Operations and improvement needs in the informal charcoal sector: a participatory value stream analysis

A. ROOS[a], D. MUTTA[b], M. LARWANOU[c], C. WEKESA[d] and G. KOWERO[b]

[a]*Swedish University of Agricultural Sciences (SLU), Department of Forest Economics, Box 7060, SE-750 07 Uppsala, Sweden*
[b]*African Forest Forum (AFF), P.O. Box 30677-00100, Nairobi, Kenya*
[c]*Département Génie Rural, Eaux et Forêts, Faculté d'Agronomie, Université Abdou Moumouni de Niamey, BP 10960, Niamey, Niger*
[d]*Kenya Forestry Research Institute (KEFRI), Taita Taveta Research Centre, P.O. Box 1206-80304, Wundanyi, Kenya*

Email: anders.roos@slu.se, D.Mutta@cgiar.org, m.larwanou@gmail.com, chemukukefri@gmail.com, G.Kowero@cgiar.org

HIGHLIGHTS

- Charcoal value chains in two Kenyan counties were anayzed to identify sustainability improvement opportunities.
- Charcoal value chain actors need specific inputs, skills and face different operational challenges.
- The trade is conducted in the informal sector, which increases the actors' vulnerability.
- Improvement needs include sustainable forest management, improved operations, business skills, and coherent policies.

SUMMARY

Developing profitable and sustainable charcoal supply chains in Sub-Saharan Africa requires good knowledge about their properties, input needs and impacts. Charcoal supply chains in Taita Taveta and Kwale counties, Kenya, were analysed to identify operational and sustainability improvement opportunities. Using operations management, lean engineering and participatory research, charcoal value streams' processes, resources, and outcomes were analysed. Charcoal production and trade have low entry barriers, slow-paced innovation, and thin profit margins for value chain actors. Production is labour intensive, and the actors need specific skills, knowhow, and resources for proper business performance. The value chain's profitability and sustainability can be improved by regenerating exploited quality tree species, improving operation efficiency and safety, promoting market development, and appropriate policies on charcoal production and trade. The study's findings can guide the development of enabling policies and regulatory frameworks for the charcoal industry and improve the actors' performance in the charcoal value chain.

Keywords: bioenergy, energy policy, lean, supply chain management, sustainable livelihoods framework

Opérations et besoins d'amélioration dans le secteur du charbon informel: une analyse de flux de la valeur participative

A. ROOS, D. MUTTA, M. LARWANOU, C. WEKESA et G. KOWERO

Développer une chaîne d'approvisionnement en charbon profitable et durable dans l'Afrique sub-saharienne requiert une bonne connaissance de ses propriétés, de son besoin d'assistance et de ses impacts. Les chaînes d'approvisionnement du charbon dans les comtés du Taita Taveta et du Kwale, au Kenya, ont été analysés, pour identifier les opportunités d'amélioration de son progrès et de sa durabilité. En utilisant la gestion des opérations, une machinerie légère et une recherche participative, les processus d'écoulement de la valeur du charbon, des ressources et des résultats ont été analysés. La production et le commerce du charbon connaissent des points d'entrée bas, une innovation lente, et de maigres marges de profit pour les acteurs de la chaîne de valeur. La production requiert beaucoup de labeur et les acteurs ont besoin de capacités spécifiques, de savoir-faire et de ressources pour aboutir à une performance commerciale convenable. La profitabilité et la durabilité de la chaîne de valeur peut être améliorée par une régénération des espèces de bois de qualité exploitées, une amélioration de l'efficacité et de la sécurité des opérations, une promotion du développement du marché, et des politiques appropriées concernant la production et le commerce du charbon. Les résultats de cette étude vont être à même de guider un développement rendant possible des cadres réglementaire et des politiques dans l'industrie du charbon, et d'améliorer la performance des acteurs dans la sa chaîne de valeur.

Las operaciones y las necesidades de mejora del sector informal del carbón vegetal: un análisis participativo de las cadenas de valor

A. ROOS, D. MUTTA, M. LARWANOU, C. WEKESA y G. KOWERO

El desarrollo de cadenas de suministro de carbón vegetal rentables y sostenibles en el África subsahariana requiere un buen conocimiento de sus propiedades, necesidades de insumos e impactos. En este estudio se analizaron las cadenas de suministro de carbón vegetal en los condados de Taita Taveta y Kwale (Kenia) para identificar oportunidades de mejora de las operaciones y la sostenibilidad. Los procesos, recursos y resultados de los flujos de las cadenas de valor del carbón se analizaron mediante la gestión de operaciones, la ingeniería ajustada (modelo *Lean*) y la investigación participativa. La producción y el comercio de carbón vegetal tienen pocas barreras de entrada, un ritmo de innovación lento y márgenes de beneficio bajos para los agentes de la cadena de valor. La producción es intensiva en mano de obra y los agentes necesitan habilidades, conocimientos y recursos específicos para el correcto funcionamiento de la empresa. La rentabilidad y la sostenibilidad de la cadena de valor pueden mejorarse mediante la regeneración de las especies arbóreas de calidad que se explotan, la mejora de la eficacia y la seguridad de las operaciones, el fomento del desarrollo del mercado y la adopción de políticas adecuadas sobre la producción y el comercio del carbón vegetal. Las conclusiones del estudio pueden orientar el desarrollo de políticas y marcos normativos propicios para la industria del carbón vegetal y mejorar el rendimiento de los agentes de la cadena de valor del carbón vegetal.

INTRODUCTION

More than two-thirds of households in Africa rely on wood energy for heating and cooking (IEA 2019). Charcoal is an affordable energy source for many low-income urban households and creates jobs and income along the supply chain (Khundi *et al.* 2011, Openshaw 2010, Schure *et al.* 2014, Sedano *et al.* 2016, Vollmer *et al.* 2017). However, charcoal production and use are largely based on unsustainable sourcing of wood, which in most cases lead to forest degradation (Bailis *et al.* 2015, Chidumayo and Gumbo 2013, Kiruki *et al.* 2017, Naughton-Treves *et al.* 2007, Ndegwa *et al*. 2016), and in other places to deforestation. Hence, the sector influences different Sustainable Development Goals in both positive and negative ways (UN General Assembly, 2015). Good knowledge of any supply chains' processes and outcomes improves the understanding of its impacts on different sustainability indicators (Carter and Rogers 2008, Krajewski *et al*. 2019, Seuring and Müller 2008). This connection is also likely to apply to charcoal supply chains (Cerutti *et al*. 2015, FAO 2017: 118, Sola *et al*. 2017).

The charcoal sector in Africa has been characterised as informal and unsustainable, but it is of great economic importance to low-income households (Baumert *et al.* 2016, Jagger and Shively 2015, Schure *et al*. 2014, Shackleton *et al.* 2011, Shively *et al*. 2010). However, few studies have investigated the operations, lead times resources, and outcomes along the charcoal supply chain to identify opportunities for improving the sector (Doggart and Meshack 2017, FAO 2017: 118, Smith *et al.* 2017). Participatory approaches for analysing the charcoal supply chain are also rare, however, Zorrilla-Miras *et al.* (2018) applied this approach in a study on charcoal and land use in Mozambique.

This study focuses on operations along charcoal supply chains in Kenya. Charcoal in the country is normally produced with traditional technologies and then transported to the markets and customers – households, hotels, restaurants, and institutions (Mutimba and Barasa 2005, Ndegwa *et al*. 2016, Njenga *et al*. 2013). Annual charcoal production in Kenya increased by 93% between 2000 and 2018, reaching 1.23 million metric tonnes. Charcoal is a primary energy source for 10% of the households in Kenya. The share is higher for urban low-income households, and charcoal is moreover often used together with other energy sources (Republic of Kenya 2019: 45).

To curb the perceived degradation of forests, in 2018, the Kenyan government implemented a moratorium on logging, which also banned production, movement, and trade of charcoal from indigenous species (The Kenya Gazette 2018). Similar measures have been used over recent years in several other African countries (FAO 2017: 95). Despite the ban, the Kenyan charcoal businesses are still operating (in 2021), albeit in a clandestine manner.

This study aimed at describing charcoal value streams and identifying improvement needs as highlighted by the actors. This was achieved in two ways: 1) mapping processes, resources, lead times, resource use, and livelihood outcomes throughout the supply chain, and 2) analysing supply chain actors' views on ways to improve its sustainability performance. The unit of analysis was the charcoal value chain from charcoal production to the retailing stage. The following section describes the study area – Taita Taveta and Kwale counties of Kenya – followed by a description of the conceptual framework and methods used in the study. The results section describes the current charcoal supply chain and the actors' improvement needs. The section thereafter outlines an improved charcoal supply chain. The results are finally discussed and conclusions are drawn.

STUDY AREA

This study was conducted in Taita Taveta and Kwale counties in the coastal region of Kenya. The two counties account for less than 5% of forest land and include gazetted, community, and private forests (KNBS 2019, Republic of Kenya 2013, 2018) (Table 1). The integrated development plans in both counties highlight the importance of community participation in the management and protection of forest resources (Republic of Kenya 2013, 2018).

TABLE 1 *Overview of Taita Taveta and Kwale counties*

County	Area (km²)	Population	Forest area (km²)
Taita Taveta	17 000	341 000	620
Kwale	8 300	867 000	450

Source: Republic of Kenya (2013, 2018, KNBS, 2019)

Charcoal is produced for use in both local urban centres and distant large cities, mainly Mombasa and Nairobi. The total annual charcoal production in Taita Taveta and Kwale is estimated to account for 1.7–3.4% of the total production in Kenya.

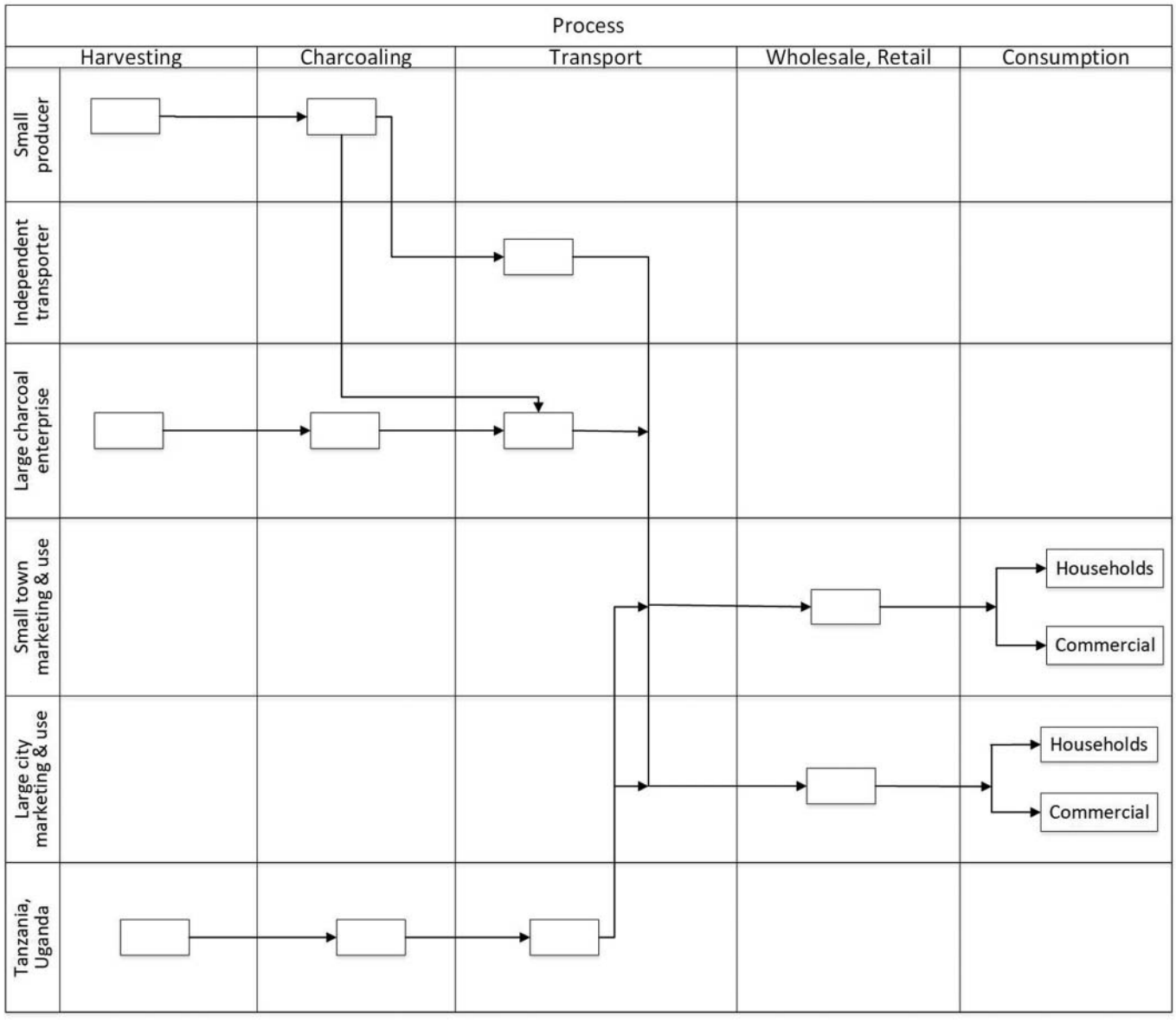
Charcoal trade and distribution in Taita Taveta and Kwale involves producers, transporters, wholesalers/vendors, and consumers (Figure 1). The production is mainly carried out at a small scale by family-owned enterprises. Prior to the charcoal ban, the producers were organised in producer associations (CPAs) and producer groups. These charcoal associations' roles and authority were partly suspended after the charcoal ban was introduced in early 2018, and the area is instead witnessing increased emergence of informal large-scale charcoal enterprises involving actors from other parts of the country. Charcoal trade also takes place across national borders to Tanzania and Uganda whereby charcoal is imported and sold in Kenyan markets using import trade permits. However, owing to the sector's informal nature, precise data about charcoal flows by different actors or between countries/counties, are hard to retrieve.

METHOD

Conceptual framework

The concepts of operations management (Krajewski *et al*. 2019), supply chain management (Lambert and Cooper 2000)

FIGURE 1 *Charcoal trade flows in Kenya*



and sustainable supply chain management (Cerutti *et al.* 2015, Seuring and Müller 2008) were used to facilitate an understanding of the charcoal value stream and its processes, lead times, and resource use. Lean theory, originally developed for the Japanese car manufacturing industry, was applied to identify improvement opportunities related to waste, quality, and efficiency. The lean theory also implicitly fosters a more sustainable production (Faulkner and Badurdeen 2014). To review the range of sustainability and livelihood implications, the study also employed the sustainable livelihoods framework (Angelsen *et al*. 2014, DFID 1999).

Research process

A qualitative case study approach was employed (Miles and Huberman 1994, Yin 2014:3). The lean tool of value stream mapping (VSM) was used to map the value stream components and key improvement areas (Caldera *et al.* 2017, Faulkner and Badurdeen 2014, Rother and Shook 1999, Vamsi Krischna Jasti and Sharma 2014). This method offers a visual representation of processes, lead times, resources, and information exchange as a product is brought to the customer. It was combined with the documentation of livelihood outcomes. Generally, the VSM analysis begins with a current *as-is* situation and concludes with a desired improved *to-be* situation, or outcome. Therefore, a participatory analysis was undertaken to map the desired improvement in charcoal production processes, lead times, and resources' use efficiency. This approach is premised on both the lean and participatory principles stating that any process analysis should be based on first-hand operational knowledge about current practices (Bolwig *et al.* 2010, King 2015, Mikkelsen 2005, Pain and Francis 2003).

Consequently, the study first constructed a *VSM (as-is)* describing processes, resources, and outcomes. An *improvement need analysis* identified problems in the charcoal production processes reducing the supply chain's efficiency and sustainability performance. A preferred *VSM (to-be)*, highlighting the key improvement areas, was finally determined and recommended for application. An improvement is defined as an overall increase in the efficiency and sustainability performance of the value stream of a product.

Data collection and analysis

Data were collected through individual interviews of, in total 103 supply chain actors and 19 key informants in 2018 and 2019 (Table 2). In addition, nine focus group discussions (FGDs), and four stakeholder workshops were conducted in 2018 and 2019 guided by the methods prescribed by Barrat *et al*. (2011), Mikkelsen (2005), and Yin (2014), which facilitated confirmation and triangulation. Survey instruments (for semi-structured interviews) were pre-tested and adjusted to capture the required information effectively. Local enumerators with university degrees and fluency in Swahili language were recruited and trained for two days to carry out the interviews.

Components of the participatory analysis encompassed the stakeholders' workshops, follow-up visits, and verification meetings where the preliminary findings were discussed with key informants (Mikkelsen 2005, Neef and Neubert 2011).

Interviewees (active in production, transport, or vending or charcoal) were identified and contacted through established CPA structures, which created an open atmosphere of trust between researchers and the respondents. The key informants included persons with in-depth knowledge about the charcoal sector, such as experts, government officers and administrators, and representatives of stakeholders' groups (Table 2). The interviews and FGDs were semi-structured and lasted 1.5 to 2 hours, each. The FGDs involved separate sessions for men, women, and the youth, comprising 4–8 participants per group. Compared with the interviews, the FGDs involved more dialogue between the participants and researchers. The stakeholders workshops lasted for one day each, and comprised key stakeholders in the charcoal supply chain. The workshops focused on documentation, listings, and discussions around challenges and desired improvements in the supply chain.

The analysis involved thematic qualitative and quantitative analyses (Mikkelsen 2005, Miles and Huberman 1994, Yin 2014) following the guidelines for qualitative operations management research (Barratt *et al*. 2011).

TABLE 2 *Data collection*

June 2018	
Data collection type	**Respondents**
Individual interviews	43 producers, 30 transporters, and 30 vendors
FGDs	9 focus groups (producers, transporters, and vendors)
Key informant interviews	8 representatives of: environmental non-governmental organizations, county governments, Kenya Forest Service, forest owners' associations, and CPAs
Workshops	Two one-day workshops with stakeholders. No. of participants: 21 (Taita Taveta) and 30 (Kwale)
June 2019	
Key informant interviews/FGDs	11 verification sessions with the focus groups and CPAs' representatives
Workshops	Two one-day workshops with stakeholders. No. of participants: 37 (Taita Taveta) and 22 (Kwale)

RESULTS

Value stream map (as-is)

Current processes in the charcoal supply chain

It takes about 40 days from when a tree is felled until the charcoal reaches the customer, although the time varies according to kiln size and distances to the markets (Figure 2). First, producers source the raw material from land with secured access, or after receiving consent from the owner. The wood is harvested, heaped in bundles, and dried for 14 days, and then it is cut into about 2 m long logs before carbonisation. Earthen kilns are mainly used for the carbonisation process. According to the respondents, the drum method (Casamance technology) did not yield sufficient volumes for profitable production.

To prepare the kiln, big logs are laid on the ground, followed by smaller ones on top, allowing for minimum space between the logs for air circulation. Soil is used to cover the kiln, and stones are placed around it. An opening is left for ignition of the kiln.

The carbonation process takes 5–7 days and is monitored two to three times per day. The charcoal is then removed from the kiln and cooled and packed in gunny bags with an average weight of 40 kg per bag. The sacks are sewn using a rope and sold to transporters who ferry them to local trading centres or to the two largest cities: Nairobi or Mombasa. The transported charcoal is sold to wholesalers and vendors, while some proportion goes directly to large customers, hotels, and institutions. The vendors repackage the charcoal in various sizes – 2 kg, 5 kg, 10 kg, and 20 kg – for re-selling to households. Cash dominates all payments, although credit purchases are also made. Producers, transporters, and vendors communicate and make deals via phone or direct meetings.

Perceived total quality, in all stages throughout the chain, depends on product quality, properties, service, trust, and price (Figure 3). Respondents' typical definitions of product-related quality were "*heavy charcoal from specific indigenous tree species*" (female vendor) and "*the charcoal that lasts longer when burnt*" (female vendor). Service quality at all stages in the supply chain depends on reliable delivery, last-mile delivery, and product availability or fill rate (Chopra 2019: 334). Communication skills, politeness, and trust comprise the additional service ingredients. Trust is defined as honouring agreements and is considered a means of acquiring and retaining loyal customers as well as the basis for credit purchasing and selling. Customers would prefer reasonable and stable pricing, while seasonal price variability is a concern for actors because it increases risk and disrupts planning.

The charcoal activity in the region is cyclic with high production and low prices in the dry season (September to March) when farming activities are low and roads are accessible for transporting the charcoal. Prices hike by 30% in the rainy season (April to August): "*During the rainy season, the price of charcoal increases since many people work in their farms, while in the dry season, many go to harvest charcoal, which reduces the charcoal price*" (male transporter). Charcoal provision can be disrupted because of rains that make roads inaccessible and impassable. Demand and prices also increase during Muslim and Christian holidays. Further, parents tend to increase charcoal production close to school openings to raise money to pay school fees for their children.

Most charcoal producers, about two thirds, are men. When a couple collaborates, the tasks are shared. Women are restricted in several ways; they are not expected to ride bicycles and they fear going alone to the forest. Women's participation in charcoal transportation is also low, except when they carry

FIGURE 2 *Value Stream Mapping (as-is). Based on about ten bags kiln size*

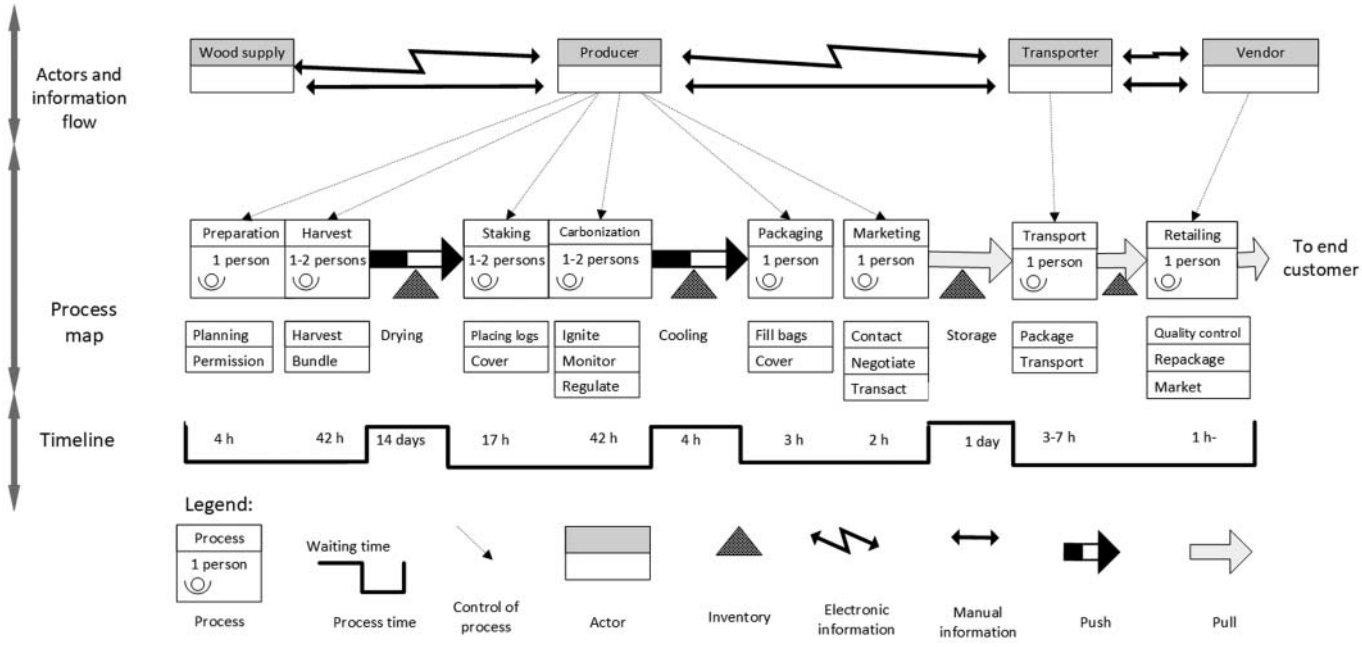
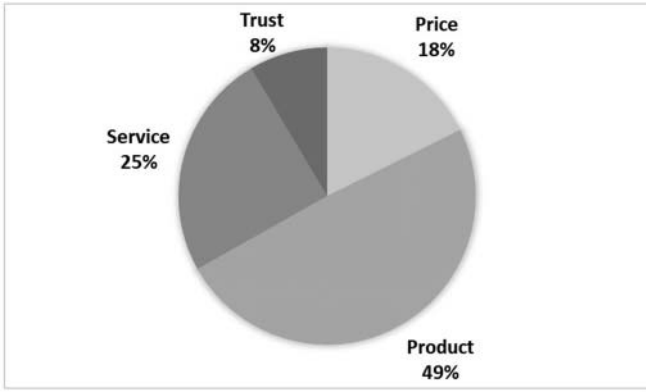


FIGURE 3 *Factors affecting quality perception and customer satisfaction according to sellers (share of 187 mentions from producers, transporters, and vendors)*



charcoal on their heads. In contrast, about 80% of the vendors are women who combine charcoal sales with shopkeeping businesses.

Resources used

The wood resource is diverse. A total of 18 indigenous and exotic tree species in 10 families are used for charcoal production in these two counties (Table 3). The *Leguminosae* family with five species (31%) accounted for the highest number of species that occur in the two counties and other similar eco-zones in Kenya. The indigenous tree species are preferred for charcoal production because they produce high-quality charcoal.

Although dry wood collected from natural forests is used, wood obtained from felling living forest trees is the most common and preferred wood by the charcoal producers. The wood raw materials are sourced from own farmland, community forests, trust lands under the jurisdiction of the county government with the community organisation management, and from leased private land. The distance to the source of the wood raw materials for charcoaling ranges from 50 m (from own farmland) to 12 km, taking the charcoal producers between 0.25 and 3 hours to walk and up to 45 minutes to ride on a motorcycle. Respondents indicated that they nowadays travel longer distances than before to find suitable trees for charcoal production.

Table 4 indicates other input needs in the charcoal trade. Production requires hand tools that are owned or borrowed/rented from neighbours and relatives (Table 4). Adequate food and water are needed due to the considerable energy expended by individuals in charcoal production.

Motorised transport involve 6–8 wheeled vehicles, with a purchasing price of US$ 4 000 for used vehicles; and motorcycles with the purchasing price of US$ 450 for used ones. Used bicycles costing US$ 30, and animal-driven carts are often used to transport charcoal from production sites to the roadside and collection centres. Charcoal is also carried on the head by women to local towns and collection centres. Informal fees of up to US$ 13.8 are sometimes charged from transporters by authorities. Although there is a fairly improving road network between trading centres and towns,

TABLE 3 *Preferred charcoaling tree species for different quality categories*

Local name	Scientific name	Utilisation*
Very high quality		
Mkone	*Grewia tembensis*	16
Mchemeri	*Acacia nilotica*	15
Mgololi	*Acacia drepanolobium*	7
High quality		
Mkulu	*Diospyros cornii*	6
Munago	*Manilkara mochisia*	5
Mpingo	*Dalbergia melanoxyon*	3
Mkame	*Vanilla roscheri*	2
Nyangakanda	*Lecaniodiscus fraxinifolius*	2
Chikuro-cha-nyoka	*Zehneria pallidinervia*	2
Mkungu	*Terminalia catappa*	1
Mhoe	*Thespesia danis*	1
Mungoloti	*Acacia adenocalyx*	1
Mvikoviko	*Garcinia livingstonei*	1
Mzale	*Julbernardia magnistipulata*	1
Ordinary quality		
Mchirangombe	*Combretum hereroense*	16
Kikwata	*Acacia senegal*	13
Mbambara	*Commiphora spp.*	2
Mdungu	*Zanthoxylum chalybeum*	1

*) Number of mentions in individual interviews

TABLE 4 *Tools and equipment used in various stages of charcoal production along the value chain**

Charcoal production
Handtools: Machete, axe, hoe, spade
Empty sacks, ropes
Transportation
Motorised (6–8 wheeled trucks, lorry, canter, 4-wheeled cars-Probox and van, and motorcycle)
Non-motorised (head-carrying, bicycle, animal-driven cart-ox, and donkey)
Fuel
Spare parts
Ropes
Vending
Vending premise and a holding area for bulk storage
Buckets
Sacks (packaging materials)
Jerricans
Tins

*) Mobile phones are used at all stages

the conditions of most roads pose a major challenge during the rain season.

Resources and facilities required for charcoal marketing include the vending premises and a holding area for bulk storage (normal renting cost US$ 15–25/month). Small bags are purchased if the charcoal is repackaged before sale. In most cases, the vending premises are either small semi-permanent *bandas* (charcoal sheds) or small grocery shops located in residential areas.

Skills and capabilities required

Considerable physical strength is required for undertaking the preparation of raw materials, assembling and operating the earth kiln, and monitoring the carbonisation process.

Although the work is done in an informal context, certain other skills are required for production, transportation, and marketing (Table 5). The supply chain is also affected by specific challenges related to charcoaling techniques, driving skills, and trade and marketing skills and information (Figure 4). One main challenge for producers is securing a process that results in high-quality charcoal and prevent breakage of the kiln. Other challenges are associated with adverse weather conditions, especially when heavy rains disturb the carbonisation or humidify the produced charcoal. Weather conditions also affect transporters when roads are impassable during the rainy season. In the words of one transporter, problems may mean "*pushing vehicle when it is stuck in the mud during rainy seasons*" (male transporter). Transporters also refer to process-related aspects such as "*when the motorbike gets punctured with a load*" (male transporter). Institutional challenges refer to confiscations, fines and bribes and affect mostly transporters. Vendors' main challenges are related to collecting market information to match supply with demand, as well as guiding decisions on stocking levels and quality management.

TABLE 5 *Important skills and capabilities according to value chain actors*

Producers
Harvesting: Identification of the trees that can produce superior quality charcoal; harvesting techniques that optimize the yield
Kiln management: Understand wood arrangement; observation skills; know how to arrange the wood and balance and identify the wind direction
Marketing: How to package the charcoal; identify the lucrative charcoal markets
Strength-related: Energy and muscle to harvest and move wood
Transporters
Marketing: Business management, polite language, negotiation, and communication skills
Transporting: Driving skills; know how to repair vehicle; Loading technique
Strength-related: Carry the charcoal to the customers
Vendors
Management: Quality control and record keeping knowledge
Marketing: Negotiation and customer relations skills
Packaging: Know how to balance the bad and the good charcoal

Normally, charcoal supply chain members learn the trade from family members or neighbours: "*I observed my family members (parents) and received training from them*" (male producer) and "*I learnt from neighbours and improved my living standard*" (female producer). Almost a quarter of the respondents (23%) reported that they merely learnt the methods by observation (Table 6): "*I learnt it from nobody. I decided to start the business because I had no other activity to do which could make me earn income*" (male transporter). Government agencies, school institutions, or associations were rarely mentioned among the information or education sources on charcoaling or transport, though this question was not put to vendors.

Reading and calculation knowledge is useful for charcoal supply chain actors. Most actors had received primary education, although the percentage decreased from 97% among vendors to about 76% among producers (Table 7). The low formal education reflects that the profession was chosen based on necessity rather than choice. As per a producer, "*I wished to do other businesses, but I could not undertake them owing to my illiteracy*" (female producer).

Knowledge from schooling is used by 69% of the respondents for keeping records of sales, making orders, and recording purchases and creditors; 93% used calculation skills to estimate expenses and revenues, make market forecasts, and set prices, and vendors used them to calculate revenue from the sale of repackaged charcoal (Figure 5). Calculations are conducted as head calculations, with mobile phones, or by use of fingers. The answers reflect that schooling contributes to the performance of management tasks, bookkeeping, keeping of customer records, and resource use planning, albeit all this is in an informal context.

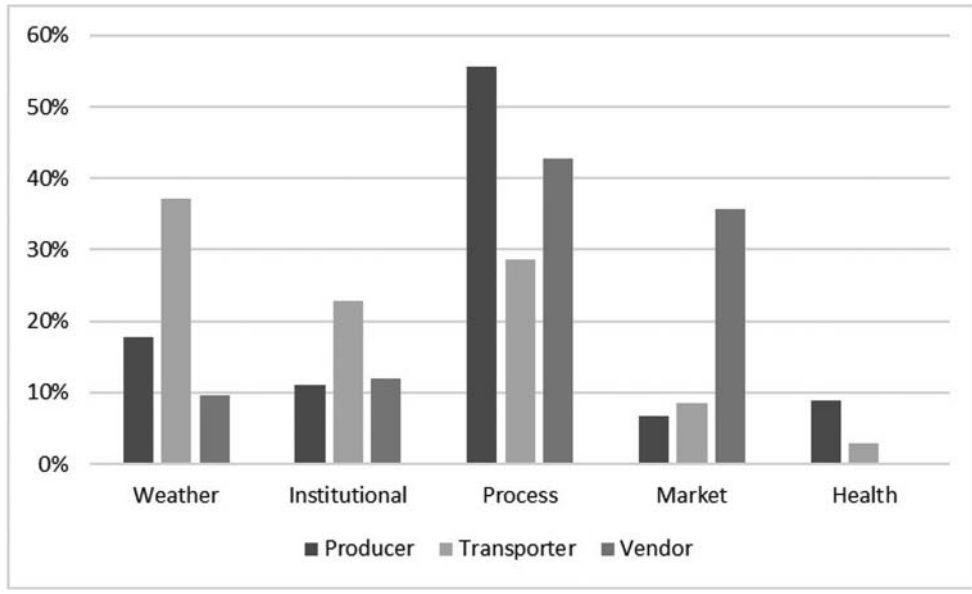
Organisational and financial resources

Organisational resources were reported to be in decline after the charcoal ban was introduced in 2018. Previously, producers were required to join registered CPAs that oversaw sustainable charcoal production. Moreover, CPAs facilitated charcoal deliveries and negotiated for better prices (Pritchard and Molony 2011). These functions were no longer carried out by CPAs due to the charcoal ban.

Financial resources or credit facilities are less important for the running of charcoal trade at its current state. This is because capital is sourced from own savings, other businesses, or the charcoal business itself. However, for all categories, lack of capital was reported as a factor limiting the expansion and further development of the charcoal business, for example, to market charcoal in Mombasa. It also limited the actors in investing in alternative income generating activities.

Value addition is made to the charcoal in the last stage of the production cycle – during packaging and transportation of the charcoal. Figure 6 shows price increases and lead times

FIGURE 4 *Perceived challenges in charcoal supply chain, percent of mentions*



for charcoal that is transported to a local town, and to the larger city Mombasa. While the price of raw wood was US$ 1/bag of charcoal produced, it increased 6–7 times in value when the wood was converted to charcoal; this price could even double when charcoal reaches the retailer. At the retailing stage, during repackaging into smaller units (e.g. packages and small tins), the price margin increased even further, by US$ 1.8–2.8/bag.

Although the graph in Figure 6 may show the effect of seasonal changes, it reflects that the charcoal producer accounts for 90% of the lead time and work hours but captures only 50% of the value.

TABLE 6 *How did you learn to produce or transport charcoal?*

Knowledge source	Mentions, percentage
Parents (father, mother, grandparents)	26
Neighbour	26
Brother/sister/cousin	8
Nobody – experience/observation	23
Friend	13
Association (CPA)	5

TABLE 7 *Education level: Based on personal interviews (percentage)*

Value chain actors	No schooling	Primary education	Secondary education
Producers n=41	24	71	5
Transporters n=30	7	76	17
Vendors n=30	3	70	27

The calculated income for a charcoal producer was below a day labourer's income of US$ 2.3–4.1/day. However, although this income earned does not lift the producers out of poverty, it is valuable because it is earned when the producers do not have other ways of engaging their labour during off-season farm work, and it goes a long way in meeting their needs. The gross profit per bag to transporters is slightly higher but the total contribution depends on the total number of trips made, the vehicle hiring cost, and the risk of paying fines while transporting the charcoal (Table 8).

Charcoal is the primary source of income for most transporters and producers (72% and 76%, respectively) and for 40% of vendors who normally sell other commonly demanded household products. However, most actors reported to have complementary income from farming, shopkeeping, and casual labour. The main fall-back income sources, when charcoal business was banned, were farming for producers, whereas transporters would perform other transportation services, and vendors would continue being in business but sell other commonly demanded products (Figure 7).

Since the charcoal ban was imposed, several producers had given up on charcoal production because it is labour intensive, yields low returns, and most recently involves high risks due to the current illegal nature of the business. Nevertheless, prolonged drought in the last five years has continued to force people to pursue charcoal production as a last resort livelihood support activity.

Improvement needs

Improvements, overview

The areas or issues that required improvement (improvement needs alluded to during the individual interviews, FGDs, and workshops) were categorised into the four areas – sustainable wood supply, improved operations, enhanced business

FIGURE 5 *Use of schooling skills by actors in charcoal supply chain in Kenya*

Examples on the use of the writing skills:

"Writing down the list of the names of the client who gave me order. Labelling sacks of the specific clients" (male producer, Taita Taveta)

"Keeping sales records and expenses" (male transporter, Kwale)

"Keeping records of my creditors. Keeping records of how many bags have been bought in one week" (female vendor, Taita Taveta)

Examples on the use of calculation skills:

"To be able to know how much money you make out of the charcoal you sell" (female producer, Kwale)

"Use cell phone to calculate how to get profit; Knowing how to get losses" (female transporter, Kwale)

"Calculating using phones to balance the cost incurred and the profit earned" (female vendor, Taita Taveta)

FIGURE 6 *Lead times in charcoal supply chain for different destinations*

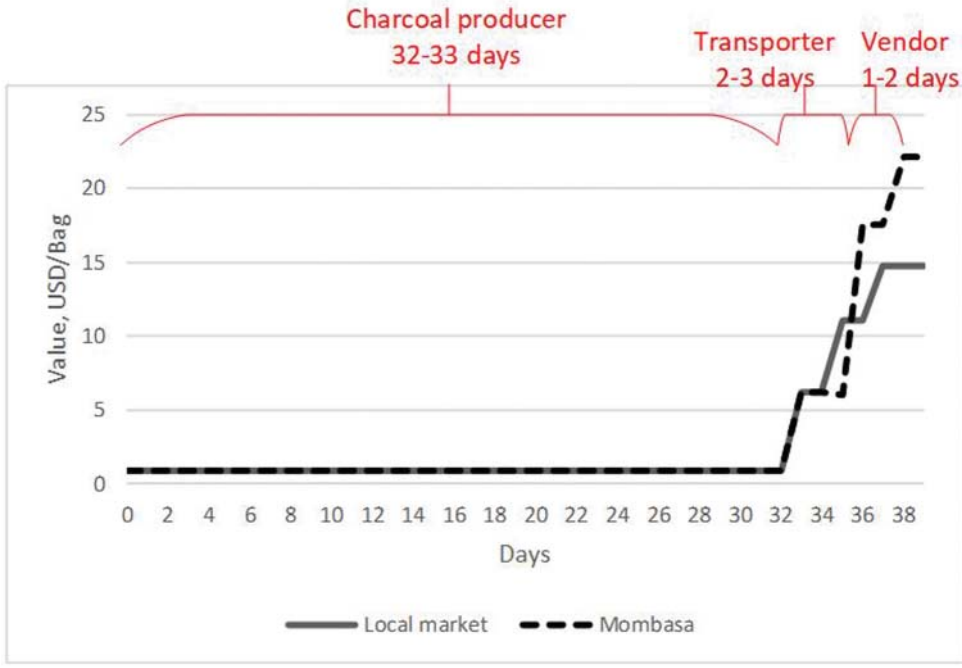
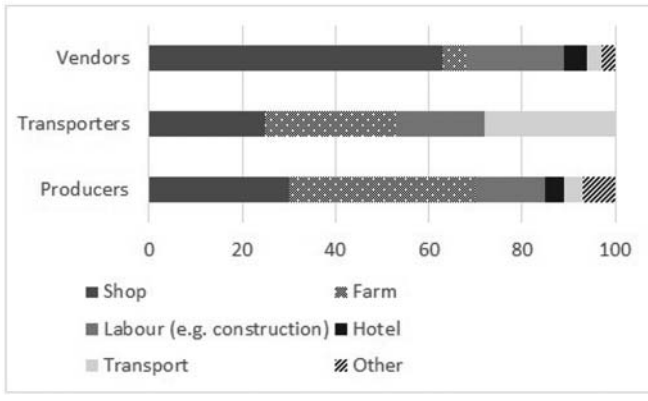


FIGURE 7 *Alternative income sources if charcoal fails*



processes, and coherent regulations. Most suggestions focused on the latter category, i.e. regulatory changes and lifting of the charcoal ban.

Sustainable wood supply

Supply chain actors observed a decline in wood supply and indicated that there is need to reverse the trend. The reduced wood availability was attributed to overharvesting of wood (65% of mentioned causes), reduced regrowth/regeneration of trees (42%), and agricultural land expansion (35%). Livestock browsing on trees and human population increase were also mentioned as reasons for the decline in wood supply for charcoal production. Respondents proposed that planting of

TABLE 8 *Income and cost overview, producer, transporter, and vendor (per bag)*

Description	Value chain actors		
	Producer	**Transporter, Motorcycle**	**Vendor**
Biomass/charcoal cost US$	1	6.7	12–20
Selling price/bag US$	6.7	12–20	15–22
Cost items	Empty bags Hand tools Fees to the CPA	Vehicle Fuel Ropes Movement fee	Marketing place Small bags/tins Movement fee
Margin/bag US$	6	3	3
Work hours/bag	10	3	-
Risks	Overburnt kiln Injuries	Threats from wild animals Breakdown Accident Confiscation	Inferior quality charcoal Theft Confiscation

trees could ensure a consistent supply of raw wood for charcoal production. The government should, according to the respondents, organise regeneration of tree species that produce high-quality charcoal in tandem with reconstituted CPAs.

Efficient and safe operations

While improved operations could lead to improved profits and reduce risks and waste, the charcoaling sector is characterised by slow-paced innovation, informal vocational training, and inefficient technologies. Recent technology shifts that could relate to this sector mainly involve the use of mobile phones for communication and calculations. However, complaints from customers indicate the need for more efficient charcoaling methods that deliver consistent quality and optimise the carbonisation process to minimise the waste associated with over-burning of the wood. A quality management approach would require improved processes throughout the supply chain – from tree species selection, wood harvesting, and transport to carbonisation and eventually charcoal transport, packaging, storage, and marketing. Supply chain actors articulated the need to acquire technical skills to enhance traditional charcoaling, and in this regard, briquetting was presented as an alternative. The supply chain actors also complained about the lack of coordination of actors in the supply chains, which led to occasional stockouts or excess inventories.

Finally, safer processes would reduce injuries and burns, medical bills, and lost work hours. The road network also posed challenges during the rain seasons, when the demand for charcoal was high and the prices were favourable.

Improved market and business practices

The respondents described the economic compensation for their work as unsatisfactory and noted that it could be enhanced by, 1) an increased product volume, such as larger kiln sizes, and 2) creation of higher net profit margins through entering high-end markets. These two strategies of improvements reflect strategies to focus on *asset turnover* or *profit margin* in cost accounting, respectively (Berk and Demarzo 2020: 80). Hence, respondents formulated the following business targets: "*produce 20–30 bags of charcoal*," "*be able to supply 30 bags in a week*," and "*sell in Mombasa*" (male and female producers); "*sell 100 bags/month*" (female vendor); and be "*able to own my own place where I can sell charcoal and improve living standards*" (female producer). The respondents reported that they lacked the competences needed for business management, market information, selection of marketing channels, and access to credit facilities. The producer sub-group, including women producers, preferred a return of collection points where producers could openly and jointly negotiate and sell charcoal to transporters and intermediaries. Producers would even prefer to organise their own transportation to more lucrative markets such as those in Mombasa and Nairobi, thereby eliminating the intermediaries (middle men) and increasing profit margins. Concerns were also expressed relating to variable prices, households' vulnerability to risks, and adverse events.

Appropriate and coherent policies

Charcoal actors felt that the charcoal ban was ineffective and unfair, and that it should be lifted. The ban has reduced incomes, undermined the CPAs to the extent of stopping their support activities to management of forest resources, and created an enabling environment for external illegal charcoal producers to thrive, thereby adversely affecting the livelihoods of rural poor people. Another concern was informal fees charged for the production and movement of charcoal. The fees reduced revenues and led charcoal producers and transporters towards less efficient methods. Respondents believed that the CPAs should be reconstituted and empowered to regulate and monitor the development and growth of the charcoal sector. This would contribute towards sustainable forest management and prevent unauthorised harvesting of trees, while at the same time ensure that tree harvesting and

reforestation plans are adhered to. Producers who are not members of the local community and CPAs should, in the view of the interviewees, be barred from engaging in charcoal production.

VSM (to-be)

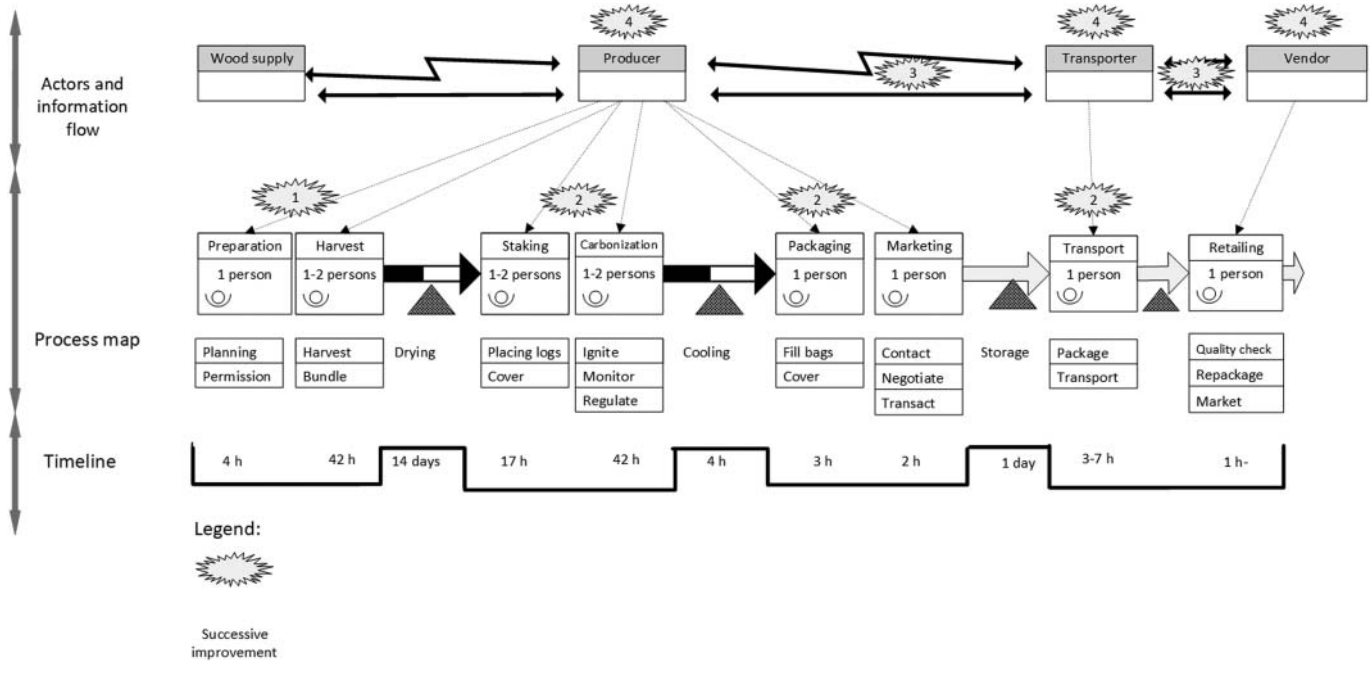
Participatory mapping of the value stream (Figure 2) and the voiced opportunities for improvement yielded a *to-be* VSM (Figure 8), which uses Kaizen bursts to highlight areas for the improvement of efficiency and quality outcomes (Vamsi Krischna Jasti and Sharma 2014). It aims to visualise improvements according to the charcoal actors.

Based on the mentioned needs above, the following four areas for improvement could be identified, corresponding to Kaizen bursts 1–4 in Figure 8:

1. Sustainable wood supply
   a. Measure: Apply sustainable forest management.
   b. Outcome: Secured long-term wood supply and the protection of certain forests.
   c. Benefit: Long-term sustainable charcoal production, creation of forest-based ecosystem services, and reduced costs to access wood.
2. Efficient and safe operations
   a. Measure: Ensure more efficient and safe harvesting, carbonisation, and transport.
   b. Outcome: Fewer kiln breakages, more even and high quality charcoal, reduced waste due to variable quality and kiln breakages, and fewer injuries.
   c. Benefits: Improved operational efficiency and customer value, which leads to higher profit margins and faster turnover, as well as improved health.
3. Improved marketing and business practices
   a. Measure: Improve marketing management, business practices and customer relations.
   b. Outcome: Access to more profitable markets, improved planning and supply chain coordination, and better revenue and cost management.
   c. Benefits: Increased profits (return on assets) and reduced market risk.
4. Improved, fair, and coherent policies
   a. Measure: Government to lift the ban on charcoal production and trade, eliminate corruption, and introduce a regulated and transparent market. Restore operations of CPAs and allow local communities to regulate harvesting of trees, and increase government recognition for the charcoal sector.
   b. Outcome: More predictable planning conditions, reduced risks for charcoal actors, and increased tax revenues to the government.
   c. Benefits: Improved livelihoods, better monitoring of the charcoal sector, improved forest management and conservation practices and improved government income.

These improvements indicated in Figure 8 reflect a vision to make the charcoal sector environmentally sustainable and efficient to promote basic livelihoods while safeguarding other forest-based ecosystem services. The first improvement refers to a long-term supply of wood through sustainable forest management. The second focuses on enhanced efficiency, quality management, and reduced waste across the supply chain. In addition, business and marketing improvements targeting the key actors' ability to make better use of resources from an economic perspective. The last improvement allow actors to make long-term plans and to align personal decisions with public interests.

FIGURE 8 *'To-be' charcoal value stream and improvement needs*



DISCUSSION

This participatory VSM study of charcoal supply chains provides useful information on the key processes, actors, resources, and economic and livelihood impacts. The charcoal sector is, for most actors, characterised by low work compensations and low profit margins – particularly at the production stage. The choice to engage in charcoal production is mainly to provide income for basic household needs, and because alternative sources of income are lacking. This study describes specific operations, resources, required skills, and challenges, and it offers a framework for constructive and participatory examination of areas for improvement.

The charcoal supply chain features typical traits for jobs in the informal economy: entry barriers are low, except for bulk transport; profit margins are thin; and safety and quality standards are not applied. Since the charcoal trade in Kenya was banned in 2018, charcoal activities have become semi-clandestine. Other typical features involve the informal training of actors and low innovation pace in the sector. This study also indicated that the actors are interested in developing the business, improve forest growth, and address quality issues. The participatory analysis identified a broad range of areas for improvement: sustainable wood supply; efficient and safe operations; improved market and business practices; and effective, fair, and coherent policies.

The observation by producers, transporters, and vendors that forests are declining, partly because of charcoal burning, are in line with previous studies on charcoal supply chains in Africa (Bailis *et al*. 2015, FAO 2020, Sedano *et al*. 2016) and in particular Kenya (Kiruki *et al.* 2017, Ndegwa *et al.* 2016). As noticed by Naughton-Treves *et al.* (2007), the degradation takes place, first, in old-growth forests.

This study's observations also confirm findings that charcoal is not an avenue out of poverty, but a resistance to acute deprivation (Ndegwa *et al.* 2016, Smith *et al.* 2017, Vollmer *et al.* 2017). It also supports the findings of Schure *et al.* (2014) and Smith *et al.* (2017) who reported that revenues from charcoal are mainly used to meet basic needs such as food, education, and healthcare.

Unclear restrictive charcoal policies that are not participatory validate some findings by FAO (2017: 118) that charcoal bans alone rarely create a sustainability transition in the sector. The study findings, based on a participatory approach to policymaking, also match the conclusion by Chidumayo and Gumbo (2013) that "Corruption coupled with unclear policy, and legal frameworks is seen as a major cause of unregulated or even illegal charcoal businesses in many parts of the tropical world." There is even a possibility of revenue leakage out of the rural areas because the *de facto* charcoal production and trade has become more unregulated owing to the charcoal ban (Baumert *et al*. 2016, Shively 2010).

Suggested improvements and propositions by charcoal producers, transporters, and vendors support the conclusions of previous scientific studies by Chidumayo and Gumbo (2013), Doggart and Meshack (2017), and FAO (2017: 118). These improvement needs range over several fields, indicating that there is no simple answer to the charcoal challenge; a mixture of measures and actions is needed.

The findings highlight the usefulness of the value stream approach in analysing forest-based industries in the informal sector. As argued by Rother and Shook (1999), whenever there is a product for a customer, there is a value stream. Hence, the VSM approach can, in a tangible way, help stakeholders to improve production in the sector. The approach is also well adapted to examine the sustainability impacts. The combination of VSM with participatory approaches was constructive in describing the processes and identifying possibilities for improvement. It is based on the premise that the actors normally have hands-on experience of the processes, and insights on opportunities for improvement. Furthermore, it suggests that improved quality, efficiency and less waste could foster business sustainability and profits in the charcoal sector. It was noted that charcoal actors have inadequate resources and weak organisational capacity to invest in measures that improve their operations. The study highlights the importance of grounding any improvement in the charcoal sector on good knowledge about the actors' different roles and factors that can influence their choices.

It is important to note that these results must be interpreted and generalised with caution. Due to the informal nature of the charcoal sector, some respondents lacked complete written records regarding prices and quantities. There are also few official records on charcoal production and trade. The Kenyan charcoal sector is furthermore prone to changes, based on changes in policies, societal dynamics, economic development, and associated polices, as well as demographics that can change its characteristics. For instance, the recent charcoal ban in Kenya may over time lead to changed market conditions and trade patterns for the product. Besides, the COVID-19 pandemic since 2020 can impact on the charcoal sector in different ways. However, it should be underscored that this qualitative study of the supply chain focuses on mapping the sequence of processes, resources, outputs and actors' perceptions – features that are probably more stable than specific quantities.

Further research should identify improved processes that address the key concerns among the actors along the supply chain. Such improvements would target sustainability performance, quality properties, business practices and the designing of more inclusive policies. The multiple challenges and concerns voiced by the actors highlight that several improvements are needed.

CONCLUSIONS

A thorough understanding about current charcoal supply chains and its actors is key for performance improvement of the sector. Hence, the combination of sustainable wood supply from tree species known for high-quality charcoal, process improvement, community involvement, and attention paid to local priorities may contribute to more sustainable charcoal supply chains. The study also sheds light on specific resources and abilities required in the sector. It informs that actors operate with very slim profit margins, and therefore slight losses or disturbances to the sector could lead to complete loss of the livelihood opportunities created by the sector.

From a scientific perspective, the VSM approach based on lean thinking yielded new insights on processes, resources, skills used and lead times. The participatory approaches generated several possible improvement areas for charcoal value stream actors. The sector operates without consistent regulations, training infrastructure, or development plans. It also encounters challenges in form of a charcoal ban, unsustainable supply of wood, and strains arising from poverty. In this regard, the participatory approach has identified and made recommendations that could guide short- and long-term improvements in this sector.

Considering the size of the sector and its implications on several sustainability indicators, the appropriate mix of measures encompassing sustainable forest management and wood supply – diffusion of efficient and safe operations; improved marketing and business practices; and fair and coherent policies – could transform the charcoal supply chain from a banned and clandestine sector to a lever for income generation and sustainable forest use.

ACKNOWLEDGEMENTS

The authors wish to thank charcoal supply chain actors in Kwale and Taita Taveta counties of Kenya for their participation and considerable contribution to the study. Prof Björn Lundgren and two anonymous reviewers are gratefully acknowledged for their valuable comments. The authors gratefully acknowledge the Swedish Research Council Formas for financial support of this project (Project no. 2017-00210).

REFERENCES

ANGELSEN, A., JAGGER, P., BABIGUMIRA, R., BELCHER, B., HOGARTH, N.J., BAUCH, S., BOERNER, J., SMITH-HALL, C., and WUNDER, S. 2014. Environmental income and rural livelihoods: A global-comparative analysis. *World Development* **64**(Supplement 1): S12–S28.

BAILIS, R., DRIGO, R., GHILARDI, A., and MASERA, O. 2015. The carbon footprint of traditional woodfuels. *Nature Climate Change* **5**: 266–272.

BARRATT, M., CHOI, T.Y., and LI, M. 2011. Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations Management* **29**: 329–342.

BAUMERT, S., LUZ, A.C., FISHER, J., VOLLMER, F., RYAN, C.M., PATENAUDE, G., ZORRILLA-MIRAS, P., ARTUR, L., NHANTUMBO, I., and MACQUEEN, D. 2016. Charcoal supply chains from Mabalane to Maputo: Who benefits? *Energy for Sustainable Development* **33**: 129–138.

BERK, J., and DEMARZO, P. 2020. *Corporate Finance* 5th ed. Pearson, Harlow, UK.

BOLWIG, S., PONTE, S., DU TOIT, A., RIISGAARD, L., and HALBERG, N. 2010. Integrating Poverty and Environmental Concerns into Value-Chain Analysis: A Conceptual Framework. *Development Policy Review* **28**: 173–194.

CALDERA, H.T.S., DESHA, C., and DAWES, L. 2017. Exploring the role of lean thinking in sustainable business practice: A systematic literature review. *Journal of Cleaner Production* **167**: 1546–1565.

CARTER, C.R., and ROGERS, D.S. 2008. A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management* **38**: 360–387.

CERUTTI, P.O., SOLA, P., CHENEVOY, A., IIYAMA, M., YILA, J., ZHOU, W., DJOUDI, H., ATYI, R.E., GAUTIER, D.J., GUMBO, D., KUEHL, Y., LEVANG, P., MARTIUS, C., MATTHEWS, R., NASI, R., NEUFELDT, H., NJENGA, M., PETROKOFSKY, G., SAUNDERS, M., SHEPHERD, G., SONWA, D.J., SUNDBERG, C., and VAN NOORDWIJK, M. 2015. The socioeconomic and environmental impacts of wood energy value chains in Sub-Saharan Africa: a systematic map protocol. *Environmental Evidence* **4**.

CHIDUMAYO, E.N., and GUMBO, D.J. 2013. The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. *Energy for Sustainable Development* **17**: 86–94.

CHOPRA, S. 2019 *Supply chain management – Strategy, planning, and operation.* Pearson, Harlow, UK.

DFID. 1999. Framework of Sustainable Livelihoods. Department for International Development, UK.

DOGGART, N., and MESHACK, C. 2017. The Marginalization of Sustainable Charcoal Production in the Policies of a Modernizing African Nation. *Frontiers in Environmental Science* **5**.

FAO. 2017. The charcoal transition: greening the charcoal value chain to mitigate climate change and improve local livelihoods, by J. van Dam. Rome, Food and Agriculture Organization of the United Nations.

FAO. 2020. FAOSTAT. http://www.fao.org/faostat/en/#data/FO, accessed 11-Feb-20

FAULKNER, W., and BADURDEEN, F. 2014. Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance. *Journal of Cleaner Production* **85**: 8–18.

IEA. 2019. *Africa Energy Outlook 2019*. International Energy Agency. Paris.

JAGGER, P., and SHIVELY, G. 2015. Taxes and Bribes in Uganda. *Journal of Development Studies* **51**: 66–79.

KHUNDI, F., JAGGER, P., SHIVELY, G., and SSERUNKUUMA, D. 2011. Income, poverty and charcoal production in Uganda. *Forest Policy and Economics* **13**: 199–205

KING, P.L. 2015. *Value Stream Mapping for the Process Industries*. Apple Academic Press Inc.

KIRUKI, H. M., VAN DER ZANDEN, E. H., MALEK, Ž., and VERBURG, P. H. 2017. Land Cover Change and Woodland Degradation in a Charcoal Producing Semi-Arid Area in Kenya. *Land Degradation & Development* **28**: 472–481.

KNBS. 2019. Kenya Population and Housing Census. Volume III: Distribution of Population by Age and Sex. Kenya National Bureau of Statistics. Nairobi, Kenya. https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-iii-distribution-of-population-by-age-sex-and-administrative-units. Accessed 30 September 2020.

KRAJEWSKI, L.J., MALHOTRA, M.K., and RITZMAN, L.P. 2019. *Operations Management – Processes and Supply Chains* 12th ed. Pearson, Harlow, U.K.

LAMBERT, D.M., and COOPER, M.C. 2000. Issues in supply chain management. *Industrial Marketing Management* **29**: 65–83.

MIKKELSEN, B. 2005. *Methods for development work and research – a new guide for practitioner*s. SAGE.

MILES M.B., and HUBERMAN A.M. 1994. *Qualitative data analysis – an expanded sourcebook.* SAGE.

MUTIMBA, S., and BARASA, M. 2005. *National Charcoal Survey of Kenya: Exploring Potential for Sustainable Charcoal Industry in East Africa*. Energy Sustainable Development Africa.

NAUGHTON-TREVES, L., KAMMEN, D.M., and CHAPMAN, C. 2007. Burning biodiversity: Woody biomass use by commercial and subsistence groups in western Uganda's forests. *Biological Conservation* **134**: 232–241.

NDEGWA, G., ANHUF, D., NEHREN, U., GHILARDI, A., and IIYAMA, M. 2016. Charcoal contribution to wealth accumulation at different scales of production among the rural population of Mutomo District in Kenya. *Energy for Sustainable Development* **33**: 167–175.

NEEF, A., and NEUBERT, D. 2011. Stakeholder participation in agricultural research projects: a conceptual framework for reflection and decision-making. *Agriculture and Human Values* **28**: 179–194.

NJENGA, M., KARANJA, N., MUNSTER, C., IIYAMA, M., NEUFELDT, H., KITHINJI, J., and JAMNADASS, R. 2013. Charcoal production and strategies to enhance its sustainability in Kenya. *Development in Practice* **23**: 359–371.

OPENSHAW, K. 2010. Biomass energy: Employment generation and its contribution to poverty alleviation. *Biomass and Bioenergy* **34**: 365–378.

PAIN, R., and FRANCIS, P. 2003. Reflections on participatory research. *Area* **35**: 46–54.

PRITCHARD, C., and MOLONY, T. 2011. *The Kenya Charcoal Policy Handbook – Current Regulations for a Sustainable Charcoal Sector*. Practical Action Consulting East Africa.

REPUBLIC OF KENYA. 2013. *First County Integrated Development Plan 2013*. County Government of Kwale.

REPUBLIC OF KENYA. 2018. *County Integrated Development Plan 2018–2022*. County Government of Taita-Taveta.

REPUBLIC OF KENYA. 2019. *Kenya Household Cooking Sector Study.* Ministry of Energy, Nairobi.

ROTHER, M., and SHOOK, J. 1999. *Learning to see. Value stream mapping to create value and eliminate muda*, Version 1.2, A lean tool kit method and workbook. The lean enterprise institute, Brookline – Massachusetts.

SCHURE, J., LEVANG, P., and WIERSUM, K.F. 2014. Producing Woodfuel for Urban Centers in the Democratic Republic of Congo: A Path Out of Poverty for Rural Households? *World Development* **64**: S80–S90.

SEDANO, F., SILVA, J.A., MACHOCO, R., MEQUE, C.H., SITOE, A., RIBEIRO, N., ANDERSON, K., OMBE, Z.A., BAULE, S.H., and TUCKER, C.J. 2016. The impact of charcoal production on forest degradation: a case study in Tete, Mozambique. *Environmental Research Letters* 11.

SEURING, S., and MUELLER, M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production* **16**: 1699–1710.

SHACKLETON, S., PAUMGARTEN, F., KASSA, H., HUSSELMAN, M., and ZIDA, M. 2011. Opportunities for enhancing poor women's socioeconomic empowerment in the value chains of three African non-timber forest products (NTFPs). *International Forestry Review* **13**: 136–151.

SHIVELY, G., JAGGER, P., SSERUNKUUMA, D., ARINAITWE, A., and CHIBWANA, C. 2010. Profits and margins along Uganda's charcoal value chain. *International Forestry Review* **12**: 270–283.

SMITH, H.E., HUDSON, M.D., and SCHRECKENBERG, K. 2017. Livelihood diversification: The role of charcoal production in southern Malawi. *Energy for Sustainable Development* **36**: 22–36.

SOLA, P., CERUTTI, P.O., ZHOU, W., GAUTIER, D., IIYAMA, M., SCHURE, J., CHENEVOY, A., YILA, J., DUFE, V., NASI, R., PETROKOFSKY, G., and SHEPHERD, G. 2017. The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: a systematic map. *Environmental Evidence* **6**: 4.

THE KENYA GAZETTE. 2018. Vol. CXX – No. 28, 26th February 2018. Nairobi, Kenya.

UN GENERAL ASSEMBLY. 2015. Transforming our world: the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1, available at: https://www.refworld.org/docid/57b6e3e44.html, accessed 13 August 2020.

VAMSI KRISHNA JASTI, N., and SHARMA, A. 2014. Lean manufacturing implementation using value stream mapping as a tool: A case study from auto components industry. *International Journal of Lean Six Sigma* **5**: 89–116.

VOLLMER, F., ZORRILLA-MIRAS, P., BAUMERT, S., LUZ, A.C., WOOLLEN, E., GRUNDY, I., ARTUR, L., RIBEIRO, N., MAHAMANE, M., and PATENAUDE, G. 2017. Charcoal income as a means to a valuable end: Scope and limitations of income from rural charcoal production to alleviate acute multidimensional poverty in Mabalane district, southern Mozambique. *World Development Perspectives* **7–8**: 43–60.

YIN, R.K. 2014. *Case Study Research – Design and Methods* (5th ed.). SAGE, Thousand Oaks, CA, United States.

ZORRILLA-MIRAS, P., MAHAMANE, M., METZGER, M.J., BAUMERT, S., VOLLMER, F., LUZ, A.C., WOOLLEN, E., SITOE, A.A., PATENAUDE, G., NHANTUMBO, I., RYAN, C.M., PATERSON, J., MATEDIANE, M.J., RIBEIRO, N.S., and GRUNDY, I.M. 2018. Environmental Conservation and Social Benefits of Charcoal Production in Mozambique. *Ecological Economics* **144**: 100–111.