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Evaluating charcoal producers' preferences for improved production systems in Marigat sub county, Baringo County

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ABSTRACT

Many households in Kenya depend on charcoal as an important source of energy. However, overharvesting of trees and the use of inefficient technologies promote unsustainable charcoal production. Furthermore, high demand for charcoal from slow-growing indigenous species contributes to increased pressure in the drylands, threatening future supply and livelihoods. Recent studies have shown that *Prosopis juliflora* an invasive species introduced to arrest desertification equally produces quality charcoal. Also, improved technologies with more efficient carbonization rates have the potential to reduce not only the number of trees harvested but also quality of charcoal. Despite the existence of improved technologies, and the presence of fast-growing *Prosopis juliflora*, charcoal production remains unsustainable in Baringo County. This study used choice experiments (CE) to determine charcoal producers willingness to pay (WTP) for improved charcoal production system in Marigat sub-county.The attributes measured include charcoal quality, wood quality, *P.juliflora* growth trend and kiln type. Primary data was collected from a sample of 384 randomly selected charcoal producers using a semi-structured questionnaire. Study results indicate that charcoal producers were willing to pay more charcoal quality improvement which is associated with improved production systems and quality wood. However, they were not willing to pay for improved kilns. The findings suggest that the charcoal producers have a natural inclination to improved technologies with the study recommending charcoal producer association (CPA) membership as the first and efficient point of contact to adopt and use improved technologies.

1. Introduction

Woodfuel (especially charcoal and firewood) is an important source of energy for cooking and heating for more than 60% of people in Kenya (MoE and CCAK, 2019). Charcoal consumption among rural households is 40% and 47% for those in the urban setup with a weekly consumption of about 7.9 and 7 kilograms respectively (MoE and CCAK, 2019). Approximately 40-75% of charcoal is produced in Kenyan drylands (Burrow and Mogaka, 2007; Iiyama et al, 2014; KFS, 2017) and producers in these areas source wood from individual farms (MoE, 2002; Mutimba and Barasa, 2005). However, still a 55% of national charcoal deficit exists (MENWR, 2013).

The demand for charcoal is projected to increase with the growing population and household preferences demanding more trees to be harvested (MoE, 2002; KFS, 2013). Slow growing *Acacia sp* are the most preferred as they produce high-quality charcoal (Oduor et al, 2012). However, the use of inefficient technologies (kilns) and over-harvesting of these tree species for charcoal production are considered as major drivers of environmental degradation (Ahrends et al, 2010; Iiyama et al, 2014) thus negatively impacting the social-economic welfare of people in these areas. For instance, 99% of charcoal producers in Kenya (Mutimba and Barasa, 2005) and 100% in Baringo county (Ndegwa et al, 2021) use traditional kilns with low wood conversion efficiency of 10-14% (Okello et al., 2001; Mutimba and Barasa, 2005; KFS, 2013) resulting to lesser output as compared to the biomass harvested.

Kenya has made deliberate efforts to meet the rising national energy demands such as rural electrification, investing in renewable energy sources such as solar, geothermal and wind energy. However, a significant growth and importance continues to be noted in the charcoal sub-sector for the period 2004-2012 with an estimated national revenue of over US$ 1.28 (Mutimba & Barasa, 2005; MEWNR, 2013). The same studies indicated that the sector supported 1 million people with over two million dependents signifying the vital role of charcoal

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in the country. Among the beneficiaries include different charcoal value chain players such as transporters, traders and consumers.

The presence of the invasive *P.juliflora* species in drylands areas is a threat to biodiversity (Mooney, 2005) and livelihoods (Mbaabu et al., 2019). However, studies have indicated that it is a potential feedstock that produces quality (high calorific value) charcoal (Oduor and Githiomi, 2013). A study conducted in Baringo in October 2019 showed that local communities obtain fourteen different products and services from *Prosopis juliflora* where men and female separately ranked charcoal as number one (Njenga et al., 2019*)*. Further, Mbaabu et al., (2019) noted that management by utilization targeting the invasive species using improved technologies will improve people's livelihood and the environment.

Recent studies focused on charcoal production in Kenyan drylands have indicated the limited use of improved production technologies with higher wood conversion rate compared to the rudimentary methods. For instance the use of improved charcoal production technologies was only limited to Voi sub-county under the sustainable land management (SLM) Project. Also, the drum kilns introduced by Kenya Forest Network were limited to only Mwatate sub-county (Wanjala, 2016). Similarly, the use of traditional kilns is prevalent in the study area (Ndegwa et al, 2021). Key hindering factors among producers to adopting improved production technologies include limited expertise, high set up and maintenance cost, and lack of mobility for some of kilns (Kitheka et al., 2019).

Therefore, there is need for an elaborate approach to be incorporated in decision making in meeting energy demands, livelihoods and protecting the environment. As such, quantitative and monetary approach are the most suitable for elicitation of economic values on the different production systems for long term use and management of natural resources (Tallis and Polasky, 2009). The advantage of choice experiment, one of the stated preference techniques (SP) is that it has the ability to elicit the WTP information for individual attributes of the production system (Louviere et al, 2000).

It is against this background that a choice experiment study was carried out in Marigat sub-county with an aim of 1) estimating producers' WTP for improved production system and 2) evaluating factors influencing willingness to pay for improved charcoal technologies. Thus evidence from the study will be relevant for coming up with an effective way of managing the invasive species through charcoal production thus meeting the rising charcoal demand as well as improving charcoal producers' livelihoood.

2. Methodological approach

2.1. Study area

The study was undertaken in Marigat sub-county of Baringo County in Kenya (Figure 1). The study site is located 250km west of Nairobi city with an altitude of 1067 metres above sea level (m.a.s.l) (Baringo County Government, 2018). According to the 2019 census, there were approximately 19,854 households in Marigat Sub County with a population of 90,955 people. Further, the census findings indicated that the average household size is 4.5 with the study area covering a total of 1,453.4 square kilometres (km^2) and a population density of 65/ people per km^2 (KNBS, 2019). Charcoal production is one of the dominant economic activity among 93.7% of the households in the study area (Ndegwa et al., 2021). Just like in Kitui and Kajiado counties, charcoal producers in the study area source wood from their farmlands for production (MEWNR, 2013). The dominant vegetation in the lowlands is *Vachelia spp* mainly deciduous shrubland and evergreen forests in the highlands (Mwangi and Swallow, 2008). For instance, the study area is comprised of *Acacia tortilis, Balanite aegyptica, Boscae spp* and bushes of *Salvadora persica* as some of the native vegetation (Andersson, 2005) covering only 23.7% of the land (Ndegwa et al., 2021). A joint initiative between the Government of Kenya and Food and Agricultural Organization (FAO) introduced *P. juliflora* in around 1983 under the Fuelwood Afforestation Extension Project (FAO, 1985). Currently, *Prosopis juliflora* has invaded most areas of the study area stretching from lowland surrounding areas of Lake Baringo to the northern and southern areas of Lake Bogoria (Undersson, 2005; Ng *et al.,* 2017).

2.2. Methods

2.2.1. Identification and selection of attributes

The first step in identifation of attributes was creating a list of the attributes in a charcoal production system. This was done through literature review and participartory rural appraisal (PRA) carried out during a reconnaisance visit to the study area. The information targeted in this stage included efficiency of the production systems, purchasing price of charcoal, training on production systems, environmental friendliness of different tecnologies, quantity and quality of output (charcoal) and wood, the trends of *P. juliflora,* and labour intensity needed in each system. A matrix comprising of improved production system attributes derived from literature review and PRA was developed and presented to the charcoal producers during a community action planning (CAP) meeting. A total of 160 (102 men and 58 women) participated in the CAP process across the study area with CAP meeetings held on different days. The respondents were then tasked with ranking of attributes considered to be important for an improved production system. This was done on a scale of 1-10, with each charcoal production attribute ranked in order of perceived importance in terms of the benefits provided to individual households in the community. The ranking process reduced the number of charcoal production attributes to be considered during the choice experiment as means of lowering participant fatigue (Alpizar *et al.,* 2001; Ryan and Gerard, 2003); as studies have shown that having more than four to five attributes in a choice set may affect the quality of the data collected due to task complexity and participant fatigue (Alpizar et al., 2001). The mean score was calculated by authors and the final outcome indicated that charcoal producers ranked the attributes of charcoal quality, wood quality, *P. juliflora* trend, technology, and cost of production, highly compared to the rest. In addition to the identified attributes, an additional attribute of payment vehicle that was familiar and reasonable with the respondents (Martin-Ortega et al., 2011) was identified together with the participants. By a consensus, the cost of installation of the production system was agreed with the respondents as their prefered payment vehicle. This payment vehicle was used in estimation of the willingness to pay for the other charcoal production attributes. The CAP also played an important role in the description of the attribute and their levels. Table 1 shows the attributes and the levels as assigned by CAP.

2.2.2. Experimental design

When creating a stated choice experiment, a complete model specification has to be determined with all the parameters to be estimated (Choice Metrics 2012). Based on the selected attributes three policy options were developed to include: two progressive options A and B that reflect choice of a more efficient charcoal production technology, and a third option C being the status quo or opt out option. After selecting the attributes and their levels, the study team generated a combination of attributes and levels that would appear in choice cards (Rodrigues et al., 2016). Such choice cards can be generated either through orthogonal or efficient designs. Orthogonal designs ensure a balance between attributes and their levels, as well as independence between estimates for all parameters (i.e. no correlation). Efficient designs aim to yield standard errors that are as low as possible during the estimation of parameters, and are currently preferred to orthogonal designs. For this study, the choice cards were generated using a multinomial logit model together with D-error measure to obtain an efficient design. A pilot study with about 30 respondents was used to obtain an efficient design, using orthogonal design choice cards generated with the software package Ngene (ChoiceMetrics, 2014). If any of the generated choice cards have

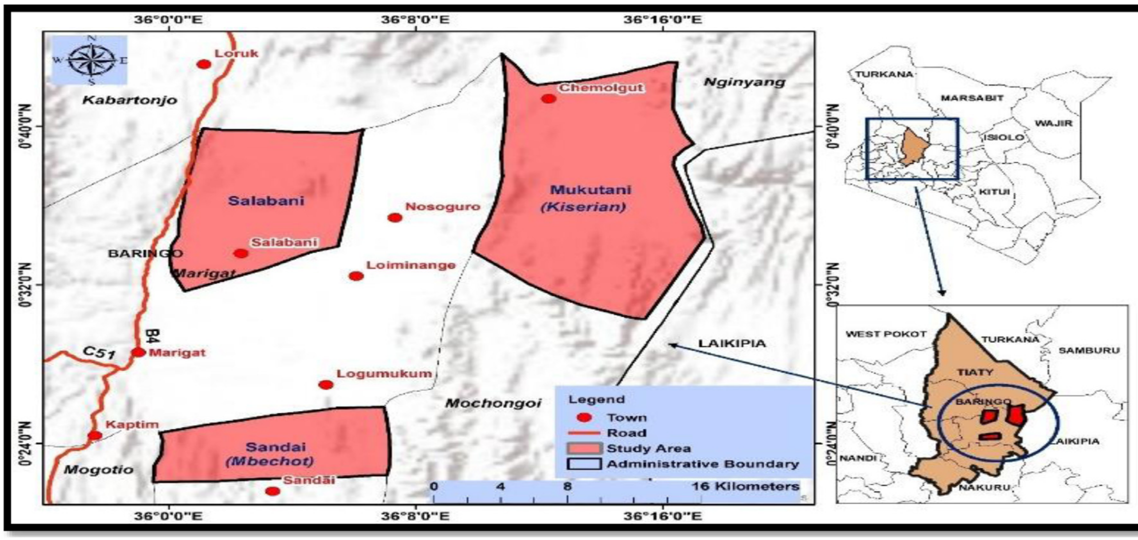

Fig. 1. Map of the study area.

Table 1
Attribute levels for choice experiment.

Attributes	Description	Levels assigned
Charcoal quality	The quality of charcoal produced in terms of (smoke produced during combustion, combustion time, weight and size)	a.) Good **b.) Poor**
Wood management	Appropriate practices done to ensure wood grows to the right size for charcoal production.	a.) High b.) Moderate **c.) Low**
Prosopis juliflora trend	Extent and regeneration of harvested trees species	a.) Declining b.) Stable **c.) Increasing**
Technology Used	Output of charcoal production to illustrate kiln efficiency	a.) Drum kiln (0.75 bag) in 0.5 days b.) 15 sacks for Improved earth kiln of the same size as an average traditional earth kiln 7 days **c.) 6 sacks of charcoal for an average Traditional Earth Kiln in 4 days**
Cost (the price of the kiln)	The price of kiln giving the cost for a certain system	a.) 6,000 b.) 5,500 c.) 3000 **d.) 500**

N/B: Bold represents current status, i.e. the current practice.

dominant alternatives, Johnson and Orme (1996) suggest that it is important to exclude implausible and dominant alternatives by including constraints at the design stage of the choice tasks. These constraints enable information on trade-off preferences as respondents normally prefer a dominant alternative, regardless of their preference (Boxall et al., 1996; Louviere et al., 2000). Trade-offs reflect an efficient design based on some of the principles associated with the design generation such as orthogonality, level balance, minimal overlap and utility balance (Mühlbacher and Johnson, 2016; Street and Burgess, 2007). However, constraints that exclude implausible combinations or dominant alternatives do introduce some degree of correlation and level imbalance in the experimental design (Johnson et al., 2013). Dominant alternatives also offer a test for measuring respondents' attentiveness to the attribute levels and definitions (Louviere et al., 2000). An alternative approach to avoid dominant choices in the choice cards is to identify the dominant choices in the experimental design and subsequently change the levels of one attribute to avoid dominance. This option was however not used, although it could have increased the utility of most of the choice cards. Instead dominant designs were included in the survey, mainly to avoid introducing correlation at the data analysis stage and to test participants' level of attentiveness. However, these were not included in data analysis since they do not yield the trade-offs required for choice experiment studies.

2.2.3. Questionnaire development and sampling

The study questionnaire consisted five sections. The first section was the consent form; the second section comprised introductory questions that ensure the respondents familiarity with the charcoal production technologies; the third section was the choice experiment; and the fourth was on debriefing questions aimed at establishing the reasoning behind the choices. The questionnaire was concluded with a final section on questions about the socio-demographic attributes of the participants. In the choice experiment we created a hypothetical market for charcoal production technologies, and we used pictograms to reduce the cognitive burden on participants (Davies et al., 2002). Prior to actual data collection, pretesting (n = 30) was carried out to test the efficacy and suitability of the choice sets and attribute descriptions. The sampling units in this study were households from across the selected sub-locations in the sub-county. Out of the 3,002 households in the study area, 2,453 households produced charcoal. Using the Yamane's (1967) formula, the sample size of the study was calculated as follows (Equation 1);

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

From the above formula, n = the required sample size; N = the population size; e = the level of precision (standard value of 0.05). When Equation 1 is applied to the above study population, the sample size is arrived at as follows (Equation 2);

$$n = \frac{2453}{1 + 2453(.05)^2} = 344 \tag{2}$$

2.2.4. Theoretical and Empirical models

The Lancaster theory of value (Lancaster, 1966) and the McFadden's random utility theory (McFadden, 1974) form the theoretical basis for the analysis of the participants stated choices. In modelling these discrete choices, the conditional logit (CL) model is used (Hensher et al., 2005). The CL model assumes that the error terms are independently and identically distributed (IID) over alternatives and individuals. This means that irrelevant alternatives with non-zero probability are independent of each other, and are thus unaffected by the introduction or removal of additional alternatives in the choice set (Louviere et al., 2000). Though computationally convenient, the IID is unlikely to hold if there is unobserved preferences heterogeneity among respondents (Louviere et al., 2000). In this case, the use of CL will lead to biased estimates. Therefore, there is a need to use a model that avoids the IID assumption such as the mixed logit (ML). Given a decision-maker who faces a choice among J alternatives, the utility of person i from alternative j is specified as;

$$U_{ij} = \beta_i' x_{ij} + \varepsilon_{ij} \tag{3}$$

Where x_{ij} are the observed variables that relate to the alternative and decision maker, β_i' is a vector of the coefficients, and ε_{ij} is the random error term. According to Hensher et al. (2005), these coefficients vary among the population with density function $f(\beta_i|\theta)$. The density function represents the individual preference heterogeneity in the sampled population. The vector θ comprises parameters characterizing the density function that captures individual deviations from the mean (Hensher et al., 2005). The decision-maker knows the value of his/her own $\beta_i s$ and $\varepsilon_{ij}s$ for all j and chooses alternative m iff $U_{im} > U_{ij}\ \forall j \neq m$. The researcher does not know β_i and therefore cannot condition β. Therefore, the unconditional choice probability over all possible β_i i.e. mixed logit probability is given by;

$$P(U_{im} > U_{ij}) = \int_{i=1}^{N} \int_{j=1}^{J} \left(\frac{e^{\beta_i' x_{im}}}{\sum_J e^{\beta_i' x_{ij}}} \right) f(\beta) d(\beta)| \tag{4}$$

Several distributions for the coefficients can be assumed for the above probability distribution, e.g. normal, lognormal, uniform or triangular (Hensher et al., 2005), which should be specified during the analysis. If the analyst intends to constrain the parameter estimates to some specific sign (positive or negative), a triangular distribution with the standard deviation restricted to equal the mean, or lognormal distribution can be used. The challenge with lognormal distribution is the asymptotic nature of the tails, which could be problematic in WTP estimations. There is an assumption that normal distribution will not constrain the parameter estimates to any specific sign, which might lead to counter intuitive results such as a positive sign for the cost attribute (Hensher et al., 2005; Kragt and Bennett, 2011).

2.2.5. Generation of choice cards

Based on the attribute levels identified in Table 1, a fractional factorial design using Ngene (Choice Metrics) software was run and resulted in 24 possible combinations for the study (Choice Metrics, 2012). The combinations were grouped into four groups and each respondent was presented with 6 choice sets. Each card consisted of two options and the status quo or opt out option. The other first two options (A and B) represented the experimentally designed options (of improved charcoal production systems) consisting of a balanced combination of the levels for each attribute. Figure 2 represents an example of a choice card used for the study.

2.3. Data collection

A pre-tested semi-structured questionnaire was used on sampled households for this study, which were households from six sub-locations namely (Kiserian, Salabani, Iling'arwa, Eldume, Ng'ambo and Maji Ndege) in Marigat sub-county, selected because of a high prevalence of charcoal production and presence of *P. juliflora*. A systematic random sampling was employed in picking respondents. Based on charcoal producing households' population of 2453, six experienced and qualified research assistants conversant with the local language visited every 6th household to administer the questionnaires using open data kit (ODK). A 10% attribution rate was allowed to take care of the non-responses and spoiled questionnaires and a total of 384 responses were collected. In determining charcoal producers willingness to pay for improved production system, the respondents were presented with the choice cards and the options. To ensure the responses captured the position of the entire household, the research assistants ensured that the respondents were well informed before picking a response. The cost implication of the options presented indicated their monetary value of the system chosen. The enumerators also played a key role in breaking down the information presented in the local dialect to the level of respondent's understanding. The marginal value of a change in one attribute was measured through the ratio of the two coefficients giving the willingness to pay as shown in the equation 5.

$$wtp = -\frac{\beta_{Attribute}}{\beta_{cost}} \tag{5}$$

3. Results and discussions

3.1. Demographic information

Relatively more men interviewed (51.3%) produced charcoal compared to women (48.7%) with a mean respondent age of 36.8 years. Majority of the respondents (81.3%) earned a monthly income of below Kenyan shilling (KES) 20,000, 16.0% earned KES 20,001-50,000 and 2.7% earned KES 50,001-75,000. Charcoal production among respondents did not depend on land ownership since both landowners and internally displaced persons[1] (IDPs) engaged in the activity. The largest land owned was 40 acres with the mean land size ownership being 5.2 acres. A majority of respondents (75.6%) preferred clear cutting as a method of managing the invasive species within their farms. The other 24.4% of the respondents practised coppicing as a method of managing *P. juliflora*. More than half of the sampled population attained upper primary (class 5 to 8) education, while only 7.6% of the population reported to having not attended any form of basic education.

A small percentage (12.2%) of the respondents were members of CPAs in the area compared to a majority (87.8%) who were non-members. This is despite the important role CPAs play in sustainable charcoal production as stipulated by the charcoal Rules 2009. Some of these CPAs include Cumins, Charcoal Farmers Association, Ilchamus CPA, Nalipo Self Help Group, Lokasacha, Nadupa group, Minkichooyo group, and Field Farmers School. From the focus group discussion (FGD), the main barriers to joining associations by the non-members were lack of associations to join,and mistrust among members. To create space for arable land, clearing of land is a common practice and results in residues used for charcoal production (Mutimba and Barasa, 2005; KFS, 2013; Ndegwa et al 2019). This explains the large percentage of

[1] Internally displaced persons (producing charcoal) did not own land as per the time of the study.

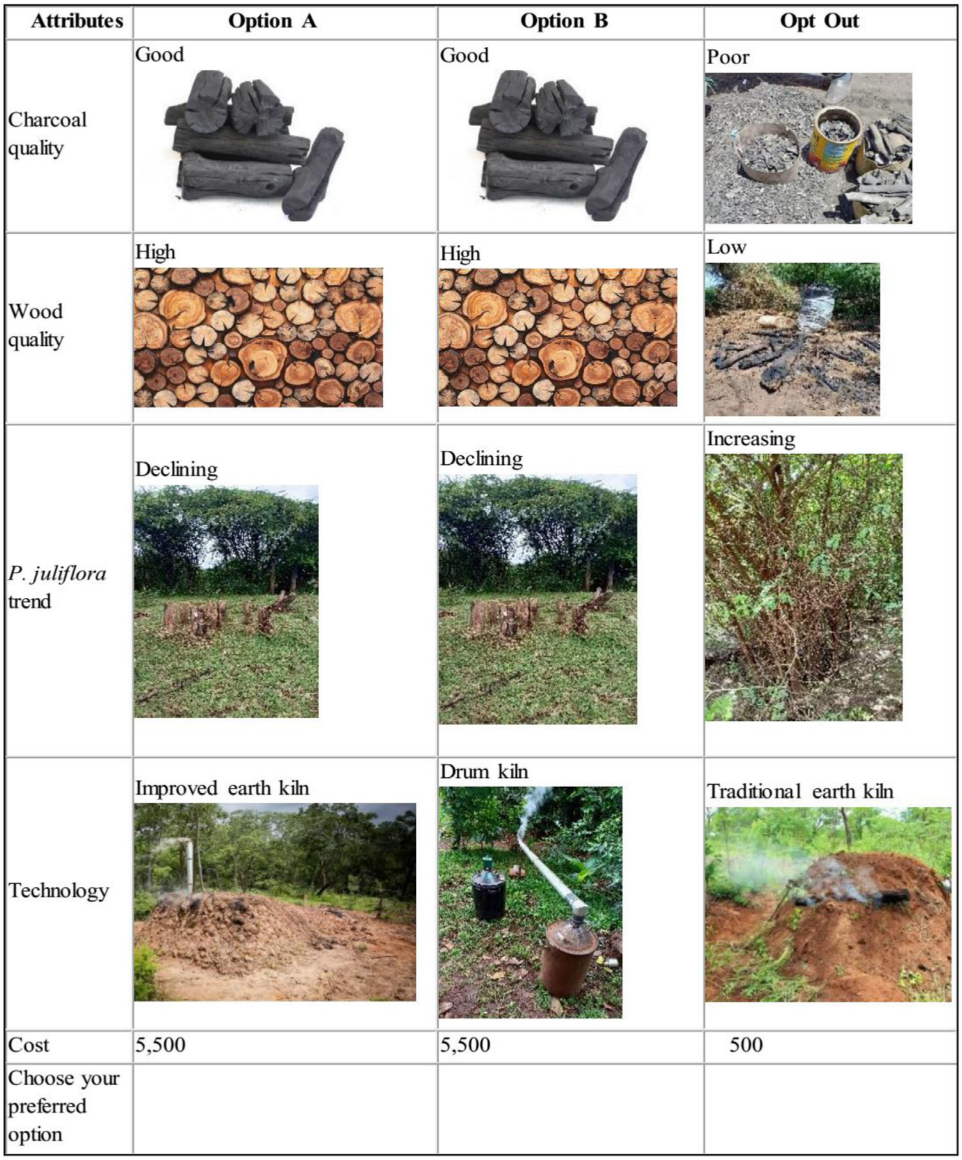

Fig. 2. Sample of choice card used in the study.

respondents practising clear cutting as a method of managing the invasive *P. juliflora*. Also, Eckert et al (2020) indicated that the invasive species regenerates at a very high rate.

3.2. Willingness to pay for improved charcoal production

Two discrete choice models i.e. Conditional Logit and Mixed logit model were deployed for the estimation of determinants of willingness to pay for improved charcoal production technologies and each was run four times covering various parameters including main effects only models; main effects and alternative specific constant models; main effects and interactive effects with alternative specific constants; and main effects with interactive effects, alternative specific constants, and with cross effects. Hensher and Johnson (1981) observed that a model with the highest McFadden's pseudo R-squared is a better fit compared to others over the same data, and so are models with higher/bigger log-likelihood also considered to be a better fit than one with smaller log-likelihood. The best fit was observed for both conditional and mixed model with interaction terms and it is only these results that have been presented as shown in Table 2.

From the results in Table 2, the alternative specific constant of the status quo (opt out option) was negative and statistically significant, an indication that respondents had a natural inclination towards the options of improved charcoal production technologies (i.e. options A & B). The statistically significant and positive coefficient shows that respondents preferred quality charcoal associated with improved charcoal production system and use of high wood quality. The negative sign of the coefficient showed that respondents preferred a declining trend of the *P. julisflora* plant. This could be because of its ubiquity in the area and fast growth which suppresses growth of other plants. The findings are in agreement with the argument of Mbaabu et al. (2019) that increase in the spread of *P. juliflora* negatively impacts the livelihood of residents in the drylands areas. Its coefficient was, however, not statistically significant indicating that it was not an important determinant of charcoal producers' willingness to pay for improved charcoal production technologies. Also, the negative coefficient of kiln technology showed that respondents preferred the existing traditional charcoal production technology to a more improved one presented by the drum kiln or improved earth kiln. The statistically significant and negative coefficient of the cost attribute showed producers were less inclined to pay for improved

Table 2
Conditional and Mixed logit Results for the choice experiment study.

Variables	Conditional logit model	Mixed logit model
ASC (status quo)	−1.2482**	−5.1599***
Charcoal quality	1.2482***	6.3542*
Wood quality	0.1381**	0.1480***
Kiln technology	−0.0231***	−0.0139
Trends in *Prosopis juliflora*	−0.3214	−0.4755
Cost (lncost)	−0.1937***	−0.2276**
Kiln*HH	−0.0011	−0.00096
HH*Prosopis	−0.0425***	−0.0098
Age*ASC	0.0126*	−0.0141
CPA*ASC	0.3378*	1.9095*
Edu*ASC	−0.1973***	−1.6274***
Gender*ASC	0.4750***	1.7199***
Income*ASC	0.00001***	0.00011***
Knowledge*ASC	0.08195	0.0475
Frequency*Kiln	−0.00953*	−0.0065
Knowledge*Prosopis	0.1716	0.1552
Summary statistics		
Log−likelihood	−2230.2784	−1819.8724
McFadden Pseudo-$\boldsymbol{R}^2$	0.0972	–
AIC	4490.557	3697.745
BIC	4592.807	3895.429
No. Observations and respondents	6746	6746

** indicates that the coefficient is significant at 90% confidence level
*** indicates that the coefficient is significant at 99% confidence level
* indicates that the coefficient is significant at 95% confidence level

Table 3
Marginal willingness to pay in US$.

	Charcoal quality	Wood quality	*P. juliflora* trend	Kiln type
Mixed Logit WTP	27.92	0.650	-.061	-2.09
Conditional Logit WTP	6.44	0.713	-0.12	-0.166

charcoal production systems, though they were more inclined to cheaper technologies.

Results from the mixed logit model were used to compute the marginal willingness to pay (MWTP) (Hanley et al, 2001). The results of MWTP[2] presented in Table 3 showed that producers disapproved the current trend of increasing *P. juliflora* and have a negative willingness to pay of US$ -0.061. The producers are however willing to pay US$ 27.92 to produced good quality of the charcoal as opposed to the poor quality they are currently producing. An improvement in wood quality is also critical in the production process and charcoal producers are willing to pay US$ 0.65 for access to improved wood quality. Although improved kilns such as drum kilns and improved earth kiln require initial capital and expertise, they produce more and better quality charcoal compared to the traditional ones, and producers have a negative willingness to pay of US$ -2.09 for these kilns. A possible explanation for the negative utility from kiln type attribute is the dominant use of traditional earth mound kiln (Ndegwa et al. 2021) which is easy and requires little capital to install and manage (FAO and Climate Care, 2014).

The interations between the different socio-economic factors and the ASC for the status quo option are an indicator of the respondents preferences to alternatives A and B. For instance members of CPA are likely to prefer the status quo option as shown by the positive interation term between the ASC and CPA. This is an unexpected result as CPAs play the role of information dissemination of charcoal production among members, thus enabling them to pool resources for purchasing improved technologies. The interation between education and ASC has a negative and significant sign, showing that individuals with a high level of education are likely to shun the status quo option and adopt other alternatives option. This expected as higher eduction exposes individuals to more information and more informed decision making. Gender (males = 1 and females = 0) and ASC were also interated, and the results show a postitive and significant result indicating that female producers are likely to prefer the other alternatives, while males prefer the status quo. An improvement in household welfare is likely to impact more on women, hence the result. Finally, income and ASC interation has a positive and significant coefficienct, indicating that households with higher incomes are likely to prefer the status quo option. This was not expected as these household have resources to adopt the modern charcoal production technologies and meet other accompanying costs.

4. Conclusion

The study aimed at finding out the monetary values that producers attach to the different production technology attributes. The study employed choice experiment in eliciting individual preferences among the suggested attributes. Key among important attributes considered in this study included, wood quality, charcoal quality, *P.juliflora* growth trend and kiln type.

Generally, charcoal production is not dependent on land ownership. In terms of socio-economic profile of charcoal producers, CPA membership and literacy level play an important role in adopting improved technologies. However, women are the likely beneficiaries of improved household welfare resulting from improved technologies suggesting that time and energy consumed in the construction of traditional kilns could be invested elsewhere to increase their livelihood. The study also found out that charcoal producers prefer quality charcoal which is associated with the use of quality wood and improved technologies. However, a negative willingness to pay for improved technologies is a major hindrance to producing quality charcoal. Based on the above findings, the study recommends sensitization of producers to join CPAs to enable pooling together of resources to purchase improved technologies, as the first point of contact of ensuring maximum use and adoption of these technologies and for effective information dissemination among members. Finally, the study proposes a system that encompasses social optimal levels of the attributes of production.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Ahrends, A., Burgess, N.D., Milledge, S.A.H., Bulling, M.T., Fisher, B., Smart, J.C.R., …, Lewis, S.L., 2010. Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. Proc. Natl. Acad. Sci. 107 (33), 14556–14561. doi:10.1073/pnas.0914471107.
Alpizar, F., Carlsson, F., Martinsson, P., 2001. Using choice experiments for non-market valuation. Work. Pap. Econ. 8, 1–37.
Andersson, S., (2005) Spread of the Introduced Tree Species *Prosopis juliflora* (Sw.) DC in the Lake Baringo Area, Kenya; Institutionen för Skoglig Vegetationsekologi Sveriges lantbruksuniversitet: UMEA, Sweden, pp. 1652–4918.

[2] Results of MWTP in USD (using a conversion rate of 1USD=KES 103.32)

Baringo County Government, (2018). Baringo *County Integrated Development Plan 2018-2022 (Report)*.

Boxall, P.C., Adamowicz, W.L., Swait, J., Williams, M., Louviere, J., 1996. A comparison of stated preference methods for environmental valuation. Ecol. Econ. 18, 243–253.

Burrow, E, Mogaka, H., 2007. Kenya's drylands – wastelands or an undervalued national economic resource. IUCN - The World Conservation Union, Eastern Africa Regional Office, Nairobi.

Choice Metrics. (2012). Ngene 1.1.1 User Manual & Reference Guide. Australia: Choice-Metrics.

Davies, A.M., Laing, R., Scott, S., 2002. Combining visualisation and choice experiments in built environment research. Proc. Int. Conf. Inf. Vis. 2002-Janua 785–790.

Eckert, S., Hamad, A., Kilawe, C.J., Linders, T.E.W., Ng, W.-T., Mbaabu, P.R., Shiferaw, H., Witt, A., Schaffner, U., 2020. Niche change analysis as a tool to inform management of two invasive species in Eastern Africa. Ecosphere 11 (2), e02987. doi:10.1002/ecs2.2987.

FAO and ClimateCare, (2014). Improving the Value chain of charcoal Production in Kenya: Kiln testing, producer group outline, value chain analysis in Baringo and Kasigau corridor and economic potential of carbon finance. FAO.

Hanley, N., Mourato, S., Wright, RE., 2001. Choice modelling approaches: A superior alternative for environmental valuation? J. Econ. Surv. 15 (3), 435–462.

Hensher, D.A., Rose, J.M., Greene, W.H., 2005. Applied Choice Analysis: A Primer. Cambridge University Press, Cambridge.

Hansher, D.A., Johnson, L.W., 1981. Applied discrete choice modelling. Croom Hell, London.

Iiyama, M., Neufeldt, H., Dobie, P., Hagen, R., Njenga, M., Ndegwa, G., Gasper Mowo, J., Kisoyan, P., Jamnadass, R., 2014b. Opportunities and challenges of landscape approaches for sustainable charcoal production and use.. World Agroforestry Centre (ICRAF), Nairobi ICRAF Policy Brief 31.

FAO (1985). Fuelwood and Afforestation Extension in Baringo. Draft report of the joint Government of Kenya/Government of Australia/FAO review mission on project GCP/KEN/051 (AUL)

Johnson, F.R., Lancsar, E., Marshall, D., Kilambi, V., Bs, B.A., Mu, A., Regier, D.A., Bresnahan, B.W., Kanninen, B., Bridges, J.F.P., (2013). Constructing Experimental designs for discrete-choice experiments: Report of the ISPOR conjoint analysis experimental design good Research Practices Task Force 6, 3–13.

Johnson, R.M., Orme, B.K., (1996). How many questions should you ask in choice-based conjoint studies.

KFS (2013). Analysis of the charcoal value chain in Kenya. A report commissioned by the Kenya Forest Service (KFS), coordinated by the National REDD+ Coordinating Office (NRCO) and carried out by Camco Advisory Services (Kenya) Limited. Nairobi, Kenya.

KFS (2017). Forest law enforcement and governance in Kenya. A paper prepared for the East African Community-led regional process in the framework of the Ministerial Declaration, Yaoundé, Cameroon, October 16, 2003 on the Africa Forest Law Enforcement and Governance (AFLEG). Nairobi, Kenya Forest Service (KFS).

Kitheka, E., Kimiti, J. M., Oduor, N., Mutinda, J. W., Ingutia, C., & Githiomi, J. (2019). Factors influencing adoption of biomass energy conservation technologies in selected areas of Kitui County, Kenya.

Kenya National Bureau of Statistics. (2019). 2019 Kenya population and housing census, volume III: Distribution of population by age and sex.

Kragt, M.E., Bennett, J., 2011. Using choice experiments to value catchment and estuary health in Tasmania with individual preference heterogeneity. Aust. J. Agric. Resour. Econ. 55, 159–179.

Lancaster J, K, 1966. A new approach to consumer theory. J. Polit. Econ 74 (2), 132–157.

Louviere, J.J., Hensher, D.A., Swait, J.D., 2000. Stated Choice Methods: Analysis and Application. Cambridge University Press, Cambridge.

Martin-Ortega, J., Giannoccaro, G., Berbel, J., 2011. Environmental and resource costs under water scarcity conditions: An estimation in the context of the European Water Framework Directive. Water Resour. Manage. 25, 1615–1633. doi:10.1007/s11269-010-9764-z.

Mbaabu, P.R., Ng, W.-T., Schaffner, U., Gichaba, M., Olago, D., Choge, S., ..., Eckert, S., 2019. Spatial evolution of prosopis invasion and its effects on LULC and livelihoods in Baringo, Kenya. Remote Sens. 11, 1217. doi:10.3390/rs11101217.

Ministry of Energy (MoE), and Cleaner Cooking Association of Kenya (CCAK). (2019). Kenya Household Cooking Sector Study. Assessment of the Supply and Demand of Cooking Solutions at the Household Level. Nairobi, Kenya.

McFadden L, D, 1974. Conditional logit analysis of qualitative choice behavior. In: Frontiers in Econometrics. Academic Press, New York (NY), pp. 105–142.

Ministry of Energy (MoE), Government of Kenya, 2002. Study on Kenya's Energy Demand, Supply and Policy Strategy for Households, Small Scale Industries and Service Establishments. Final Report for the Ministry of Energy. May, Kamfor Company Ltd.

Ministry of Environment, Water and Natural Resources (MoEWNR), Government of Kenya (GoK) 2013. Analysis of Charcoal Value Chain in Kenya GoK: Nairobi

Mooney, H.A., 2005. Invasive alien species: a new synthesis, 63. Island press.

Mühlbacher, A., Johnson, F., 2016. Choice experiments to quantify preferences for health and healthcare: state of the practice. Appl. Health Econ. Health Policy 14, 253–266.

Mutimba, S., and Barasa, M. (2005). Exploring the potential for a sustainable charcoal industry in Kenya. National Charcoal Survey: Energy for Sustainable Development Africa, Report, Nairobi 74 p.

Mwangi, E, Swallow, B., 2008. *Prosopis juliflora* Invasion and Rural Livelihoods in the Lake Baringo area of Kenya. Conserv. Soc. 6, 130–140.

Ndegwa, G, Sola, P, Siko, I, Kirimi, M, Wanjira, EO, Koech, G, Ihalainen, M, Iiyama, M, Muriuki, J, Njenga, M., 2021. The charcoal value chain in Kenya: Actors, practices and trade flows in selected sites. World Agroforestry, Nairobi, Kenya Technical Report.

Ng,W.-T., Rima, P., Einzmann, K., Immitzer, M., Atzberger, C., Eckert, S. (2017). Assessing the Potential of Sentinel-2 and Pléiades Data for the Detection of Prosopis and *Vachellia* Spp. in Kenya. Remote Sens. 9, 74.

Njenga, M., Kirimi, M., Koech., G., Otieno, E., and Sola, P., (2019). *Training of Trainers (ToT) on sustainable Prosopis Juliflora woodfuel production and utilization in Baringo County, Kenya.* Bogor, Indonesia: Center for International Forestry Research (CIFOR). https://www2.cifor.org/wpcontent/uploads/sites/38/2019/11/ToT%20Sustainable%20Woodfuel%20Baringo%209-11%20October%202019%20V2.pdf.

Oduor, N. M., and Githiomi, J. K., (2013). Fuel-wood energy properties of Prosopis juliflora and Prosopis pallida grown in Baringo District, Kenya.

Oduor, N.M., Ngugi, W., Gathui, T.W., 2012. Sustainable tree management for charcoal production Acacia species in Kenya. Practical Action Consulting East Africa, Nairobi, Kenya.

Okello, B.D., O'connor, T.G., Young, T.P., 2001. Growth, biomass estimates, and charcoal production of Acacia drepanolobium in Laikipia, Kenya. Forest Ecol. Manag. 142 (1–3), 143–153. doi:10.1016/S0378-1127(00)00346-7.

Ryan, M., Gerard, K., 2003. Using discrete choice experiments to value health care programmes: current practice and future research reflections. Appl. Heal. Econ. Heal. 2, 55–64.

Rodrigues, L., Van den Bergh, J., Loureiro, M., Nunes, P., Rossi, S., 2016. The cost of Mediterranean Sea warming and acidification: a choice experiment among scuba divers at Medes Islands, Spain. Environ. Resour. Econ. 63, 289–311.

Street, D., Burgess, L., 2007. The construction of optimal stated choice experiments. Theory and Methods. John Wiley and Sons.

Tallis, H., Polasky, S., 2009. Mapping and valuing ecosystem services as an approach for conservation and natural-resource management. Ann. N. Y. Acad. Sci. 1162, 265–283.

Wanjala, M.C., 2016. Sustainable charcoal production technologies in Kenya: The case of Kwale, Narok and Taita Taveta counties. Final report on field project activities. Kenya Forest Service, Nairobi, Kenya.

Yamane, Taro., 1967. Statistics, An Introductory Analysis, 2nd Ed Harper and Row, New York.