Journal of Arid Environments 158 (2018) 9–18

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Economic impacts of *Prosopis spp*. invasions on dryland ecosystem services in Ethiopia and Kenya: Evidence from choice experimental data

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A R T I C L E I N F O

Keywords:
Prosopis
Ecosystem service
Discrete choice experiment
Random parameters logit
Willingness-to-pay
Individual preference heterogeneity

A B S T R A C T

Biological invasions can induce trajectories of changes that make ecosystems fragile and less reliable in providing services and goods. Here we set out to assess the economic value of dry land ecosystem services affected by the invasive tree Prosopis, which was originally introduced in Africa and elsewhere for providing firewood, animal fodder and other services to rural people. Based on choice experiment method, we estimated the economic values of dry land ecosystem services affected by Prosopis in the heavily invaded Afar region, Ethiopia and Baringo County, Kenya. Including labor and cash contributions as payment attributes, a random parameters logit model was employed for analyzing households' preferences for the affected ecosystem services. We found that, despite the services provided by Prosopis, households from both regions were willing to pay for its management primarily driven by biodiversity and water. WTP was on average higher in Afar (USD 50.42/year) than in Baringo (USD 37.74/year), which may be because the ecosystems in Afar were less degraded prior to the invasion by Prosopis than in Baringo and that charcoal production in Afar is officially prohibited. Our results indicate that the costs imposed by the deliberately introduced Prosopis outweigh its benefits in both Afar and Baringo.

1. Introduction

Dryland ecosystems in Eastern Africa provide numerous goods and services to about 30 million pastoralists and agro-pastoralists (Davies and Hatfield, 2007; Kassahun et al., 2008). For example, their products constitute 35% and 50% of the agricultural gross domestic product (GDP) in Ethiopia and Kenya, respectively (Davies and Hatfield, 2007). In addition, dryland ecosystems in Eastern Africa are home to a large diversity of charismatic animal and plant species supporting cultural services such as tourism (Witt and Luke, 2017). However, over the past decades the dryland ecosystems of the region have experienced broad and dynamic trajectories of ecological degradation, with significant socio-economic consequences for the rural communities inhabiting these ecosystems (Martín-Llópez et al., 2008). Key factors driving degradation of dryland ecosystems degradation in Eastern Africa include over-grazing, conversion to agriculture and enchroachment by invasive alien species (IAS) (Witt and Luke, 2017).

Prosopis spp. (hereafter referred to as *Prosopis*) is a group of closely related woody plant species and hybrids that were introduced in the region in the late 1970s and early 1980s for different environmental and socio-economic benefits (Pasiecznik et al., 2001). For instance, *Prosopis* was introduced in Ethiopia to curb desertification (Haregeweyn et al., 2013) and in Kenya to alleviate the negative effects of deforestation (Mwangi and Swallow, 2008). *Prosopis* can also serve as shade and wind break, as a source for firewood, charcoal production and construction material and regulate microclimate (Pasiecznik et al., 2001; Maundu et al., 2009; Tilahun et al., 2016).

However, soon after its introduction, *Prosopis* started escaping from the plantations and invading the surrounding natural and semi-natural ecosystems, thereby threating biodiversity, reducing fodder for livestock production and causing ground water depletion (Maundu et al., 2009; Wise et al., 2012; Shackleton et al., 2014). In addition, its rapid encroachment into pathways, homesteads and water points limits mobility of animals and humans and causes body injury (Mwangi and Swallow, 2008; Haregeweyn et al., 2013; Ayanu et al., 2015).

In Eastern Africa, some uncoordinated attempts have been made to manage the invasion of *Prosopis*, but with little success so far. Invasion appears to continue at an alarming rate, thereby creating fragile and less resilient ecosystems (Maundu et al., 2009; Ilukor et al., 2016; Wakie et al., 2016). A possible explanation of the lack of a concerted action to manage *Prosopis* in the region may be a lack of sound quantitative and comprehensive empirical monetary values on the impacts

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https://doi.org/10.1016/j.jaridenv.2018.07.001
Received 18 December 2017; Received in revised form 20 May 2018; Accepted 3 July 2018
Available online 17 July 2018
0140-1963/

of the invasion (Martín-López et al., 2008; Wise et al., 2012; Costanza et al., 2014). Understanding the changes in ecological and socio-economic values due to ecosystem degradation is essential for making empirically sound decisions in environmental management (Martín-López et al., 2008; Gómez-Baggethun et al., 2009; Pejchar and Mooney, 2009; Costanza et al., 2014; Freeman et al., 2014). Yet, the intricate nature of the dryland ecosystems in Eastern Africa and the societal values that govern pastoralists' and agro-pastoralists' economic and social interactions with their environment pose critical challenges in estimating values on the economic consequences of the pressure *Prosopis* exerts on pastoral and agro-pastoral ecosystems. In these dryland ecosystems, most natural resources are common property (rival but non-excludable) and have non-market values in which conventional market systems and privatization frameworks are inapplicable for valuating impacts on environmental resources (Sagoff, 1998). To assess the value of ecosystem services (ES) affected by IAS, or by their management, an approach that is suitable for non-market services should be applied to estimate values of ecosystem goods and services, rather than using conventional methods used for producing valid market-value estimates (Costanza et al., 2014).

A plausible way to overcome such challenges is to consider the changed value perceived by the community that generates benefits from a given ecosystem (Pearce and Turner, 1990; Sagoff, 1998; Kontoleon et al., 2007; Barkmann et al., 2008; Gómez-Baggethun et al., 2009; Kenter et al., 2011; Costanza et al., 2014; Vaz et al., 2017). Values which a community attaches to communal resources are functional in the framework of theory of collective action wherein individual members in the collectivity coordinate efforts to solve their communal encounters (Kenter et al., 2011; Freeman et al., 2014). Hence, economic valuation via willingness-to-pay (WTP) estimation of the effects of IAS on ES using ecosystem service approach (MA, 2005; Barkmann et al., 2008) can be a viable solution since it enables to comprehensively valuate the intricate linkage between the ecosystem and human welfare (Pejchar and Mooney, 2009).

The main aim of this study was to estimate the monetary values of ES affected by *Prosopis* in the drylands of Afar National Regional State (hereafter called Afar) in Ethiopia and Baringo County (hereafter called Baringo) in Kenya. The study was guided by the following questions: What ES are given due attention by the local communities in managing *Prosopis* invasion? Is there preference heterogeneity among households (HHs) in the study areas? What are the socio-economic determinants of preference heterogeneity that affects communities' WTP for *Prosopis* management strategies that can bring improvements in ES? What is the estimated economic value of the affected ES? In addition to these primary aims, the study intended to show the applicability of choice experiment (CE) method in ES valuation in subsistence economy of developing countries.

The underlying hypothesis was that the local communities in the study areas perceive that the negative effects of *Prosopis* invasion outweigh its positive effects and that they are willing to contribute to *Prosopis* management that will reduce the negative effects of *Prosopis* on ES. However, due to differences in perception (Barkmann et al., 2008; García-Llorente et al., 2008), HH demographic and socio-economic characteristics (Adamowicz et al., 1998; Train, 2003; Colombo et al., 2009; Kenter et al., 2011; Tilahun et al., 2016) preference heterogeneities are likely to prevail among HHs in the study areas. Further, owing to institutional differences, WTP may differ between HHs from Afar and Baringo.

2. Methods

2.1. Study areas

Both Afar Region in Ethiopia and Baringo County in Kenya are part of the Great Rift Valley of Eastern Africa. Afar Region is located between 39°34′ and 42°28′ East Longitude and 8°49′and 14°30′ North Latitude in the northeastern part of Ethiopia covering about 270,000 km^2. The region covers about 10% of the total landmass of Ethiopia and about 29% of pastoral lowlands. The region is in arid and semi-arid part of the country, with a mean annual temperature of 31 °C. Rainfall is erratic and scarce with annual precipitation between 200 mm and 600 mm. The major watershed in the Afar region is the Awash River Basin. The population of the region is estimated to be about 1.77 million (CSA, 2015). Pastoralism is the most dominant production system (87%). Agro-pastoralism which has emerged following development of small-scale irrigation schemes, accounts only for 13% of the economy. The Afar people highly depend on Awash River flood plain for grazing their livestock during the drought periods and for small-scale irrigation. Currently, the flood plains are either highly invaded or under risk of invasion by *Prosopis* (Ayanu et al., 2015; Ilukor et al., 2016).

Baringo County covers an area of 1015 km^2 and lies between Latitudes 0°13″ South and 1°40″ North and Longitudes 35°36″ and 36°30″ East (Mwangi and Swallow, 2008). The County has two distinct weather patterns, with temperatures in the southern part ranging between 25 °C during the cold months (June and July) and 30 °C during the hot months (January and February) while in the northern parts, temperatures range between 30 °C and 35 °C. It receives between 1000 mm and 1500 mm of rainfall annually in the highlands and 600 mm in the lowlands. The county has two rainy seasons, March to June (long rains) and November (short rains). The major economic activities include pastoralism, agriculture, honey production and sand harvesting (Maundu et al., 2009). Agricultural activities include dairy farming and maize, groundnuts, cotton and coffee production dominantly in the highlands. Pastoralism is practiced in the low-lying plains of the county where rearing of goats, sheep and cattle are the dominant livestock activities.

The main vegetation types in the two study areas comprise bush land, shrub land, riverine forests, grasslands and seasonal marshes and swamps. Currently, however, these vegetations are facing *Prosopis* encroachment.

2.2. Sampling procedure and survey administration

A combination of probability and non-probability sampling designs were applied at different stages of sample selections in each study area. Afar Region and Baringo County were selected purposively as both areas belong to the most heavily invaded areas in East Africa. In Afar, Amibara, Gewane and Awash Fentale districts were randomly selected from highly, moderately and low invaded districts, respectively. Following this, Kebeles with mean *Prosopis* invasion levels of 4–59% were identified in all the three districts in consultation with community representatives and local experts. Subsequently, using proportionate random sampling technique, five, three and two Kebeles were selected from Amibara, Awash Fentale and Gewane districts, respectively. The last stage involved simple random sampling with probability proportional to population size in selecting a total of 253 sample HHs from Afar region of Ethiopia.

Baringo County has six sub-counties of which Marigat and Kabarnet sub-counties are *Prosopis* invaded. From the two invaded sub-counties, Marigat sub-county was purposively selected as it is more invaded than Kabarnet. The sub-county consists of 11 locations which are further divided into 18 sub-locations. Using *Prosopis* invasion levels, these sub-locations were stratified into three. In the same fashion used for selecting sample *Kebeles* in Afar, 10 sub-locations were selected with invasion levels ranging from 7 to 68%, and finally a total of 250 sample HHs were selected using simple random sampling with probability proportional to population size. In both study areas, we used household as the unit of analysis.

Surveys were administered by trained local enumerators. In recruiting enumerators three main criteria were used in both the study areas; a minimum of diploma degree, experience in administering similar surveys and fluency with respective local languages. In order not to compromise quality of the data, three supervisors were also recruited for each sample study area. Training to the enumerators was delivered two times i.e. before and after HH pretest interviews. The second round training was given based on the feedback from enumerators about the difficulties and errors they encountered during the pretest.

2.3. Choice experiment design

Relying on utilitarian microeconomic theory, the study applied CE method, which is a family of stated preference (SP) valuation techniques. When compared to revealed preference (RP), SP valuation approach is more relevant since it accounts both for marketed and non-marketed values and since it enables to estimate both use and non-use values (in the Total Economic Value– TEV framework) of environmental changes (Bennett and Blamey, 2001; Freeman et al., 2014).

The SP valuation method consists of two economic valuation techniques: contingent valuation method (CVM) and CE method. The latter is suitable in valuing ES changes in detail ways (Adamowicz et al., 1998; Hanley et al., 2001; Hoyos, 2010). Though it is more complex and costly compared to CVM, CE method is more informative for policy making for multi-sectors as it applies multiple disaggregated attribute-based non-market values of changes (Hoyos, 2010). Again, it offers clues where to focus and which sectors should participate in designing and implementing viable management option(s) (Hanley et al., 2001). The CE estimates marginal values of each attribute of an ecosystem change and their relative importance or trade-offs inform environmental management practitioners. It enables them to gain a deeper understanding on the trade-offs between different attributes (Adamowicz et al., 1998; Hanley et al., 2001; Hoyos, 2010).

The approach involves evaluation of public's preferences by asking respondents to choose from a series of mutually exclusive hypothetical scenarios of choice sets, each described in terms of combination of attributes including price (Hoyos, 2010). When compared to CVM, this design is more appropriate to minimize strategic biases of the respondents (Hanley et al., 2001).

The CE method uses surveys to ask respondents to state their preferences in one or more hypothetical scenarios in estimating the value of goods and services not usually traded in existing markets (Adamowicz et al., 1998; Louviere et al., 2000).

The CE relies on Lancaster's characterization of consumer theory, which states that consumers derive utility from different characteristics/attributes by which a good can be described, rather than from the good *per se*, and on random utility theory (RUT), which states that, when provided with a choice, a respondent selects an alternative that maximizes her/his underlying utility function i.e. the utility received from the selected alternative is greater than the utility of its counterparts and any deviation from this is accounted as random (Boxall et al., 1996). Accordingly, Lancaster's characterization of consumer theory and RUT lay bases for assessing the ES affected by *Prosopis* in the study areas. In our case, the CE provides two unlabelled or generic hypothetical alternatives with a status quo as a third alternative or opt-out option to the respondents where the alternatives differ from each other in terms of ES affected by *Prosopis* and costs of management options. While the two generic alternatives represented combinations of ES improving management option(s) to be implemented in the coming 10 years, the status quo was used to indicate business-*as*-usual (e.g. utilization of *Prosopis* wood for charcoal production in Baringo, but not in Afar) at level of ES with no cost (no HHs' contributions) for its improvements.

The first stage in designing CE is the characterization of the good under valuation (Boxall et al., 1996). Following Adamowicz et al. (1998), we made concerted efforts to select attributes and the respective levels that well represent the main effects of *Prosopis* on the ES without creating considerable cognitive burden on local respondents.

In order to identify relevant attributes associated with effects of *Prosopis* on ES, we held five focal group discussions (FGDs) in each study area using a checklist of potential attributes prepared in consultation with literature (e.g. Mwangi and Swallow, 2008; Kassahun et al., 2008; Maundu et al., 2009; Tilahun et al., 2016; Maundu et al., 2009; Ayanu et al., 2015; Wakie et al., 2016) and local experts. The ES affected by *Prosopis* were attributed to different characteristics which are understandable by local pastoralist and agro-pastoralist, credible, realistic and relevant for policy making processes (Bennett and Blamey, 2001; Hanley et al., 2001). ES were categorized into four groups, namely provisioning, regulating, cultural and supporting services (MA, 2005). However, to avoid double counting (Kontoleon et al., 2007; Gómez-Baggethun et al., 2009), only attributes associated with the first three services were considered in this study. Appendix A provides an overview of the positive ES, such as improved microclimate, erosion control, charcoal and fuel wood production, and the negative ES (or disservices as defined by Vaz et al., 2017) such as its high water consumption, reduced fodder for livestock, loss of mobility or human injuries, and how they were prioritized during the FGDs in order of relevance in the two study regions. The term biodiversity was included in the discussion despite the fact that it is not an ES in the narrow sense. Biodiversity, water availability, microclimate regulation, tourism and mobility ranked highest among the ES discussed during the FGDs (Appendix A). Here, while biodiversity and water represented provisioning services, mobility and tourism were proxies to cultural services. Though biodiversity is a complex concept, it is conceptualized in the study areas in terms of the number of native species (both usable and non-usable) (Kontoleon et al., 2007). As the majority of local communities are natural resources dependents, they well understand that *Prosopis* invasion causes a decline in native species richness or diversity (e.g. Shackleton et al., 2014). For instance, the discussants expressed that different grass and tree species disappeared due to the invasion. During the FDGs, the discussants stated that they attributed to the term biodiversity multiple services, including fodder for livestock and the availability of medicinal plant species.

Prosopis has been shown to reduce both surface and underground water availability (Mwangi and Swallow, 2008; Dzikiti et al., 2012; Wise et al., 2012); one of the most important and scarce resources for east African pastoralists and agro-pastoralists. When asked about water availability before and after *Prosopis* invasion, FGDs discussants agreed that water availability is negatively affected by the invasion.

Mobility is an important cultural identity marker for East African pastoralists (Hundie and Padmanabhan, 2008; Rogers et al., 2017). *Prosopis* has turned the flood plains into dense shrub land and formed impenetrable thickets that block human and herd mobility and hinder the traditional nomadic lifestyle (Ayanu et al., 2015). The loss of grazing lands, therefore, causes a feeling of insecurity among the pastoralists. In discussions with local communities during FGDs, we also found that the communities acknowledge conservation of tourist sites in their localities which directly or indirectly contribute to their livelihoods. For instance, in Afar, they agreed that national parks (Yangudi Rasa National Parks, Allideghi Animal Reserve and Awash National Park) are used as a buffer zone. The HHs are allowed to cut and carry grasses to their livestock during severe drought periods – used as emergency buffer zone. In Baringo, Lake Bogoria National Reserve and Lake Baringo areas are threatened by *Prosopis* invasion and the discussions highlighted that it is highly likely that local and national revenues will be reduced. The other attribute was that *Prosopis* regulates temperature, reduces the occurrences of sand storms and offers shade in these arid and semiarid ecosystems (Ilukor et al., 2016) and the local communities well acknowledged that. Accordingly, microclimate regulation was identified as positive effect and ranked first in both the study areas. Further, two more attributes, annual cash payment and labor contribution, were included as attributes to facilitate the ways local communities could express their WTP for managing *Prosopis* invasion and rehabilitate the ES within a period of 10 years.

Table 1
Attributes of dryland ecosystem services and 'payment' contributions included in the choice experiment.

Attribute (Ecosystem services)	Description	Levels		Expected effect on welfare
		Afar	Baringo	
Biodiversity	Plant species richness	Low, Medium, High	Low, Medium, High	+
Water	Water availability in their locations per seasons in a year	Only summer, Two seasons	Only summer, Two seasons	+
Mobility	Opportunity to move from their locations to others and within their locations per year	No mobility, Twice, Thrice	No mobility, Twice, Thrice	+
Tourists	Number of tourists in their nearby tourist site	Current Number, 50% Decrease, Doubled	Current Number, 50% Decrease, Doubled	+
Microclimate	Local HHs' perceptions on the effect of *Prosopis* on the local temperature and sand storms	Current, 50% Decrease, 25% Decrease	Current, 50% Decrease, 25% Decrease	–
Labor	Number of days you contribute to *Prosopis* management in a year	0 Days, 5 Days, 16 Days, 27 Days	0 Days, 5 Days, 13 Days, 21 Days	–
Payment	Your contribution to *Prosopis* management in a year in cash	0 Birr, 25 Birr, 86 Birr, 246 Birr	0 Shilling, 77 Shilling, 239 Shilling, 853 Shilling	–

The CE allows capturing the effects of environmental change on single ecosystem services, while controlling other potentially positive or negative attributes. It should be noted that all other ES not addressed individually in the CE are included in the status quo scenario. Hence, the choice of managing *Prosopis* included not only the effects on the five ES prioritized in this study, but also on other ES such as provisioning of wood, which would decreased if stakeholders express willingness in managing and thereby reducing densities of *Prosopis* on their land.

The second stage in designing CE is the decision on levels of each selected attribute. Specific to each study area, levels were assigned to each attribute that represent a relevant range of variation in the present or future market of interest (Adamowicz et al., 1998) that are feasible, realistic, non-linearly spaced, and span the range of respondents' preference maps (Boxall et al., 1996) (Table 1).

Using the wealth ranking method, we determined in consultation with the local people the lowest, average and highest amounts of payments in local currency and the amount of labor contribution in terms of number of days the respondents were willing to contribute to the management of *Prosopis* in each study region. In both cash and labor, contribution levels were also checked against local community members' annual contribution for development work in their localities. Though the number of livestock holdings is used as measure of wealth in pastoral communities in general, owning a particular animal type is taken as a symbol of household wealth among Afar pastoralists. In particular, camel, cattle and shoat holding are the first, second and third important animal types in symbolizing household wealth. In Baringo, HH wealth ranking was based on food aid dependency level. A HH is poor if it receives food aid from government and/or non-government organizations more than once a year; average if it receives only once a year and rich if it receives no food aid.

Table 3
Frequency distributions on perception and management of *Prosopis*.

		Afar		Baringo	
		Freq.	Per cent	Freq.	Per cent
Attitude of the respondent on the benefits and costs	Negative only	76	30	1	0.40
	Positive only	0	0	1	0.40
	Both	177	70	248	99.20
	I do not know	0	0	0	0
Attitude of the respondent to participate in managing *Prosopis* from further invasion	Yes	249	98.40	248	99.20
	No	4	1.60	2	0.80
	I do not know	0	0	0	0

The third stage in designing CE is creating alternative scenarios. Guided with statistical design theory (Alpízar et al., 2003), the random combinations of levels from each attribute form alternative scenarios or profiles. While a full factorial design would provide all possible combinations in the domain, it provides an impractically large number of choice sets to be evaluated in order to estimate main effects of each attribute (Louviere et al., 2000). The common approach is to reduce the number of choice sets to a manageable size. This can be done through fractional factorial orthogonal designs (Alpízar et al., 2003). In order to obtain optimal choice sets from a large set of choice sets, D-optimality

Table 2
Descriptive results of households' socioeconomic variables. Numbers in parantheses indicate official average figures for the variables based on CSA (2015) for Afar and KNBS (2012) for Baringo. a: based on chi-square; *,** and*** indicate levels of significance at 10%, 5% and 1%, respectively.

Characteristics	Afar (N = 248)				Baringo (N = 249)				Mean Diff.
	Mean	SD	Min	Max	Mean	SD	Min	Max	t-value
Female (%)	7 (43)	–	–	–	10 (49.8)	–	–	–	1.30NSa
Male (%)	93 (57)	–	–	–	90 (50.2)	–	–	–	
Age of HH head	40.71 (45)	12.56	20	80	44.99 (59)	12.34	21	85	3.85***
Family size	5.32 (6)	2.04	1	12	5.76 (5.02)	2.20	1	15	2.39**
HH education level (years)	1.51 (2)	1.54	0	9	6.75	2.65	0	13	27.15***
TLU[a]	13.80	10.43	0	43.3	7.83	6.38	0	44	−2.47**
LabSS	3.28	1.51	0.9	8.15	4.00	1.92	0.9	10.75	4.41***
NFIncm (in USD)	677.16	1158.08	0	12408	1627.85	1826.03	0	17169	4.88***
PerBio	4.18	1	1	5	4.38	0.60	1	5	1.40NS
PerWat	3.47	1.24	1	5	3.70	1.48	1	5	1.54NS
PerMic	3.58	1.29	1	5	3.96	1.25	1	5	3.12***
PerMob	4.20	1.12	1	5	4.16	1.04	1	5	−1.98**
HH dependent on Pastoralism (%)	71 (87)				39 (42)				−3.29***a

[a] Tropical Livestock Unit (TLU) is a hypothetical animal equals to 250 kg body weight. It is used to bring different animal species under a common denominator. Standard conversion factors for different animal species are Camels = 1.0; Cattle = 0.7; Sheep and goats = 0.1.

Table 4
Selected ES (attributes) ranking by sample respondents (%).

Rank	Biodiversity		Water		Mobility		Tourism		Microclimate	
	Afar	Baringo	Afar	Baringo	Afar	Baringo	Afar	Baringo	Afar	Baringo
1st	0.19	46.77	75.2	50.40	1.6	1.61	0.4	0	4	2.02
2nd	63.20	41.94	23.2	43.95	8	8.06	0.4	1.61	4.8	5.24
3rd	14.80	6.45	1.6	4.44	41.6	43.55	13.6	8.87	28.4	33.47
4th	1.20	4.03	0	0.81	27.6	25.81	34	50.81	37.2	19.35
5th	2	0.81	0	0.40	21.2	20.97	51.6	38.71	25.6	39.92

criteria was used (for details see Louviere et al., 2000; Alpízar et al., 2003). Accordingly, optimal and balanced design containing 36 choice sets with the main effect design D-errors of 3.83% for Afar and 2.07% for Baringo was obtained using SAS software. In order to reduce cognitive burden on subjects, these 36 choice set were randomly blocked into three choice cards each containing 12 choice sets or cards (see Appendix B for a template choice card). Then the choice sets from each block were equally distributed in both study regions. Each sample household thus made choice decisions on 12 choice sets resulting in a total of 8964 (12*3*249) and 8928 (12*3*248) observations in Afar and Baringo, respectively. Excluding protesting respondents, the analyzed data were for 248 HH in Afar and 249 HH in Baringo.

In each choice set, a participant was presented with three alternatives each containing combinations of levels of attributes that differ in levels of at least one attribute. Respondent's perception (Per), HH head age (Age), average HH education year (Edu), HH labor supply (LabSS) and annual HH non-farm income (NFIncm) as a proxy of HH income diversification were asked to capture HH socioeconomic characteristics influencing preference for participation in *Prosopis* management option(s).

In calculating adult man equivalent unit of a household, sex and age structures and activity for which labor supply was needed were considered. Weeding was considered as a labor demanding activity in household's *Prosopis* management participation. Age groups were ranged as 6–9, 10–15, 16–55 and > 55 years for both sex. Following Panin (1986), adult equivalence unit conversion factors in the orders of age ranges were 0.1, 0.85, 1 and 0.65 for male while 0.1, 0.65, 0.8 and 0.45 for female members in a household. In the survey, respondents were asked to rate on a five-point Likert scale the effects of *Prosopis* on the identified attributes before choice sets interviews; 1 = strongly disagree; 2 = disagree; 3 = indifferent; 4 = agree; 5 = strongly agree. To prevent a forced choice, respondent also had the option to tick 6 = I do not know. Respondent's perception about the negative effects of *Prosopis* on biodiversity (PerBio), water availability (PerWat) and mobility (PerMob) were interacted with respective alternative specific values of the attributes in both study areas. Following the same fashion, perception about positive effects of the plant on microclimate regulation (PerMic) was included in both study areas.

2.4. Econometric model specification

As RUT links the deterministic model with a statistical model of human behavior (Train, 2003), the indirect utility a respondent (decision maker) *n* receives from choosing an alternative *j* at *t* choice occasion can be specified as:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \tag{1}$$

where (U_{njt}) the indirect utility function for the respondent *n* which can be decomposed into two components: observable to the researcher (V_{njt}), which is a linear index of the attributes of the *j* alternative in the choice set, and a random error component (ε_{njt}) which captures variations in choice due to scale heterogeneity and/or preference heterogeneity, omitted variables and measurement errors (Louviere et al., 2000). The randomness of the unknown part of the utility function suggests that only analysis of the probability of choosing one alternative over another is possible (Train, 2003). Considering a Type 1 extreme value distribution of utility error term, random parameters logit (RPL) model was estimated. Unlike the most applied model, the standardized multinomial model, the RPL relaxes the iid assumption and captures the very natural heterogeneity of individuals' preferences (Colombo et al., 2009). Therefore, the probability of individual *n*'s observed sequence of choices [y_1, y_2, …. y_T] is calculated by solving the integral:

$$p_n(y_1, y_2, \ldots y_T) = \int \prod_{t=1}^{T} \frac{\exp^{\lambda V}{}_{njt}}{\sum_{h\in J} \exp^{\lambda V}{}_{nht}} = \int \frac{\exp^{\lambda\beta' x}{}_{njt}}{\sum_{h\in J} \exp^{\lambda\beta' x}{}_{njt}} f(\beta/\theta)d(\beta), \quad \forall\, h \neq j \tag{2}$$

where $f(\beta/\theta)$ is the density function of β i.e. RPL choice probability does not depend/conditional on the values of β but a function of θ. Train (2003) precisely expresses RPL probability is a weighted average of the standard logit formula evaluated at different values of β, with the weights given by the density $f(\beta)$. The random taste variations among respondents were explained through interaction terms between alternative specific attributes and socioeconomic characteristics of the respondents (Adamowicz et al., 1998; Train, 2003) (see lower part of Table 5). Following Hasan-Basri and Abd Karim (2013), in this study dummy coding was applied.

Following Hensher et al. (2005), in RPL model estimation, labor and payment attributes were fixed while all other ES parameters were assumed random (respondent-specific) in distribution. The normal distribution assumption allowed both signs for coefficients so that preference heterogeneity across individuals was captured from the estimated coefficients of attributes and their respective standard deviations (Train, 2003). Using both contribution attributes fixed enabled the estimation of WTP for other random attributes or ES (Hoyos, 2010). The RPL model was estimated in STATA version 13 using simulated maximum likelihood with 100 Halton draws. WTP including standard errors and 95% confidence intervals were calculated using Krinsky Robb (parametric bootstrap) method (the technique is available in STATA 13).

In the framework of standard consumer theory and assumption of weak substitutability of environmental values, average HH implicit price (WTP) of each attribute was estimated by computing the marginal rate of substitution between estimated value of ES (attributes) and the payment attributions (Bennett and Blamey, 2001):

$$WTP = -\frac{\beta_{attribute}}{\beta_{payment}} \tag{3}$$

The WTP for a marginal change in the level of each environmental attribute is obtained by dividing the coefficient of the attribute by the coefficient of the cost attribute (implicit price). In other words, it is the rate at which respondents are willing to pay for the improvement of an ES attribute.

Finally, the social benefits generated from an ecosystem services improvement management alternative was estimated average household's WTP considering all respondents, with the exception of those

Table 5
RPL model estimates.*,** and*** show significance levels at 10%, 5% and 1%, respectively. Values in the parentheses are standard errors.

ES attributes	Afar				Baringo			
	Coeff.	Z	SD	Z	Coeff.	Z	SD	Z
Labor	−0.02 (0.00)	−6.38***	–	–	−0.30 (0.11)	−2.64***	–	–
Payment	−0.00 (0.00)	−4.78***	–	–	−1.12 (0.12)	−9.00***	–	–
Biodiversity	1.12 (0.07)	15.35***	0.93 (0.08)	12.33***	2.61 (0.20)	12.94***	2.61 (0.25)	10.59***
Water	0.65 (0.09)	7.44***	1.07 (0.09)	12.29***	2.39 (0.19)	12.68***	3.71 (0.31)	12.17***
Mobility	0.23 (0.04)	6.07***	0.09 (0.10)	0.93	−0.21 (0.08)	−2.55**	0.68 (0.10)	6.88***
Tourism	0.11 (0.04)	2.91***	0.11 (0.12)	0.86	0.07 (0.06)	1.16	0.06 (0.10)	0.64
Microclimate	−0.20 (0.04)	−5.01***	0.28 (0.06)	4.64***	−0.45 (0.07)	−6.84***	0.15 (0.07)	2.25**
PerBio	0.05 (0.06)	0.95	–	–	0.04 (0.14)	0.28	–	–
PerWat	0.17 (0.06)	2.64***	–	–	1.24 (0.12)	10.19***	–	–
PerMic	−0.10 (0.03)	−3.45***	–	–	−0.07 (0.04)	1.65*	–	–
PerMob	–	–			0.32 (0.07)	4.30***		
NFIncm	-7E-04 (0.00)	−2.55**	–	–	0.16 (0.18)	0.85	–	–
Age	−0.29 (0.09)	−3.06***	–	–	0.38 (0.34)	1.10	–	–
Edu	−5.67 (2.22)	−2.55**	–	–	−0.64 (0.77)	0.84	–	–
LabSS	1.34 (0.58)	2.31**	–	–	3.99 (3.63)	1.10	–	–
Number of obs.	8964				8928			
LRI	0.28				0.37			

who believed that the government should pay for *Prosopis* management option(s). This gives the aggregated WTP values for the local community of an ecosystem to mitigate the damages caused by *Prosopis* (Sagoff, 1998). Thus, annual social benefit for a given community can be calculated as:

$$WTP_{total} = WTP_{hh} * HH * R_{wtp} \quad (4)$$

where WTP_{hh} is the mean household WTP, household represents the total number of households in the affected ecosystem and r_{wtp} percentage of respondent's willingness to contribute.

3. Results

3.1. Descriptive results

3.1.1. Characteristics of sample households

In both areas, the large majority of respondents were male (93% in Afar, 90% in Baringo; Table 2). However, the HH from the two countries differed in various socio-economic characteristics; HH from Kenya had larger family size, higher education level, more labor availability and higher income from non-livestock activities than HHs from Ethiopia. Respondents in Baringo were also older than respondents in Afar. Households' livestock holding was more in Ethiopia than in Kenya. Similarly, 71% of sample HHs were pure pastoralists in Afar, compared to 39% in Baringo.

3.1.2. Local perception about Prosopis effects on ecosystem services

Most of the respondents from the two study areas replied that the plant has both benefits and adverse effects (Table 3). However, in Afar a considerable proportion of the respondents (30%) replied that *Prosopis* has only negative effects.

Almost all sample respondents from both the study areas were willing to participate in managing *Prosopis* by contributing cash and/or labor (Table 3). Most of the sample respondents were willing to contribute in labor (74% in Afar and 64% in Baringo) in the management of *Prosopis*.

In Afar, the majority of the respondents indicated that improved availability of water and biodiversity were the main reasons for participating in management activities, followed by mobility (Table 4). The rank order was similar for Baringo respondents except for a slightly higher ranking of tourism than microclimate.

3.2. Econometric results

3.2.1. Estimates of CE utility coefficients

For both study areas, the likelihood ratio indices (LRI) were within the range characteristic for well fitted models (0.2–0.4; Hoyos, 2010). Almost all attributes (except for tourism in Baringo) were statistically significant with the expected signs (Table 5), showing that the role of the selected attributes to characterize the effects (both positive and negative) of *Prosopis* invasion on ES in determining the respondents' choices of management participation was well understood by the sample HHs. In both study areas, respondents' participation decision is positively affected by biodiversity and water availability but negatively by microclimate regulation. Mobility affects choice decisions positively in Afar but negatively in Baringo. Tourism seems to positively affect a respondent's choice decision in Afar while it was not significant in Baringo. In line with the basic economic problem – scarcity, statistically strong negative coefficients on labor and cash contribution variables indicate that HHs prefer management option(s) that cost less, *ceteris paribus*.

The mean value of coefficients and standard deviations of the three attributes (biodiversity, water availability and microclimate regulation) were highly significant in both the study areas, implying that individual preferences varied in the respective population for these attributes (Table 5). In Baringo, individual preference heterogeneity was also observed for mobility. HH head age (Age), average HH education year (Edu), HH labor supply (LabSS), annual HH non-farm income (NFIncm) as a proxy of HH income diversification and perception (Per) about the effects of the invasion all explained a significant amount of the individual preference heterogeneities (Table 5).

3.2.2. WTP and aggregated social welfare costs

Using Equation (3), the estimated marginal WTP for specific ES are in convergence with results in section 3.1.2, showing that biodiversity and water availability were highly valued in both the study areas (Table 6). Further, considering microclimate regulation benefits of *Prosopis*, average respondent HHs from Afar and Baringo felt that if *Prosopis* is reduced below a certain threshold, they will lose USD 5.36 and USD 3.89 per annual, respectively. In Afar, on average, annual marginal HH WTP for seasonal mobility and tourism were estimated to be USD 6.07 and USD 3.02, respectively. The WTP for tourism in Baringo was not calculated as it did not significant affect respondents' management choice decisions.

When we interpret average annual HH WTPs in terms of the percentage of a HH's annual labor supply or availability (labor elasticity of

Table 6
Marginal Willingness-to-pay with standard deviations in parenthesis. Official rates during the survey Birr 1 = 0.044 USD and KSH 1 = 0.0097 USD.

WTP for:	Afar		Baringo	
	Birr per annual	USD	KSH per annual	USD14
Biodiversity	670.86 (463)	29.52 (20.37)	2336.81 (234)	22.67 (2.27)
Water	390.13 (535)	17.17 (23.54)	2137.84 (332)	20.74 (3.22)
Microclimate	121.75 (141)	5.36 (6.20)	400.63 (13)	3.89 (0.13)
Mobility	138.04 (45)	6.07 (1.98)	183.72 (61)	1.78 (0.59)
Tourism	68.55 (53)	3.02 (2.33)	–	–
Labor	11.58	0.51	265.56	2.58
HH Mean	1146 (955)	50.42 (42.02)	4257.70 (614)	37.74 (5.36)

Table 7
Aggregated social welfare (in 1,000,000) with standard deviations in parenthesis at 95% confidence intervals.

	Afar		Baringo	
	Birr	USD	KSH	USD
Aggregated mean per annual	168.44 (140.38)	6.10 (5.10)	425.06 (62.75)	4.20 (0.62)
Aggregated mean discounted for 5 years at 3%	769.75 (643.29)	27.94 (23.35)	1943.14 (283.37)	19.20 (2.80)
Aggregated mean discounted for 5 years at 5%	727.60 (608.30)	26.41 (22.08)	1841.93 (273.25)	18.20 (2.70)
Aggregated mean discounted for 5 years at 7%	689.03 (576.07)	25.01 (20.91)	1740.73 (253.01)	17.20 (2.50)

WTP), a HH is willing to contribute 4.76%[1] and 2.87% in Afar and Baringo, respectively. In terms of money, the average annual HH WTPs for a *Prosopis* management option that will improve ES were estimated to be USD 50.42 (95% confidence interval: USD 8.40 - USD 92.44) and USD 37.74 (USD 32.38 - USD 43.10) for Afar and Baringo, respectively (Table 6).

Using Equation (4) aggregated annual and over five years period social welfares were calculated for both the study areas (Table 7). In Afar, three zones (Awsi, Gabi-Rasu and Hari) are invaded by *Prosopis*. Considering a total population of 767,573 for these three zones and an average HH size of six persons in the region (CSA, 2015), the total number of HHs in the three zones was estimated to be 121,260. Similarly, the total number of HHs in Baringo was estimated to be 111,112 (KNBS, 2012). The aggregated average social welfare (annual social costs if the invasion continues or social benefit if the invasion is managed) for Afar in Ethiopia and Baringo in Kenya were estimated to be Birr 168.44 (USD 6.1) million and KSH 425.06 (USD 4.2) million, respectively.

The present values of these social welfare estimates were calculated over five years considering different discount rates (Table 7). For instance, using a 5% discount rate, the 2018 values of the average social welfare over five years for *Prosopis* management option(s) were estimated to be Birr 728 (USD 26.41) million for Afar and KSH 1841.93 (USD 18.20) million for Baringo, respectively.

4. Discussions

Overall, sample HHs in both Afar region in Ethiopia and Baringo County in Kenya perceived that *Prosopis* has both negative and positive effects on the ecosystem. This is A peculiar characteristic of many deliberately introduced woody plant species that have become invasive (Shackleton et al., 2016). However, considering current invasion levels, our results indicated that respondents from both the study areas were consistently willing to contribute to *Prosopis* management option(s) that improve ES and minimize ecosystem disservices in their respective localities. The results suggest that the invasion has reached a level where the negative effects of *Prosopis* outweigh its positive effects in both regions.

4.1. ES affected by Prosopis

In both study areas, the two most important ES that determine a HH's willingness to participate in *Prosopis* management were biodiversity and water. Looking at WTP estimates (Table 6), the most preferred *Prosopis* management options by the respondents in both study areas are those which restore indigenous grasses and plant species richness. This is followed by management options which improve water availability for home and livestock consumption. These results show that, on average, respondent HHs understand well the well-documented negative ecological effects of *Prosopis* on water availability (Dzikiti et al., 2012; Wise et al., 2012) and plant diversity (Ayanu et al., 2015; Shackleton et al., 2016).

Despite the recognized losses of these two ES, HHs from both study areas recognize the positive contribution of *Prosopis* to microclimate regulation. Results for microclimate regulation show that if current *Prosopis* cover is reduced below a certain threshold level, that will result in a disservice (Vaz et al., 2017). This is in line with prior findings highlighting local communities‘ appreciation of different regulating services provided by *Prosopis* (e.g. shade, wind breaking and microclimate regulation; Pasiecznik et al., 2001; Wise et al., 2012; Maundu et al., 2009; Ilukor et al., 2016). This result suggests that in arid and semi-arid ecosystem, in order to substitute the disservice due to *Prosopis* reduction, restoration of indigenous trees should be done in parallel with the reduction of *Prosopis* populations.

In addition to these three choice decision determining attributes, mobility is a determinant ES for Afar HHs but not for Baringo (Table 5). This might be explained by the fact that the majority of Afar population are pastoralists. Although the current Ethiopian government strategy has favored sedentarization (Hundie and Padmanabhan, 2008; Rogers et al., 2017), the real preference of the community may still be pastoralism, and *Prosopis* considered as a factor making pastoralism more difficult (Rogers et al., 2017). Tourism also positively affects a respondents' choice decision in Afar while it was not significant in Baringo (Table 5). This might be because Afar pastoralists use the national parks (e.g. Awash National Park and Yangudi Rasa National Park) for livestock grazing during drought periods.

4.2. Individual preference heterogeneities and their socioeconomic determinants

Our results from RPL estimates revealed the presence of preference heterogeneity among households in both study areas on three ES: water, biodiversity and microclimate regulation (Table 5). In other words, there are some HHs who do not support *Prosopis* management options which improve biodiversity and water availability. Similarly, some HHs in Afar did not acknowledge microclimate regulating benefits of *Prosopis* in their area and a large portion of the sample respondents (61.79%) in Baringo were against management options that improve mobility.

Contrary to expectation, ES repeatedly put in context with *Prosopis*, such as provisioning of wood for various purposes or seed pods for animal feed, were not ranked high during the FGDs. In neither of the

[1] USD 50.42/[3.28*365*USD 0.88(minimum wage rate in Ethiopia)] = 4.76%, USD 37.74/[4*365*USD .90 (minimum wage rate in Kenya)] = 2.87% (see Table 2).

study areas were charcoal production and feed ranked among the top five attributes. Nevertheless, attributes not assessed individually are still included in CE, as they are part of the status quo scenario. Socioeconomic characteristics of the sample HHs partly explained the WTP heterogeneous preferences among the respondents. In both study areas, the results show that respondents who strongly perceived that *Prosopis* has negative effect on water availability were more likely to contribute to *Prosopis* management that will improve water availability than their counterparts (Table 5). In addition, a strong perception by respondents of a positive microclimate regulation by the plant appeared to influence them not to participate in *Prosopis* management. Hence, our findings support that local perception or understandings about the benefits and adverse effects of an invasion implicitly affect WTP for IAS management option(s) (Barkmann et al., 2008; García-Llorente et al., 2008).

Similar to findings by Tilahun et al. (2016), a HH with higher labor availability was more likely to contribute to *Prosopis* management option(s) than their counterparts. Contrary to García-Llorente et al. (2008) and Martín-Llópez et al. (2008), our results indicate that less educated HHs were more likely to contribute to the invasion management options. This might be because more educated persons are less dependent on natural resources as they have more options to generate incomes from non-farm activities, such as permanent employment in private and public organizations (Haregeweyn et al., 2013).

The presence of individual preference heterogeneity and that the average preference for *Prosopis* management for improving ES is not shared by all HH has critical policy implications for designing area specific interventions. Uncovering HH specific reasons for preference heterogeneity towards *Prosopis* management are important information for decision making processes (Barkmann et al., 2008; Martín-Llópez et al., 2008) and consideration of the reasons may increase the likelihood of commitment of local community members. For instance, variation in the perception of the effects of *Prosopis* on ES suggest that grassroots level communication on both negative and positive effects of the plant needs to be reinforced before sustainable *Prosopis* management option(s) should be planned and implemented. Furthermore, considering that (non-diversified) pastoralist households in Afar have larger availability of labor, the engagement of younger and lower educated individuals will enhance the likelihood of successful participatory *Prosopis* management.

Our results suggest that no single management option is accepted by every HH in the study areas. Rather, integrated and community specific *Prosopis* management options (Wise et al., 2012; Ilukor et al., 2016; Shackleton et al., 2016) might be feasible in the study areas. In line with this implication, the recently launched national strategy on *Prosopis* management in Ethiopia calls for coordinated and integrated management approach by different governmental and non-governmental developmental institutions (MOLF, 2017).

4.3. Estimated economic values of the affected ES and aggregated social welfare

The estimated average annual HH WTPs were USD 50.42 and USD 37.74 for Afar and Baringo, respectively. Similar study, which applied CE, by Rai and Scarborough (2012) on an invasive plant species (*Mikania micrantha*) in a rural community of Nepal found that the annual HH WTP for the expected outcome was USD 33.55. Applying CVM in Afar region of Ethiopia, Tilahun et al. (2016) estimated that the median willingness to contribute to *Prosopis* management ranges between 30 and 43 days/HH/year in labor. Using a minimum wage rate of USD 0.88, this amounts at an annual HH WTP of USD 26.40 and USD 37.84, which is approx. 25–50% less than our estimate of the annual HH WTP. When estimating average annual HH WTPs for rock climbing in Scotland, Hanley et al. (2001) also found an approximately 50% lower value when using CVM, relative to CE. The difference between the two methods is likely due to the fact that, unlike CVM, CE disaggregates environmental resources into their constituent attributes (Hanley et al., 2001) so that strategic bias is minimized. In ES valuation for decision making processes, a greater value is likely to be better for the benefit of the doubt. That is, future potential costs, in the context of irreversibility, uncertainty and uniqueness of ES, should be taken into account when valuing nature for decision making processes (Pearce and Turner, 1990; Barkmann et al., 2008; Wise et al., 2012).

Aggregating social welfare from estimated monetary values provides valuable information for policy makers in *Prosopis* management decision making processes (Sagoff, 1998; Freeman et al., 2014). For instance, at 5% discount rate, it is economically sound to budget Birr 728 (USD 26) and KSH 1842 (USD 18) million for five years to manage *Prosopis* invasion in Afar region and Baringo County, respectively. In other words, if the invasion is not managed, the social welfare lost is estimated to be approximately USD 6 million per year in Afar and USD 3.5 million per year in Baringo.

On average, Afar HHs were willing to pay more for *Prosopis* management than Baringo HHs (Table 6). This difference is also revealed in labor opportunity costs. The estimated opportunity costs of labor were 57.9% (0.51/0.88) and 287.71% (2.58/0.90) of minimum labor wages in Afar and Baringo, respectively (Table 6). This might indicate that Baringo respondents feel they contribute labor in managing *Prosopis* at a significantly higher expense of other HH farm activities. From both WTP and labor opportunity costs, it can be implied that Afar HHs are more adversely affected by *Prosopis* invasion and hence more responsive to implementing potential management solutions. This might be due to the fact that charcoal production in Afar region is banned, which further reduces the benefits of the plant. In contrast, the trend towards a lower amount of average annual HH WTP in Baringo may be explained by a more heavily degraded ecosystem prior to the introduction of *Prosopis* (Mwangi and Swallow, 2008) and the permission of charcoal production during the study period.

4.4. CE application in environmental change valuation in subsistence economy

The consistency between the descriptive and experimental results of this study suggests that CE can be a suitable method for valuing ES impact of IAS in developing countries. From its very nature, CE closely mimics the familiar consumer behavior of selecting among competing goods based on key attributes (Adamowicz et al., 1998). The CE based environmental valuation is practical from a policy and management perspective because the information it provides can be used in the design of multidimensional policy options (Hanley et al., 2001; Kenter et al., 2011). Regulating ES, which are often not marketed (Costanza et al., 2014), are particularly affected by IAS that interfere with the structure and functioning of natural ecosystems. Here, being a stated preference method, CE allows accounting for non-marketed ES values through a deeper understanding of the trade-offs between different ES (Adamowicz et al., 1998). While it has been argued that CE is not feasible in cash constrained subsistence economy of developing countries (Otieno, 2011), our findings substantiate results from previous studies which highlighted that in subsistence rural economy, where cash is a constraint, stated preference based environmental values can be accounted for using labor contribution as an alternative payment attribute (Mekonnen, 2000; Kassahun et al., 2008; Kenter et al., 2011; Rai and Scarborough, 2012; Banzhaf et al., 2014). When comparing the two payment vehicles, the majority of the sample respondents in our case study areas were willing to contribute in labor to the management of *Prosopis*. This suggests that in rural communities of developing countries, where natural resources are often exploited under communal land use forms and HHs usually participate in public development campaigns via labor contribution, integrating non-monetary contribution options in CE appears to be essential for economic valuation of environmental change.

5. Conclusions

Based on choice experimental data from Afar region in Ethiopia and Baringo County in Kenya, we conclude that the invasion by *Prosopis* in these regions has reached a level where the negative effects outweigh the positive effects of these deliberately introduced tree species. Results from both study areas indicate that concerns about the negative impacts of *Prosopis* on biodiversity and water, which are both well supported by scientific evidence, determined the households' choice decision to contribute to *Prosopis* management. The estimated willingness-to-pay for *Prosopis* management has two important implications for decision makers in drylands of Eastern Africa. First, since *Prosopis* causes significant amounts of welfare costs, prompt actions should be taken to minimize its negative consequences on the pastoral and agro-pastoral livelihoods. Second, the estimated willingness-to-pay serves as a basis for allocating economically justifiable annual budgets for implementing sustainable control and management strategies in the two study areas.

The consistency between the descriptive and experimental results obtained in our study suggest that CE can be a suitable method for valuing ES impact due to environmental change in subsistence rural economy in the developing world, provided that stated preference based environmental values can be accounted for using both cash and labor contributions as payment attributes.

Acknowledgements

This work was supported by the Swiss Programme for Research on Global Issues for Development (r4d), funded by the Swiss National Science Foundation and the Swiss Agency for Development and Cooperation, for the project “Woody invasive alien species in East Africa: Assessing and mitigating their negative impact on ecosystem services and rural livelihood” (Grant Number: 400440_152085). Urs Schaffner was supported by CABI with core financial support from its member countries (see http://www.cabi.org/about-cabi/who-we-work-with/key-donors/).

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jaridenv.2018.07.001.

Appendices

Appendix Table A
Ranking of putative negative and positive attributes of *Prosopis* by participants of each of five focal group discussions (FGDs) in Afar and Baringo. Attributes were scored on a Likert scape from 1 (strongly disagree) to 5 (strongly agree). The five attributes with the highest average score were included in the CE study.

Negative Attributes	Afar						Baringo					
	FGD-1	FGD-2	FGD-3	FGD-4	FGD-5	Average	FGD-1	FGD-2	FGD-3	FGD-4	FGD-5	Average
Reduces seasonal mobility of herds	4	4	5	5	4	**4.4**	3	5	4	3	5	**4.0**
Increases risks of injuries of household members and livestock	4	3	2	2	3	3.6	1	1	3	2	3	2.0
Blocking pathways	3	3	2	2	2	2.4	2	1	1	3	2	1.8
Reduces number of tourists	3	4	4	3	5	**3.8**	5	5	4	4	5	**4.6**
Increases mosquito densities	3	2	1	2	2	2.0	1	1	2	2	1	1.4
Negatively affects livestock health due to feeding on seed pods	3	3	2	2	2	2.4	3	2	1	2	1	1.8
Reduces biodiversity	5	5	5	5	5	**5.0**	4	4	5	5	4	**4.4**
Invades farmland and reduces crop production	2	1	2	1	1	1.4	3	3	4	2	3	3.0
Reduces ground water availability	3	4	5	4	4	**4.0**	5	4	4	5	5	**4.6**
Causes social/ethnic conflicts	3	3	4	3	3	3.2	3	2	2	2	3	2.4
Positive Attributes												
Increases income from charcoal and fuelwood	2	3	2	3	2	2.4	3	4	2	3	4	3.2
Provides seed pods as forage for livestock	1	1	1	2	2	1.4	2	2	3	3	1	2.2
Provides fencing material	3	3	3	3	3	3.0	2	1	4	3	4	2.8
Provides material for house construction	2	3	5	4	4	3.6	1	5	3	2	2	2.6
Increases nectar availability for bee keeping	1	1	1	1	1	1.0	3	3	4	2	1	2.6
Increases protection from soil erosion	4	4	3	3	3	3.4	4	5	2	1	3	3.0
Improves microclimate	5	4	5	4	4	**4.4**	5	4	5	5	3	**4.4**
Enhances soil fertility	3	3	4	2	2	2.8	4	3	4	4	2	3.4

Appendix Table B
A sample choice card.

Attribute	Alternative 1	Alternative 2	Status Quo
Biodiversity	High	Medium	Low
Water	Only summer	Two seasons	Only Summer

(*continued on next page*)

Appendix Table B (*continued*)

Attribute	Alternative 1	Alternative 2	Status Quo
Mobility	Thrice	Twice	No mobility
Tourists	Current number	Doubled	Current Number
Microclimate	50% decrease	25% decrease	Current
Labor	16 days	5 days	0 days
Payment	Birr 25	Birr 246	Birr 0
Select preferred alternative (√)			

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