests) respectively (2). The 2009–2014 national forest inventory revealed that Tanzania had a total wood volume of 3.3 billion cubic metres, 97% from trees of natural origin and 3% from planted trees. While half of Tanzania's total wood volume is found in protected areas, the standing volume of wood per capita was estimated at 74.4 cubic metres. Moreover, the average demand for wood was estimated at 1.39 m³/year/capita while the Annual Allowable Cut (AAC) was 0.95 m³/year/capita, with a growing stock of 125 m³/ha and 48.8 m³/ha for natural forests and mangroves respectively (14). Commercial forest plantations account for 325,000 hectares (15), largely composed of conifer species, mainly of pine. Common tree species found in natural forests in order of abundance are *Diplorhynchus condylocarpon*, *Combretum zeyheri*, *Brachystegia spiciformis*, *Combretum molle*, *Julbernardia globiflora*, *Brachystegia boehmii*, *Dichrostachys cinerea*, *Pseudolachnostylis maprouneiolia*, *Combretum sp*, *Grewia sp*, *Gre-*

wia bicolor, *Commiphora Africana*, *Acacia sp*, *Commiphora sp*, *Markhamia obtusifolia*, *Uapaca kirkiana*, *Terminalia sericea*, *Brachystegia longifolia*, *Diplorhynchus mossambicensis* and *Dalbergia species*. On the other hand, the most important plantation species are *Pinus patula*, *Pinus elliottii*, *Pinus caribaea*, *Cupressus lusitana*, *Eucalyptus Saligna*, *Eucalyptus maidenii* and *Tectona grandis* (2).

Current status shows that total forest plantation area is estimated at 583,691 hectares, of which planted area under Tanzania Forest Services Agency (TFS) is 117,864 hectares. Planted forest area under large private plantation companies and individual woodlots is estimated at 50,827 hectares and 415,000 hectares respectively (16). Wood production from Central government and Natural forests is estimated at 1,022,123 cubic metres and 500,000 cubic metres respectively (15). Based on the 2012 national housing and population census, forest area per capita has decreased from three ha/capita in the early 1980s to 1.1ha/capita (14).

With a population growth rate of 2.7 in 2012, Tanzania had a total population of 44,928,923 (21,869,990 males and 23,058,933 females). The 2022 national population census revealed that Tanzania has a total population of 61,741,120 (30,053,130 males and 31,687,990 females) growing at a rate of 3.2 (17). Agriculture (mainly crop farming and livestock keeping) remains as the backbone of economic growth for most communities, with various crops such as maize, rice, beans, cassava, peas, banana, sweet potatoes, Irish potatoes and various fruits being grown in the country. While land for expansion of agriculture/forestry is limited, the increasing human population continues to cause pressure on the available forest resources, jeopardizing forest conservation measures including the regulation and management of woodfuel production from forests.

Conceptual framework

Includes the type of briquettes to effect charcoal and firewood by different institutions both at production and utilization levels (Figure 1)

The potential for substitution of charcoal and firewood depends on the current briquettes production and consumption, which is a reflection of the level of adoption of briquetting technologies. The rate of adoption to briquetting technologies has a close linkage with social needs, economic needs and environmental objectives. We hy-

pothesize that the higher the substitution potential for woodfuel by briquettes, the higher the impact on reducing forest degradation and deforestation. The impact however might be affected with other factors than those in Figure 1, which according to this study forms the basis for the aforementioned hypothesis.

In the conceptual framework, the level of activities included those aimed at i) enhancing social welfare and well-being of the briquettes producers and consumers exemplified by the need to have alternative cooking energy due to declining woodfuel supplies ; ii) attaining economic benefits such as income generation through employment opportunities and by selling or buying briquettes instead of woodfuel ; and iii) solving environmental issues such as conservation of environment through promotion of renewable energy technologies, promotion of clean energy, and minimizing the overdependence on woodfuel to save the natural forests, which usually have the highest conservation and biodiversity value compared to artificial forests.

Similarly, products considered in this case are firewood, charcoal, non-carbonized briquettes and carbonized briquettes. The objective is to replace/substitute firewood and charcoal (which has been accelerating forest loss and degradation in Tanzania) with non-carbonized briquettes and carbonized briquettes respectively. The replacement of firewood and charcoal is considered in the two major aspects of production and consumption, which means supply and demand respectively.

Reconnaissance survey

An initial survey following literature review was implemented to establish the status of briquettes production and utilization. Due to presence of a lot of man-made forests in southern highlands of Tanzania (2) with a po-

tential to generate plenty of wood residues, the survey was implemented at Mufindi district in Iringa region between 2022 and 2023 (18). From the reconnaissance survey, it was observed that despite the presence of many wood-based factories alongside a substantial amount of wood residues generated from timber processing, much of the consumption of briquettes takes place in Dar es Salaam, Arusha and partly in Kilimanjaro region (Figure 2). As a result, the second phase of the study was shifted to Arusha and Kilimanjaro regions, not covering Dar es Salaam due to time and financial limitations. Also, the presence of some large scale briquetting companies from both public and private sectors provided an indication of wider adoption of briquettes compared to other regions, where most briquetting activities are much more scattered.

Collection of basic information

Basic information of institutions involved in production and consumption of briquettes was collected through consultation with relevant government offices. The sample size was established from the list acquired from Tanzania Industrial Research and Development Organization (TIRDO), a sub-autonomous department of the government of Tanzania which made a survey for briquettes producers in 2021. Even though other producers had already stopped production during implementation of the current research, an additional list of adopters was established from the contacted active producers during adopters' analysis phase. As a result of adopters' consultation,

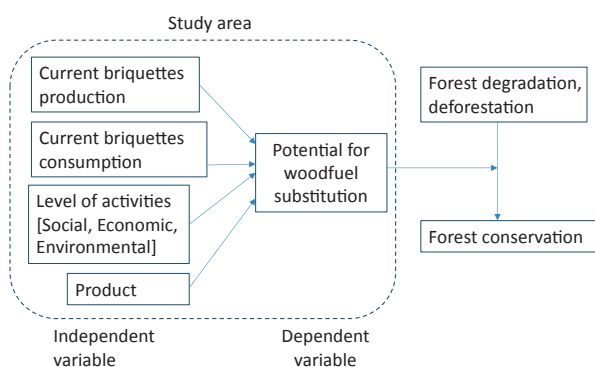


Fig. 1 Conceptual framework

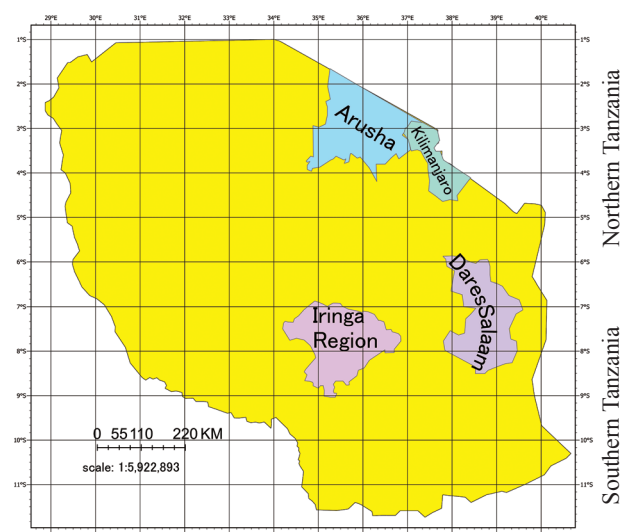


Fig. 2 Regions with on-going briquettes production and utilization

25 adopters were visited. Their willingness to participate in answering the questionnaire made the research activity possible. From the list acquired, the sectoral categories are briquetting companies, non-briquettes private companies, government agencies, community-based organizations, non-governmental organizations, households and individual producers/consumers (Table 1).

Actual field survey implementation in northern Tanzania

Implementation of field survey using an open and close-ended questionnaire was done in northern Tanzania (selected parts of Arusha region and Moshi municipality in Kilimanjaro region). Data on briquettes production/utilization were collected in different sectors/institutions following description of briquette adopters. Since there are no specific boundaries between north, south, east or west sides of Tanzania, the term northern Tanzania in this context is used only to indicate the general location of the study sites, which are Arusha region and Moshi municipality in Kilimanjaro region.

3. Results

Overview of the surveyed area

A large proportion of man-made forests have been established in the Southern Highlands of Tanzania, consisting of approximately 80% of Tanzania's forest plantations, the Sao Hill forest plantation being the largest with around 50,000 ha (19). Compared to the northern part of

Tanzania, there is high biomass potential for briquettes production in the south. On dry basis, 270,446 tonnes of processing residues per year can be produced from 0.79 million m³ of sawlogs, resulting from 1.8 million m³ of estimated industrial roundwood production in Tanzania (19).

Even though there is a high woody biomass production potential in the Southern highlands due to many man-made forests, the reconnaissance survey (18) revealed that much of the briquettes produced in the area are sold in Arusha, Kilimanjaro and Dar es Salaam. Therefore, the high biomass potential in southern Tanzania makes it possible to carry out briquettes production, of which some of the produced briquettes are sold in northern Tanzania, Arusha region in particular. Apart from benefiting local residents, the available residues will reduce the demand and impact of woodfuel use, which accounts for 90% of the cooking energy in Tanzania. Additionally, there have been on-going initiatives from both government and private sectors on briquettes production and consumption with promising results on adoption in the north (Arusha region) following the declined supply of woodfuel. According to the national housing and population census of 2012, total human population in Arusha is 2,356,285, with an increasing growth rate of 3.3 in 2022 from 2.7 in 2012 ; while Kilimanjaro region has 1,861,934 total human population, with a population growth rate of 1.3 (17).

Table 1 Description of briquettes adopters covered in the current study

Stakeholders	Description of role in relation to briquettes production/utilization
o Business companies	Companies dealing with production, marketing and/or utilization of biomass briquettes.
o Government agencies	Government and public entities benefiting from briquettes value chains. Examples include government schools and government vocation training institutions.
o Community-based organizations	Institutions/organizations implementing their activities with the community for community benefits. Example: Charity groups.
o Households	Briquettes production/utilization is done for the purpose of the entire household, i.e. participation in briquettes chain as an activity for the household.
o Non-Governmental Organizations	Non-profit organizations/institutions which are not part of the government and implements their activities by themselves. Example; Environmental conservation organizations
o Private institutions	Entities/private companies of which their main activities are not related to briquettes production/utilization.
o Individuals	Production and/or utilization of briquettes is implemented by an individual person. Adoption of briquettes is by and for the person himself/herself only.



Fig. 3 Non-carbonized briquettes adopted in Tanzania

Basic information on briquettes production and utilization

Results from the questionnaire survey indicated that production and utilization of briquettes was implemented by various adopters, ranging from sole individuals to corporate organizations both from private and public sectors (Table 1). Briquette adopters differ in their roles in the briquettes value chain, operating at various levels from the individual to joint ventures, project based and business oriented briquetting operations.

Status of production and utilization of briquettes

Of all briquette types (Figure 3), per capita consumption amounted to 6.7 tonnes/year. We found further that 7,702 tonnes/year and 40,807 tonnes/year of carbonized and non-carbonized briquettes were consumed by the selected sample respectively.

We observed that more production volumes were recorded from government agencies than other sectors/institutions (Table 2); the reasons being differences in financial, technical and human resource conditions, with government institutions having better conditions.

Further, varied sectoral attributes and institutional characteristics such as presence of subsidies, main activities, briquettes end-use and the number of people hosted in an institution affects the levels and quantities of production and utilization of a particular type of briquettes (Table 3). On average, most producers operate with low briquetting technologies with simple prototypes of technology (Figure 4) which can be assembled within the country.

Moreover, some producers claimed to suffer from (i) low financial/investment capacity, (ii) insecure markets and low market niche due to immature technology and risk aversion, (iii) short-term experiences for mastering improved technologies and production efficiency maxi-

Table 2 Monthly briquettes production and consumption

Briquettes production		Briquettes consumption	
Producers	Amount (Tons)	Consumers	Amount (Kgs)
BCs	930	BCs	20,110
GAs	1,464	CBOs	930
Households	12	GAs	110,500
Individuals	102	Households	60
NGOs	17	PIs	1,300
Grand Total	2,525	Grand Total	132,900

BCs – Business companies, Gas – Government agencies, NGOs – Non-governmental organizations, CBOs – Community based organizations, PIs – Private institutions

zation. On a different note, the already existing stoves (Figure 5) for non-carbonized briquettes users had a role to play as it saved the cost of buying new stove designs for utilizing briquettes unless it is for carbonized briquettes which usually are intended for substituting conventional charcoal. Similar to subsidies, the presence of improved firewood stoves for consumers in the public sector was highly observed in government schools and other government training institutions.

However, there is still a lot to be done in terms of standardizing or lowering the price of briquettes so as it can be more competitive with that of charcoal and firewood. In the current study for example, the price of charcoal in Arusha was 60,000 Tshs/bag (1 bag weighs 70 kilograms on average) while that of firewood was 50,000 Tshs/m³; equivalent to 857.143 Tshs/kg and 71.429 Tshs/kg respectively (basic density of firewood is

Table 3 Production and consumption of briquettes in different institutions studied

Briquette type	Adopters	*Institution	Characteristic nature	*Main objective	Sub-objectives	Previous fuel	Number of people per institution	Production/consumption (tonnes/year)	Per capita production/consumption (tonnes/year)
Carbonized	Producers	BC	As business for income generation/alternative energy	EC	EC	C	5	1,825	4,380
		IN	Operating for vital need (alternative energy)	SC	EN	C	5	1,825	1,971
		IN	Operating for vital need (alternative energy)	SC		C	7	2,555	1,564
		IN	Operating as business for income generation	EC	SC	C	6	2,190	2,738
		HH	Operating as business for income generation	EC	SC	C	6	2,190	730
		NGO	Funded project for environmental conservation	EN	SC	C	6	2,190	913
		BC	Operating as business for income generation	EC		C	150	54,750	1,606
	Consumers	BC	Foreign investor for alternative energy, environmental conservation	EN		C	5	7,300	1,460
		HH	Operating for vital need (alternative energy)	SC	EN	C	6	22	4
		HT	Operating as business for income generation	EC		C	25	40	2
		CH	Offers humanitarian assistance for disadvantaged groups	SC	EN	C	22	121	6
		CH	Offers humanitarian assistance for disadvantaged groups	SC	EN	C	18	110	6
		CH	Offers humanitarian assistance for disadvantaged groups	SC	EN	C	20	110	6
Non-carbonized	Producers	GA	Offers vocational trainings, subsidized for vital need	SC	SC	F	12	4,380	40,880
		NGO	Funded, with long history for renewable energy, trainings	EN	SC	F	5	1,825	110
		IN	Purposively for trainings and environmental conservation	EN	SC	F	1	365	365
		BC	Operating as business for income generation	EC		F	7	2,555	10,950
		GA	Responsible for alternative energy trainings, subsidized	SC	EC	F	14	5,110	3,129
	Consumers	GA	Responsible for vocational trainings, subsidized for vital need	SC		F	560	730	1
		PI	Operating as business for income generation	EC		F	58	475	8
		GA	High school academic trainings, subsidized for alternative energy	SC		F	1,400	2,190	2
		GA	High school academic trainings, subsidized for alternative energy	SC		F	1,285	2,373	2
		GA	High school academic trainings, subsidized for alternative energy	SC		F	1,314	2,190	2
		GA	High school academic trainings, subsidized for alternative energy	SC		F	2,500	32,850	13

* BC = Business company; IN = Individual; HH = Household; HT = Hotel; CH = Charity group; GA = Government agency, NGO = Non-governmental organization; PI = Private institution; C = Charcoal; F = Firewood; EC = Economical related; SC = Social welfare; EN = Environmental related



Fig. 4 Low scale briquetting machines made in Arusha



Fig. 5 Stoves currently using briquettes for cooking meals

assumed to be 700 kg/m^3 as most reported in literatures). On the other hand, the price of carbonized briquettes and non-carbonized briquettes in Arusha and Moshi (Kilimanjaro region) was 550 Tshs/kg and 600 Tshs/kg respectively. From these data, the price of firewood per unit weight is much lower than for non-carbonized briquettes (the substitute of firewood). Moreover, the price per unit weight of carbonized briquettes (the substitute fuel for charcoal) is slightly lower than that of charcoal in Arusha region. The reason for a higher price of charcoal is that, in Arusha region, there has been a ban on wood-fuel production whereby neither licensing nor permits for charcoal production have been issued (personal communication with Mr. Boaz Mtokoma, forest officer in Longido district, Arusha). A different situation prevails in areas such as Morogoro region where the supply of charcoal or firewood is higher and scarcity is less of a problem compared to Arusha region.

Briquettes potential for enhancing forest conservation

Results show that, non-carbonized briquettes are effective means to substitute firewood, which is predominantly consumed in large quantities in rural areas. Rural areas form the basis and proximity of natural forests for

which much of the charcoal is illegally harvested from. On the other hand, areas in the city were much more supplied with carbonized briquettes. It should be noted that, much of charcoal in Tanzania is consumed in urban areas (11). In the current, we observed that the supply of carbonized briquettes and their higher market potential occurs more in the city areas of Arusha and Moshi (18). Experiences from the questionnaire survey show that charcoal and firewood are closely related in terms of end-uses with carbonized and non-carbonized briquettes respectively. Therefore, the chains of supply to the desired market places are decisive of the type of briquettes suitable in a particular area. To this end, carbonized briquettes have higher market potential in urban areas while non-carbonized briquettes are appropriate for communities near forest areas – rural areas which are usually located far from the cities. In order to make non-carbonized briquettes even more effective in substituting firewood, strengthening the management of forests by effective implementation of forest laws and regulations is necessary. While taking into account of the community needs, financing for alternative energy technologies including technologies for briquettes production and utilization would help minimize pressure on the remaining forest resources.

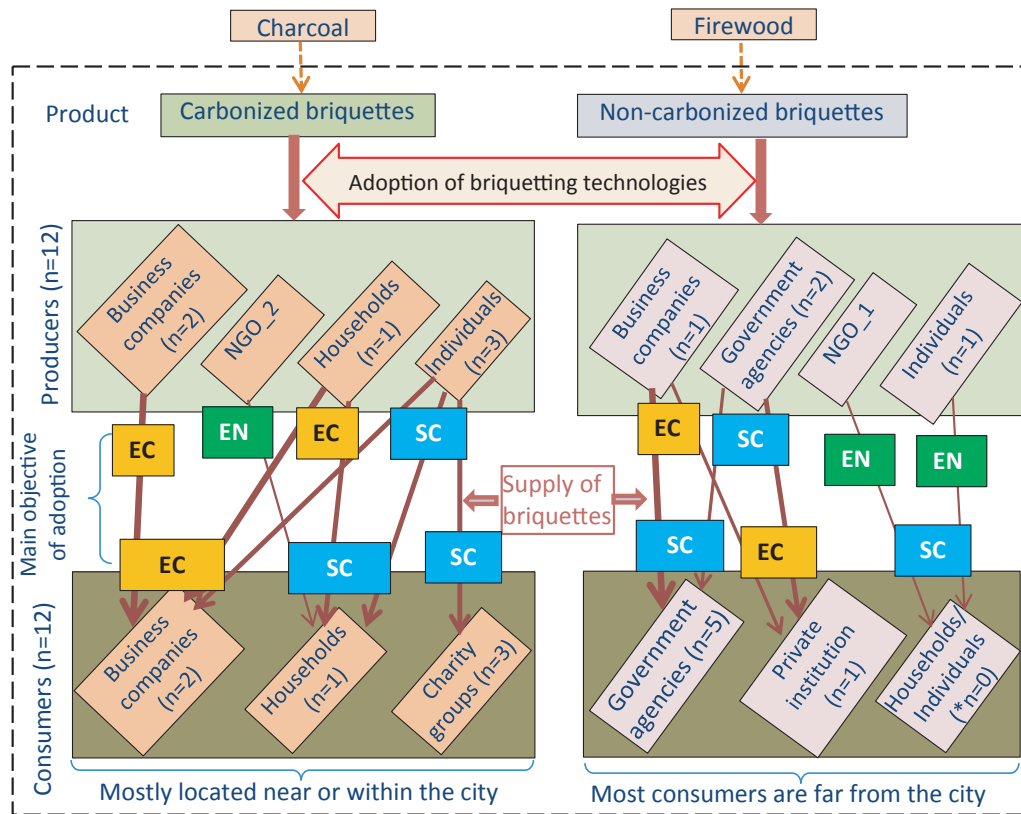


Fig. 6 The linkage of briquettes substitution for woodfuel and sustainability factors driving adoption of briquettes in northern Tanzania [SC = Social related, EC = economical related, EN = Environmental related]

4. Discussions

The inter-relationship between the factors investigated (Table 3 in the previous sub-section) was developed. Figure 6 shows the linkages between the main purposes of adoption to briquetting technologies, all of which depends on the products' end-uses. Our results indicate that adoption of briquettes is linked to a multitude of factors, all of which are associated with the main objective of adoption and the type of end-use; that is whether firewood or charcoal is being substituted. Such factors are related to enhancing communities' social welfare, economic gains and or environmental concerns. In Figure 6, the thickness of the lines linking the producers to the respective consumers indicates not only how strong the connection is but also the quantity produced and quantity of briquettes consumed. Thicker lines represent large quantity of briquettes produced/consumed by a particular briquettes adopter.

At briquettes production level, individual producers, corporate producers (NGOs), and business companies rely heavily on matters related to social welfare, environ-

mental issues, and economic objectives respectively. Likewise at utilization level, business companies focus more on economic gains, government agencies such as schools and training institutions on social welfare, while individual and corporate consumers are more driven by environmental issues that are linked with the overdependence on either charcoal or firewood. With these factors, we hope that wider adoption of briquettes associated with increased levels of production and consumption, will have the effect of reducing the overdependence on woodfuel and hence more trees could be saved resulting from woodfuel substitution. Taking into consideration the communities' energy needs, the promotion of the use of briquettes as an alternative to woodfuel alongside with strengthened and effective forest management would contribute to forest conservation and therefore result in the reduction of deforestation.

5. Conclusion

Briquettes have a potential role in minimizing the overdependence on charcoal and firewood in Tanzania thus contributing to efficient utilization of forest resources.

es. In our study, it was revealed that adoption of briquettes by different adopters is highly affected by several factors emanating from social, economic and environmental perspectives for all producers and consumers of carbonized and non-carbonized briquettes. As for each briquette adopters, the driving factors mainly the objectives and purpose of adoption are different and solely implemented. However, a direct linkage of the driving factors is observed in this study, linking up both producers and consumers of all types of briquettes, with a direct relationship of the briquettes end-use. This highlights the importance and need for consideration of all sustainability factors to promote efficient and effective implementation of briquetting projects with the aim of reversing the current decline in forests.

Similarly, understanding the characteristic nature of adopters, funding status and subsidies are necessary so as to achieve maximum results in minimizing the overdependence on charcoal and firewood. We therefore recommend that funding and allocation of subsidies be implemented at this early stage of adoption by different institutions and sectors. Funding and subsidies will facilitate the growth and development of the briquetting industry thus ultimately contributing to efficient utilization of artificial forests and saving the declining natural forests in Tanzania.

Acknowledgement

This study received funding from the Research Institute of Tokyo University of Agriculture, under the “2023 Doctoral Research Support Programme”. We owe thanks to the Research Institute for the financial support, without which it would have been impossible to travel and conduct research in Tanzania. Ms. Raheli E. Nazayoeli from Tanzania Industrial Research Development Organization (TIRDO) is also appreciated for her kind support in linking up with the briquettes producers during adopters’ analysis in Arusha and Moshi.

References

- 1) UNEP (2019) Review of Woodfuel Biomass Production and Utilization in Africa : A desk study. United Nations Environment Programme, Nairobi, Kenya.
- 2) MNRT (2015) National forest resources monitoring and assessment of Tanzania mainland : main results. Ministry of Natural Resources and Tourism (MNRT), Dar es Salaam, Tanzania.
- 3) CAMCO (2014) Biomass energy strategy (BEST) Tanzania. Tanzania biomass energy strategy and action plan,

- Final report. Dar es Salaam, Tanzania. Pp.138.
- 4) KAALE BK (2005) Baseline study on biomass energy conservation in Tanzania. SADC Programme for Biomass Energy Conservation (ProBEC). MEM, Dar es Salaam Tanzania.
- 5) WWF (2007) Assessment of Charcoal Dynamics, policy and Fuel switching. Dar es Salaam charcoal project. Dar es Salaam, Tanzania : World Wide Fund for Nature (WWF). 103p.
- 6) WORLD BANK (2009) Transforming the charcoal sector in Tanzania : A Policy Note. Environmental Crisis or Sustainable Development Opportunity? The World Bank. Pp.10, 33.
- 7) CHIDUMAYO EN and GUMBO DJ (2013) The environmental impacts of charcoal production in tropical ecosystems of the world : A synthesis. *Energy for Sustainable Development*, 17 (2) : 86–94.
- 8) GLADSTONE S, TERSIGNIA V, KENNEDY J, HALDEMAN J A (2014) Targeting briquetting as an alternative fuel source in Tanzania. *Procedia Engineering* 78 : 287–291
- 9) EAMCEF (2013) Baseline survey report for 8 Nature reserves and 1 National park in the Eastern Arc Mountains of Tanzania. *Eastern Arc Mountains Conservation Endowment Fund* (EAMCEF). Morogoro, Tanzania.
- 10) MANIBOG FR (1984) Improved cooking stoves in developing countries : Problems and opportunities. *Ann. Rev. Energy* 9 : 199–227.
- 11) MWAMPAMBA T H (2007) Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. *Energy Policy* 35 : 4221–4234.
- 12) GUTA DD (2014) Effect of fuelwood scarcity and socio-economic factors on household bio-based energy use and energy substitution in rural Ethiopia. *Energy Policy*, 75 : 217–227
- 13) MWAMPAMBA T H, OWEN M and PIGAHT M (2013) Opportunities, challenges and way forward for the charcoal briquette industry in Sub-Saharan Africa. *Energy for Sustainable Development*, 158–170.
- 14) LUKUMBUZYA K and SIANGA C (2017) Overview of the Timber Trade in East and Southern Africa : National Perspectives and Regional Trade Linkages, Pp.53. TRAFFIC and WWF. Cambridge, UK. TRAFFIC.
- 15) FORESTRY AND BEEKEEPING DIVISION (2021) The contribution of forestry sector to the national economy. Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania.
- 16) URT (2022) Feasibility Study on Enhancing Management of State Forest Plantations and Mangroves Forest Reserves in Tanzania, Draft report. The United Republic of Tanzania. Dar es Salaam, Tanzania.
- 17) TANZANIA NATIONAL BUREAU OF STATISTICS (2022) The 2022 Population and Housing Census : Administrative Units Population Distribution Report ; Tanzania Mainland. Dar es Salaam, Tanzania.
- 18) KOLONEL C P, YOSHINO S, SATO T (2023) An overview of briquettes production to enhance forest biomass recovery and efficient utilization from roundwood-producing forests in Tanzania. *Kanto Forest Society*, 74 : 13–16.
- 19) FAO (2009) Criteria and indicators for sustainable woodfuel : Case studies from Brazil, Guyana, Nepal, Philippines and Tanzania. Food and Agriculture Organization of the United Nations. Rome, Italy.

タンザニア北部における森林保全のための 木質ブリケットの導入

クリスチャン パウロ コロネル*・吉野 聡**[†]・佐藤孝吉**

(令和6年5月16日受付/令和6年9月13日受理)

要約:タンザニアでは、急速な森林消失問題に対応するため、現存する森林資源を保全し充実させることと、有効利用を促進することの2つの戦略が適応できる。本研究では森林資源の有効利用の1つとして、北部タンザニアにおけるブリケットの生産および利用状況の現状分析から、持続的な森林経営への可能性を検討した。森林に関する基本データや現地踏査、ブリケットの生産および消費に関連する基本情報の収集、そして、北部タンザニアのアルーシャ州およびキロマンジャロ地域の実地調査を実施した。その結果、ブリケットの生産および消費は、様々な導入者によって実施されていた。ブリケットの生産は、薪あるいは木炭の代替品として展開し、個人生産者、企業生産者（NGO）、および事業会社などで実施され、それぞれ社会福祉、環境問題、経済発展を事業目的としていた。ブリケットの利用は、会社においては生産物販売による利益向上のため、学校や研修期間など政府関連団体では安定した生活など社会福祉のため、個人や協力団体では薪や炭などによる過度の依存を和らげるなど環境問題への対応を目的として行われていた。持続的な森林経営のためには、それぞれの事業の社会、環境、経済対策を連携させ、補助や基金など総合的な対応が必要であると結論づけた。

キーワード:ブリケット、木質燃料代替材、ブリケット技術、森林減少、タンザニア

* 東京農業大学 大学院地域環境科学研究科 林学専攻

** 東京農業大学 地域環境科学部 森林総合科学科

[†] Corresponding author (E-mail : sy202075@nodai.ac.jp)