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Rural households' perception on the effects of *Prosopis juliflora* invasion: The case of Amibara District of Afar National Regional State, Ethiopia

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Abstract

In Ethiopia, *Prosopis juliflora* (*P. juliflora*) becomes one of the worst invasive alien species threatening the livelihood and thus food security of pastoral and agro-pastoral communities. However, up to the present, there have been few studies on the social aspects of the problem. This study explores households' perceptions about the effects of *P. juliflora* invasions in Amibara district of Afar National Regional State, Ethiopia. The study used cross-sectional data collected from 130 randomly selected households based on probability proportional to household size. To measure households' perceptions, a perception index was constructed based on a five-point Likert scale, and a two-limit tobit regression model was used to determine factors affecting households' perception. The abundance of *P. juliflora* was perceived to have increased since its introduction in the study area, mainly due to the mobility of dispersal agents and the species' ability to resist the harsh environment. Between the time when the first trees were planted and today, households' mean perception about the effect of *P. juliflora* invasion has experienced a significant shift; whilst initially some 78% of the sampled households were in favour of the tree species, today, less than 1% still favour the tree and some 90% disfavour it. Empirical evidence indicates that gender, market distance, extension service and livelihood strategy had a significant negative influence whilst proximity to the bush land had a significant positive effect on households' perceptions about the effects of *P. juliflora* invasion. Almost all sampled households had applied some form of control measure on their individually own land, including uprooting of seedlings or cutting and burning of trees. We recommend that government bodies should, in collaboration with other stakeholders, design *P. juliflora* management programmes, which take into account the households' interests, demographic and socio-economic characteristics and institutional settings.

Keywords: *Prosopis juliflora*, Households' perception, Likert scale, Two-limit tobit regression

Introduction

Prosopis juliflora (Sw.) DC. is among the most invasive plant species in Ethiopia, the reason for which the federal government has declared the need for its control (Taye et al. 2007). This tree, which is native to Central America, was first introduced to Afar region in the late 1970s, through coordinated efforts between the government and communities, with the aim of stopping desertification, greening up the region and mitigating the impacts of drought (Wakie et al. 2016). Even though *P. juliflora* was first introduced to Afar National Regional States, it then spread to Oromia, Amhara, Somali, and Dire-Dawa regions, but it particularly became a serious concern in Afar and Dire-Dawa regions. According to Shiferaw et al. (2019), over the last 31 years, the species has invaded 1.17 million ha of land in Afar region, negatively impacting rangeland areas and drastically reducing the biomass of

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forage grasses and livestock production (Wakie et al. 2012). By 2017, approximately 32% of Amibara district was invaded by *P. juliflora* (Shiferaw et al. 2019). Invasion costs the communities around USD 6.1 million per year (Bekele et al. 2018). Besides the serious negative impacts, *P. juliflora* has also positive effects for rural people. For instance, it can be used as firewood, fodder, fencing, windbreak and charcoal production to generate income (Oduor and Githiomi 2013). In Afar region, cropland cleared from *P. juliflora* produces 26% higher yield than cropland with no invasion history due to the species positive contribution to soil fertility (Jema and Abdu 2013). A study conducted in Dupti area of Afar region shows that parameters such as SOC, total N, available P, electrical conductivity, sand fraction and exchangeable cations' (Ca, Mg, and K) content were found to be highest in the *P. juliflora* land than in others, i.e. without *P. juliflora*, and pH was lowest under *P. juliflora* land, whilst pH, CEC and clay content were highest in the cultivated land without invasion history (Merkineh and Tsegaye 2017). Generally, rural households' preferences about the invasive plants may change, as the nature of the goods and services offered by those plants continues to change with time and technology and as unforeseen impacts begin to manifest themselves (e.g. Binggeli 2001; Shackleton et al. 2007). Some species which are considered detrimental to a specific group of rural people may be considered useful to others (e.g. Kannan et al. 2008; Mwangi and Swallow 2008). This is because invasive species (like *P. juliflora*) have differing characteristics offering a variety of services to farm households in developing countries. This inconsistency of interests led to explicit calls from both science and policy for research on communities' perceptions, in order to gain public support for invasive species management programmes (Fischer et al. 2011). However, most research conducted in the country (like Taye et al. 2007; Haregeweyn et al. 2013; Behailu 2013) has focused on ecological aspects of biological invasions. According to Panneta and Timmins (2004), the first criterion for eradication success or successful management of invasive species is to create a suitable socio-political environment. Therefore, public perceptions of invasive species are crucial for evaluating the management strategies and a key factor in the shaping of policies and interventions that are both effective and accepted by interested parties. Thus, this study examined rural households' perceptions about the effects of *P. juliflora* invasion on rural communities and the determinants of their perceptions in Amibara district of Afar region of Ethiopia.

Study area

Amibara District is one of the six districts of zone three (Gabi resu) in the Afar National Regional State in eastern Ethiopia (Fig. 1; geographic coordinates 09° 13′–09° 30′ N and 40° 05′–40° 25′ E). The district covers almost 3000 km^2 and has a total population of around 40,000. Amibara District is where *P. juliflora* was presumed to be initially planted in the region and where the invasion has become particularly pronounced. The study area is characterized by plains with a slope range of 0–8% and an altitudinal range of 665–815 m a. s. l. Transhumance pastoralism is the major production system in the study area, with cattle, camels goats and sheep being the dominant livestock species. The cattle population of Afar region is approximately 1.6 million with around 131,000 of them found in Amibara District. Livestock is primarily kept for milk, meat and income generation (Ilukor et al. 2014).

Methods

Sampling technique and methods of data collection

The research design followed a three-stage sampling procedure. Firstly, Amibara District was selected purposely for this particular study since there is high invasion of *P. juliflora* species in the area. Secondly, 5 of the 15 *kebeles* (i.e. clustered villages) of the district (Serkamo, Sidhafage, Halaydege, Angelele, and Kel'atburi) were randomly selected with the consent of community representatives and the district experts on this issue to ensure meaningful representation of the study area. Finally, after obtaining the sampling frame from each sampled *kebele* offices, a total of 130 households were randomly selected from the sample *kebeles* based on probability proportional to size.

The data for the study were collected through a semi-structured questionnaire. The questionnaire was used to capture demographic, socio-economic, institutional and attitudinal characteristics of rural households, and their perception towards *P. juliflora* invasion. Before carrying out the actual survey, enumerators who know the local norms, customs and languages were selected and trained on how to collect the data using the questionnaire. The questionnaire was also translated to the local language *Afar aff*, and the objectives of the survey were explained and discussed with the informants in order to ensure their cooperation. A total of ten trained enumerators (two for each *kebele*) with a minimum of High school Diploma degree were hired and trained for conducting the survey under close supervision of the principal investigator. Data were collected between the months of August and September 2016[1].

Data analysis

Descriptive statistics like percentages, mean, standard deviation and econometric model were employed for data analysis. Response measures taken by local communities against *P. juliflora* invasions were also described qualitatively. The household heads' knowledge about *P. juliflora* was assessed using a knowledge self-assessment method (perceived knowledge). Furthermore, to assess

[1]A *kebele* is the smallest administrative unit of Ethiopia.

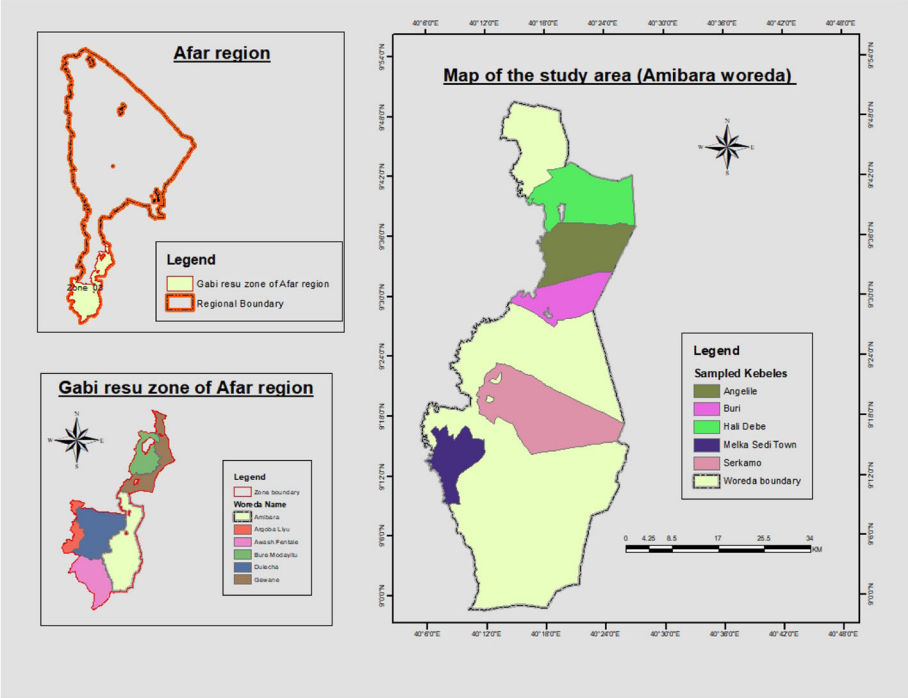

Fig. 1 Map of the study area

public willingness or preference, respondents were asked questions about the type of control measures that they would prefer for managing the invasion of *P. juliflora*.

Measuring perceptions

To quantify overall perceptions, a scale consisting of items was constructed following the procedure suggested by Likert (1932). Each individual item is carefully designed in the way to be meaningful and interesting, even exciting to respondents by using simple, clear and direct sentences. Items were then attached to a five-point Likert scale ranging from 'strongly disagree' to 'strongly agree' with the mid-point being 'indifferent'. Positive items were scored from 1 to 5, respectively, whilst negative items were scored in reverse. A mean score across all items was calculated for each respondent taking into consideration any items not answered. Respondents' scores were then summed and converted into a perception score ranging from 0.2 to 1, whereas 0.2 means strong negative perception and 1 means strong positive perception. Finally, by using this index, perception was regressed to the hypothesized explanatory variables.

Basu (2016) mentions that in calculating reliability of Likert-type measurement, Cronbach's alpha is better to use for interval nature of Likert data. It is the most widely used statistic and generally used as a measure of internal consistency or reliability of a psychometric instrument like Likert data. In other words, it measures how well a set of variables or items measures a single or one-dimensional latent aspect of individuals. Therefore, the study used this index for checking reliability of the dependent variable.

Econometric model

In this situation where the dependent variable is limited in its range, using ordinary least squares for such data is known to lead to biased and inconsistent parameter estimates given the censored nature of the data (Goldberger 1964; Fraser and Wind 1986; Greene 2003). The weakness of such model (i.e. OLS) lies in the concentration of zero values 'observed' in the two limits. Besides, the model OLS can predict values that are not possible values, i.e. below 0.2 or above 1. Therefore, this nature of the data prompted the use of a tobit model, which yields consistent and asymptotically normal maximum likelihood estimators of parameters (Kennedy 2003). The detailed structure of the model (i.e. two-limit tobit model) is given below:

$$\begin{aligned} y_n^* &= \beta_n x_n + u_n \\ y_n &= L_1 if y_n^* \le L_1 \\ y_n &= L_2 if y_n^* \ge L_2 \\ y_n &= y_n^* if L_1 < y_n^* < L_2 \end{aligned} \quad (1)$$

where y_n^* (HHperc) is the latent variable (unobserved for values smaller than L_1, i.e. 0.2, and greater than L_2, i.e. 1) representing the perception level; x_n is a vector of independent variables, which include the factors affecting

household perception; β_n is a vector of unknown parameters to be estimated; and u_n is the disturbance assumed to be independently and normally distributed with 0 mean and constant variance.

The likelihood function for the nth observation ($n = 1, 2 \ldots N$) of the two-limit tobit model is given by:

$$L_n = \Phi\left[\frac{L_1 - \beta' X_n}{\sigma}\right]^{d_{n_0}} \left[\frac{1}{\sigma}\phi\left(\frac{y_n - \beta' X_n}{\sigma}\right)\right]^{d_{n_1}} \left[1 - \Phi\left(\frac{L_2 - \beta' X_n}{\sigma}\right)\right]^{d_{n_2}}$$

where Φ (.) is the standard normal cumulative distribution function, ϕ (.) is the standard normal probability density function, β is the vector of regression coefficients, σ is the standard deviation, X_n is the matrix of independent variables and y_n is the observed value of the normally distributed dependent variable. For each observation, one of the exponents d_{n_j} ($j = 0, 1, 2$) will take a value of 1, depending upon whether the value of the observed y_n is equal to the lower limit, is in the interval between limits or is equal to the upper limit, respectively, and all other exponents will take a value of 0.

Results and discussion

Household characteristics

The interviewed household heads (12.3% female and 87.7% male, see Table 1) had a very low educational level, with almost 80% having no formal education. The mean age of the sampled household heads was about 39 years (range 22–99 years), and almost all (95%) respondents were below 64 years. The family size in terms of man equivalent ranged from 1 to 9.4 with an average family size of approximately 4 per household (Table 2). On average, the sample households owned 0.7 ha of land (range 0–4 ha) and 31.3 tropical livestock units (TLU; range 2.4–86.2 TLU). Camel, cows, oxen, sheep and goats are among the livestock that the households owned. Since most of the Afar people have a nomadic way of life, households' average number of years of experience in crop production was very low (approximately 2 years); some 40% of the sample households still pursued pastoralism only (Table 1).

Table 1 Descriptive statistics results (dummy variables)

Variable	Category	Frequency	Percentage
Gender	Female	16	12.3
	Male	114	87.7
Irrigation access	No	52	40
	Yes	78	60
Telephone access	No	66	50.8
	Yes	64	49.2
Livelihood strategy	Not only pastoralism	72	60
	Only pastoralism	58	40

Source: Own survey result, 2017

Table 2 Descriptive statistics results (continuous variables)

Variables	Mean	Std Dev.	Min	Max
Age (years)	39.1	11.5	22	99
Education (class years)	0.5	1.8	0	13
Years lived (years)	38.5	11.7	5	99
Family size (ME[a])	4	1.5	1	9.4
Market distance (km)	27.6	17.8	3	55
Proximity to bush land[b] (km)	16.3	10.2	0.5	40
Extension service (number of contacts)	5.7	6.7	0	45
Experience on crop (years)	2.16	3.47	0	25
Livestock holding (TLU)	31.27	11.39	2.4	86.2
Land holding (ha)	0.7	0.71	0	4

[a]Man equivalent (male < 10 years 0 value, 10–13 years 0.2 value, 14–16 years 0.5 value, 17–50 years 1 value, > 50 years 0.7 value; female < 10 years 0 value, 10–13 years 0.2 value, 14–16 years 0.4 value, 17–50 years 0.8 value, > 50 years 0.5 value). Source: Storck et al. (1991)

[b]Bush land describes the uncultivable land that is covered with trees, shrubs or other natural vegetation

TLU tropical livestock unit

Source: Own survey result, 2017

The distance that household heads had to travel to the nearest market ranged from 3 to 55 km, and the nearest bush land was between 0.5 and 40 km away. The number of contacts per year with extension agents varied between 0 and 45 contacts, 49% of the sampled households were using mobile phones for information exchange and 60% of them had access to irrigation.

Introduction, abundance and spreading pattern of *P. juliflora*

Almost all respondents knew *P. juliflora*, and 83% felt they had at least some knowledge about the species (see Table 3). Women's perceived knowledge about *P. juliflora* was higher than men's perceived knowledge: about 94% of the women considered themselves as knowing 'a great deal', 'a fair amount' and 'some' about *P. juliflora* as opposed to only 84% men placing themselves in these three top categories. The respondents' source of information about *P. juliflora* was either own experience, friends and family, or development agents, yet their predominant source of information was their own experience, accounting for about 57% of the answers.

The survey revealed that different respondents had different views about when *P. juliflora* was introduced in the study area, by whom and for what purpose. The majority of the respondents (64%) thought that the plant was introduced first in Amibara irrigation project by a foreigner, who worked in the project around Melkawerer town, whilst the others did not know where the species came from.

Most household heads (96%) said that they knew when it was introduced to the study area. Over half of these said that *P. juliflora* was introduced to the area 30 years

Table 3 Households' perceptions about the introduction, abundance and spread of *P. juliflora* in Amibara district

Variable	Category	Frequency	Number
Knowledge	A great deal	45	34.6
	A fair amount	8	6.1
	Some	55	42.3
	Very little	18	14
	No response	4	3
Source of information	Own experience	74	57
	Friends and family	49	38
	DAs[a]	7	5
Origin	Worer irrigation	83	64
	Do not know	47	36
Agent of introduction	Foreigners	103	79
	Do not know	27	21
Year of introduction	> 30 years	67	51.5
	> 25 years	36	27.5
	> 20 years	22	17
	Do not know	5	4
Purpose of introduction	Combating desertification	83	64
	Greening up region	8	6.1
	Firewood and fodder	30	23
	Rehabilitating soil	3	2.3
	Do not know	6	4.6
Agents of spread	Animal dung	121	93.1
	Human being	3	2.3
	Flood and wind	6	4.6
Abundance	Increasing	130	100
Reason for abundance	Animal mobility	68	52.3
	Ability to resist harsh environment	52	40
	Do not know	10	7.7

[a]Development agents (DAs) are agricultural experts in the area

ago. Around 64% of the respondents perceived that combating desertification was the main reason for introducing *P. juliflora* in Amibara district, since the area was known for frequent droughts. Climate regulation, soil conservation and access to firewood and fodder were other reasons mentioned by the respondents. Only 5% of respondents did not know why *P. juliflora* was introduced in their area. Thus, the above result indicates that the vast majority of respondents knew that *P. juliflora* was intentionally introduced in the study region (Table 3).

The majority of the respondents (93%) perceived that animal dung, including livestock's dung, were the main agents for *P. juliflora* spread, but also human beings, flood events and wind. All respondents in the study area replied that the abundance of *P. juliflora* increased since the species introduction in the area. The factors for the alarming rate of spread of this species were considered to be animal mobility and the amazing ability of *P. juliflora* to adapt and resist to harsh environmental conditions; one respondent said that 'this Weyane tree (local name for *P. juliflora*) grows everywhere, even in rocky areas or on stones'.

Households' perception about the effects of *P. juliflora* invasions

The result of the reliability index (i.e. Cronbach's alpha) revealed that the Likert scale was an excellent scale to measure a unidimensional latent variable with an alpha value of 0.93. Households' perception index had a mean value of 0.37 (SD = 0.1, range 0.23–0.7). Following literature, the five-level Likert scale dependent variable was grouped into three categories (i.e. negative, indifferent and positive). Some 90% of respondents (n = 117) had an

overall negative perception towards the effects of *P. juliflora* invasion on the rural community (score < 3), 9% ($n = 12$) an indifferent (score = 3) and less than 1% ($n = 1$) a positive perception (score > 3). The current perceptions towards the species differed considerably from the perceptions the household heads used to have at the time *P. juliflora* was introduced in the study area. At that time, only 8% ($n = 11$) of the respondents had an overall negative perception, whilst 13% ($n = 17$) had an indifferent and 78% ($n = 102$) even a positive perception about *P. juliflora* (Table 4).

The reason for this positive perception might be that, in those days, households had little awareness and knowledge about the upcoming adverse effects of *P. juliflora* invasion due to low abundance of the species. With increasing *P. juliflora* densities in Amibara district, a shift from positive to negative perception was observed. Nowadays, respondents think that livestock keeping and crop farming are in danger by the unchecked expansion of *P. juliflora*. Most respondents mentioned extinctions of indigenous multi-purpose tree species and replacement by *P. juliflora*, reduction of grazing land and livestock population, road blockages and human health problems as the main adverse impacts of *P. juliflora* invasion. With regard to health, one household head told us that the *P. juliflora* thorns are very dangerous and inflict pain that is like being bitten by a snake.

Uses of *P. juliflora* in the study area

Although *P. juliflora* causes economic and environmental harms, households mentioned that they use the species for various purposes: as a hedge plant, as a source of fuel wood or charcoal and as construction material and fodder for goats and cattle, particularly during the dry season when grass and other fodder are not available. Besides, they used the species as a medicinal plant, especially to heal wounds injured by the same species' thorns. Thus, farm households' responses to the invasive plant can be considered as making the best out of the bad situation. To conclude, respondents perceived that the effects of *P. juliflora* invasion have become more serious with increasing abundance and this species now impairs rural livelihood options and increases vulnerability in Amibara district. This is because the use of *P. juliflora* is likely to be constrained as the basic pasture and bush land products, including firewood and fodder it offers are mostly secondary rather than preferred since it is only used during the dry season, when there is a scarcity of good quality fodder. This means that *P. juliflora* never entirely replaced the services of the species which disappeared due to its invasion.

Management of *P. juliflora* in the study area

To reduce the adverse impacts of *P. juliflora*, the local people mainly used mechanical control (hand grubbing, uprooting and cutting) using local tools like *Qonchera* (i.e. billhook), *Mencha* or *Zabiya (hoe)*. Burning was the other control method that was mentioned by a few respondents. Over half of the respondents favoured complete eradication of *P. juliflora* from both cropland and grasslands, through application of chemicals and replacement with other, less invasive and thorny trees.

At the time this survey was conducted, measures in response to *P. juliflora* invasion were limited to privately controlled farms and homesteads, where individuals had control over the benefits of their efforts. Only very limited attempts to reduce the spread of the species had been conducted on communal grazing areas (i.e. rangeland plains and mountains). Yet, these habitats are a key for sustaining the livestock sector, which is at the basis of the pastoral community's livelihood strategy. So, all individual households should be involved in clearing *P. juliflora* from communal grasslands, but since the invasion is very high in these areas, government's assistance may be required. On public lands, especially rangelands and mountains, almost all sampled household heads suggested that the regional government (i.e. Bureau of Agriculture) should lead management efforts and coordinate them with the local communities, with some help from

Table 4 Households' perception about *P. juliflora*

Variable	Category		Frequency	Percentage	
Perception at the time of introduction	Negative		11	8.46	
	Indifferent		17	13.08	
	Positive		102	78.46	
Current perception	Negative		117	90	
	Indifferent		12	9.23	
	Positive		1	0.77	
Total			130	100	
	Obs	Mean	Std. Dev.	Min	Max
HH perception index	130	0.375	0.101	0.233	0.710

external actors, including federal government and non-governmental organizations.

Determinants of households' perception about *P. juliflora*

As presented in Table 5, results of the two-limit regression model indicate that gender, market distance, extension service, livelihood strategy and proximity to the bush land were found to be the major determinants of households' perceptions about the effects of *P. juliflora* invasion. The discussions about the significant variables are given as follows:

Gender of the household head was a statistically significant determinant of the household's perception about overall effects of *P. juliflora* invasion. Male household heads were more likely to perceive the species negatively than female-headed households since the daily activities of the latter include the collection of firewood for cooking, woods for traditional house construction and feed/forage for livestock, which may benefit from the presence of *P. juliflora*. The marginal effect results of the tobit model indicate that being male increases the probability of a household to perceive the species negatively by 0.96%. The finding is consistent with results from previous studies (e.g. Veitch and Mick 2001; Mwangi and Swallow 2005; Wakie et al. 2016).

The coefficient for *market distance* is negative and significant at the 1% probability level. Access to market enables households to participate in productive utilization of the species, whereas those who are far from the market disfavour the species as they were not able to benefit from sales of *P. juliflora* products due to high transaction costs. The sign of the coefficient is also in line with the hypothesis and results of other studies like Mohammed (2012). The marginal effect results indicate that, when households' distance to the nearest market increases by 1 km, it increases the probability of their negative perceptions by 0.08%.

The *livelihood strategy* pursued by an individual was statistically significant at the 1% probability level and negatively related to the dependent variable. The result may reflect that households with diversified livelihoods were more likely to perceive the effects of *P. juliflora* invasion less negatively than pastoralists whose main livelihood strategy is livestock keeping, because of high costs incurred in clearing of valuable rangeland and cropland. The grasslands that are used by Afar pastoralists for dry season grazing were also described as the land-use category most heavily invaded by *P. juliflora*; therefore, *P. juliflora* invasion adversely affected households whose livelihood depended on livestock rearing by curtailing the grasslands (Wakie et al. 2016). The marginal effect results indicate that pure pastoralism increases the probability of households' negative perceptions by 1.33% compared to those who have diversified their livelihood. This result was also consistent with the findings of Binggeli (2001), Pasiecznik et al. (2001) and Ayanu et al. (2015).

Extension service was statistically significant at the 1% probability level and had a negative influence on households' perceptions about *P. juliflora*. The result suggests that extension agents did not promote the utilization of *P. juliflora* in the study area and/or that contacts with DAs (development agents) increased households' awareness

Table 5 Two-limit tobit regression results on households' perceptions about *P. juliflora*

Variables	Coef.	Std. Err.	$\frac{\partial E(y*)}{\partial x}$	Std. Err.
Gender	− 0.074***	0.020	− 0.0096***	0.004
Education	− 0.022	0.014	− 0.0062	0.004
Family size (ME)	0.002	0.005	0.0007	0.001
Livelihood strategy	− 0.039***	0.014	− 0.0133***	0.007
Livestock owned (TLU)	− 0.000	0.000	− 0.0000	0.000
Land holding	0.004	0.013	0.0011	0.003
Experience in crop production	0.002	0.002	0.0007	0.000
Extension service	− 0.003***	0.001	− 0.0010***	0.000
Income	1.63	1.65	4.46e0	0.000
Market distance	− 0.003***	0.000	− 0.0008***	0.000
Proximity to the bush land	0.001*	0.000	0.0003*	0.000
Irrigation use	− 0.0016	0.020	− 0.0043	0.005
Phone usage	− 0.001	0.014	0.0003	0.004
Constant	0.531***	0.039		
Sigma	0.071***	0.004		

* and *** indicate significant at 10%, 5% and 1% probability levels respectively
Source: Own survey result, 2017

about the adverse effects of the species invasion so that households developed a negative perception towards the invasive species. The marginal effect results indicate that, when household's contact with extension agents increases by 1, it increases the probability of households' negative perceptions by 0.1%.

The coefficient for *proximity to the bush land* was positive and significant at the 10% probability level. This relationship implies that the infestation by *P. juliflora* influences the bush land-dependent households by displacing native species. Even if the case was similar with non-infested areas, species diversity and richness of the woody vegetation in Gewane and Amibara were found to be low. As reported by Ilukor et al. (2016) and Linders et al. (2019), in areas of medium and high *P. juliflora* invasion levels, native plant species are not available at all; therefore, *P. juliflora* reduces native biodiversity further. The marginal effect results indicate that, when the household is further away from the nearest bush land by a kilometer, the probability of positive perceptions towards *P. juliflora* will increase by 0.03%. A result of this study is consistent with the hypothesis and with the results of other studies like Sapkota and Oden (2008) and Rai et al. (2012).

Conclusion

Even if *P. juliflora* was intentionally introduced into the study area through coordinated efforts between the community and foreigners for some intended purpose, it became invasive and households' main livelihood strategy, livestock rearing, was highly harmed by its invasion. A significant change was observed between past and present perceptions about the overall effect of *P. juliflora* on rural livelihoods due to higher negative impacts from increasing densities of this invasive species. Dung from wildlife and livestock like boar, cattle and goats are considered to be the main agents of *P. juliflora* spread, and factors like animal mobility and the amazing ability of the species to adapt and resist to harsh conditions are believed to contribute to the rapid invasion of the species. Almost all sampled households have employed some form of control measures like uprooting seedlings, cutting and burning to reduce or avoid adverse impacts of *P. juliflora*. Gender, market distance, extension service, livelihood strategy and proximity to the bush land were the major determinants of households' perceptions about the effects of *P. juliflora* invasion.

Recommendations

Our study provides evidence that the public perception in Amibara district towards *P. juliflora* offers suitable conditions for the shaping of policies and interventions that promote sustainable management of this invasive species. Extension services appear to have raised awareness among the local stakeholders about the negative impacts of *P. julifora*, but so far, there is little evidence that they provide advice for a sustainable management of this species. Thus, we propose that sub-national institutions, such as the Regional Pastoral Agriculture and Rural Development Bureau, should offer practical management training at grass root level and that they support the extension system in a way that enables upgrading of the practical skills of extension officers.

We further recommend that any interventions aiming to control the negative effects of *P. juliflora* invasion should consider the different perceptions of men and women. Women are dependent on this species for fuel wood, and thus, before proceeding to any eradication attempt, it is important to check whether services of *P. juliflora* (feed and fuel wood supply) can be covered by other plants or whether alternative resources need to be established.

Livelihood strategy had also a significant and negative influence on households' perceptions about the effect of *P. juliflora*. This is due to the highly adverse effects of the species on livestock-based livelihood system (i.e. pastoralism). Thus, management of *P. juliflora* should put emphasis on mitigating the impact of this invasive species on pastoralism, e.g. by keeping drought-season grazing areas free from *P. juliflora* encroachment.

In general, we recommend that government bodies, in collaboration with local stakeholders, should design strategies and programmes which take into account households' perceptions and needs, which is likely to facilitate uptake of management interventions. In the process of developing the strategy, households living near highly invaded areas should be in the frontline because they are reacting to the invasive species instantly as an injured party and a principal to utilize the species. In line with this, efforts should be put into improving households' incentives to participate in the joint management of *P. julifora* on communal lands.

Abbreviations

P. juliflora: *Prosopis juliflora*; OLS: Ordinary least square; TLU: Tropical livestock unit; SD: Standard deviation; DA: Development agent

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Authors' contributions

OS collected and analyzed the data and drafted the manuscript. JHM drafted the conceptual framework and revised the manuscript. BL revised the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The dataset used during this study is available from the corresponding author on reasonable request.

Ethics approval and consent to participate
The information sheet and consent form, purpose and importance of the study were explained to every participant. Voluntary participation clearly stated that they can choose to participate or not and to discontinue the process at any time. To ensure confidentiality of the participant's information, codes used whereby the name of the participant and any identifier of participants would not be written on the questionnaire.

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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