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The invasion of *Prosopis juliflora* and Afar pastoral livelihoods in the Middle Awash area of Ethiopia

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Abstract

Introduction: An evergreen shrub, *Prosopis juliflora* is one of the most invasive species in arid and semi-arid areas. Since its introduction to the Middle Awash area of Ethiopia, it has invaded a huge acreage of grass- and rangelands which are life-supporting unit for Afar pastoralists.

Methods: Survey, using group discussion and questionnaire, was made to study the effect of *P. juliflora* invasion on Afar pastoral livelihoods. The obtained data were analyzed using Wilcoxon signed-rank test, chi-square analysis, and logistic regression.

Results: According to the result, 84 % of the total surveyed households rated *P. juliflora* as undesirable species even though the bush was often used for fuelwood, fencing homesteads, and barn and house construction. Invasion of *P. juliflora* was also blamed to limit transhumance, occupying settlement areas and affecting multipurpose trees/bushes and grass availability. All these effects put pressure on the livestock assets causing about 80 % livestock loss, testing the pastoral livelihoods heavily. Each household, on average, lost 6.5 small stock and 7 cattle during the past 10 years due to health hazards caused by *P. juliflora* pod. Consequently, *P. juliflora* as a source of income was considered by a quarter of the surveyed pastoral households, with the age of a household head and change in livestock asset being influential variables in decision-making.

Conclusions: In sum, *P. juliflora* invasion has made livestock rearing extremely difficult which raised pastoralists' ecological vulnerability in the fragile ecosystem they possess.

Keywords: Afar pastoralists; Middle Awash area; *Prosopis juliflora*; Invasion; Livestock; Livelihoods

Introduction

Prosopis juliflora (Swarz) DC, commonly known as mesquite, is an evergreen tree/bush native to the Caribbean, Central and northern South America (Pasiecznik 1999). *P. juliflora* has a very wide ecological adaptability which can grow on soils from sand dune to clay soil, and from saline to alkaline soil type, below 200 to above 1500 m above sea level, and with a mean annual rainfall ranging from 50 to 1500 mm (Pasiecznic et al. 2004; Zeila et al. 2004). Because of the wider ecological adaptability, *P. juliflora* had been extensively planted in the 1970s and 1980s in deforested and desertification prone areas for reclamation as well as a source of fuelwood and fodder for rural community (Pasiecznik et al. 2001, 2004). However, despite the anticipated benefits, in many cases, it has remained being a major irritant for local people by interfering with resource use systems. The species has occupied millions of hectares of land which were under different land use systems in Australia, coastal Asia, and Southern and Eastern Africa (Sudanupdate 1997; Pasiecznik 1999; Catterson 2003). According to a report by Invasive Species Specialist Group (ISSG), *Prosopis* spp. is one of the top 100 invasive plant species (Lowe et al. 2004).

Invasive plants like *P. juliflora* are also characterized by vigorous growth which helps them to outcompete indigenous plant species to cover huge areas of land in a relatively short period of time (Manchester and Bullock 2000; D'Antonio and Kark 2002). The invaded lands could be of different use systems, such as rangeland and riverbank, to interfere with rural livelihoods activities by

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impeding land use system and incurring extra costs to check the expansion (Shackleton et al. 2006). When *P. juliflora* appears on grazing lands, it reduces grass cover and thereby affects stocking density (Pasiecznik 1999), and in severe cases, it can form impermeable dense thickets.

In Ethiopia, documentation is lacking regarding when, from where, how, and by whom the alien invasive *P. juliflora* was first introduced, but speculation exists. The earliest time of notice is believed to be in the late 1970s in the eastern part of the country where India is a probable source (EARO and HADRA 2005). If the speculation holds, the seed sources of *P. juliflora* for India and sub-Saharan Africa were with inferior phenotype and a non-palatable type (Alban et al. 2002). According to Kassahun et al. (2005), *P. juliflora* found in Ethiopia are thorny and mostly characterized by bushy growth nature, confirming the inferior quality of the introduced germ plasm. In the Middle Awash area of Ethiopia, *P. juliflora* was introduced some three decades before (personal communication with elders at Worer, Afar region). By that time, pastoralists were told about the multipurpose uses of the plant such as pods as an additional feed for their livestock, trunks as a source of fuelwood, and the plant itself as reclaiming degraded and salt-affected lands. Anticipating the benefits, the local people were willing and thus *P. juliflora* was planted over large areas in the region by campaigns like Food for Work Program until 1988 (EARO and HADRA 2005).

The purposeful planting has given the plant an opportunity to base in the Middle Awash area. Besides its inherent robust growth, the viable *P. juliflora* seeds surviving in livestock and warthogs' droppings serve as a vehicle for the plant to reach distant areas to have unchecked expansion throughout the region (Hailu et al. 2004). Currently, more than 30,000 ha of grasslands, rangelands, water points, and croplands are estimated to be occupied by *P. juliflora* in the Middle Awash area. The invasion is still continuing. These invaded resources are basically key resources for livestock rearing, which in turn are the main stay for Afar pastoralists in their fragile ecosystem. Therefore, the objective of this study was to assess the perception of Afar pastoralists of the Middle Awash area about *P. juliflora* invasion in the context of their livelihoods and also to investigate the effect of *P. juliflora* invasion on Afar pastorals' vulnerability to recurrent moisture stress the area experiences.

Methods

Study area and sampling

The study was conducted in the Middle Awash area, Northeastern Ethiopia (Fig. 1). The altitude of the study area ranges from 500 to 820 m above sea level, and it is located between 9° 30′ and 10° 20′ N and 40° 30′ and 40° 50′ E. Livestock population of the study area is estimated to be 414,568 small stock (sheep and goats), 224,670 cattle, and 76,600 camels, and about 100,000 people live in the study area (data obtained from Pastoral and Agro-pastoral Bureau of the study area). Amibara, Awash Arba, Gewane, Halaideghe, Sideha-Faghe, and Worer areas were selected for data collection based on accessibility. Each of the selected sites has 5, 5, 4, 3, 10, and 11 pastoral villages, respectively, and 2 from each of Amibara, Awash Arba, Gewane, and Halaideghe areas, 4 from Sideha-Faghe, and 7 from Worer areas were selected using random sampling technique. The total households enumerated in the randomly selected villages were 452 with the following distribution: 56 (18), 41 (14), 64 (21), 76 (20), 87 (25), and

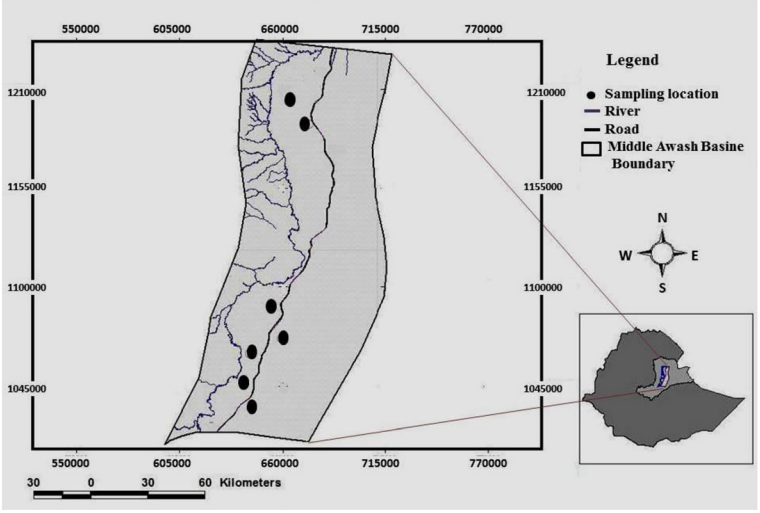

Fig. 1 Map of the Middle Awash Basin of Ethiopia showing sampling sites. Awash Arba, Sideha-Faghe, Worer, Halaideghe, Amibara, and Gewane (*top two points*) as one move from south to north (source: EIAR)

128 (44) households from Amibara, Awash Arba, Gewane, Halaideghe, Sideha-Faghe, and Worer, respectively, where the numbers in brackets show the number of households surveyed in each village.

Data collection and analysis

Group discussion with community elders (five elders from Sideha-Faghe, Halaideghe, and Worer and four elders from Gewane area) was carried out before the employment of survey. Group discussion was made in August 2007, and survey was conducted both in August 2007 and 2012. Structured interviews, open- and closed-ended questions, were used to collect data. Group discussion checklists and questionnaire for household survey are found in Additional file 1. Personal observations were also used to understand the situations during the survey. In this study, the household served as a unit of analysis. Because of cultural norm, it is the household head who is expected to speak on the household's behalf. Most households were male headed, and even for the few widows, the matured son acted as head of the household. As a result, quite few respondents were females. However, housewives of most interviewed households were also involved in answering open-ended questions. During the survey, cards shaded with different colors in different proportions were used to ease answering questions having proportions as a response. Wilcoxon signed-rank test was done for matched-pair comparison between past and current individual household's livestock assets and chi-square analysis to compare frequencies.

Logistic regression was also used to identify influential variables to use *P. juliflora* as a source of income and for diversification of livelihood strategies in a given household. In the logistic regression, logit model was estimated using maximum likelihood method for predefined explanatory variables. The livestock asset of each household in the regression model was measured by tropical livestock unit (TLU). TLU commonly takes 250 kg live weight as a standard of unit, and accordingly, the TLU conversion factor for camels, cattle, and small stocks is 1, 0.7, and 0.1, respectively (Jahnke 1982). Worer was used as a reference place as it is a source of *P. juliflora* for the rest of the locations in the study area.

Results

Afar pastoralists' perception about *P. juliflora*

The awareness of the pastoralists about the existence of *P. juliflora* in the Middle Awash area was assessed. Accordingly, about three fourths of the respondents knew the bush after 1985. With regard to its importance, 84 % of the surveyed pastoral households perceived *P. juliflora* as a harmful bush, whereas only 2 % of the households replied as beneficial, and the remaining 14 % of the households considered the bush as having both beneficial and harmful effects. The proportion of respondents who replied *P. juliflora* being both beneficial and harmful was higher for Worer, Amibara, and Sideha-Faghe than the rest of the villages. In these three villages, there was a trial campaign carried out for 2 years (2002–2004) to minimize the spread of the bush by utilization, where pastoralists were organized in groups to produce charcoal out of *P. juliflora* and also to use its pods for fodder after grinding. As a consequence, these villagers might have realized that some benefits can be obtained from *P. juliflora*.

Benefits of *P. juliflora* for Afar pastoralists

Even though *P. juliflora* is generally considered as a harmful bush by most of the respondents, it has, however, provided some abundant driven benefits to the pastoralists (Table 1). In all the villages surveyed, the plant was highly used as a source of feed, for fuelwood, for homestead fencing, and for barn construction as well. On the other hand, the use of *P. juliflora* for house construction was more in Gewane than the rest of the villages, Halaideghe being the least. Figure 2 shows traditional Afar thatch house frame and small stalk barn made from *P. juliflora*.

Certain pastoralists used *P. juliflora* as a source of income (Table 1). To know factors influencing the utilization of *P. juliflora* for income reason, logit model was estimated (Table 2). According to the result, household head age, change in livestock assets, and location were found significantly affecting a household to make income from *P. juliflora* ($G = 20.83$, $p = 0.022$). Households with reduced livestock asset and old-headed households tended lesser to earn income from *P. juliflora*. Because fuelwood collection and the process of charcoal making for sale are labor demanding, old-headed household involves less in this business. From location dummies (indicator variables), households at Halaideghe rangeland were less likely to use *P. juliflora* than those from Worer, whereas higher likelihood was observed for Gewane households than Worer.

Effects of *P. juliflora* invasion on Afar pastoralists

Except for invasion of graveyards and being sheltered for predators and rustlers, the effects of *P. juliflora* were similar in all villages (Table 1). The species has invaded lands of different use systems. It also competes with indigenous plant species. Pastoralists complained that they spend huge labor on clearing *P. juliflora* from homestead and footpaths. Besides, more people are required in herd-keeping squad to protect herds from entering into deep thickets of *P. juliflora*. A villager from Worer explained the impact of the invasion on cattle track:

> We [Afar men] always hold machete to clear *P. juliflora* on our ways. These days, a herd which used to be cared by one is demanding more people for protecting cattle from entering into deep thicket on

Table 1 The benefits and effects of *P. juliflora* to pastoral households in the Middle Awash area of Ethiopia

	Villages					
	Worer	Sideha-Faghe	Amibara	Halaideghe	Awash Arba	Gewane
Benefits of *P. juliflora*						
Means of income	15 (34.1)	7 (28.0)	5 (27.8)	2 (10.0)	3 (21.4)	9 (42.9)
Feed	31 (70.5)	17 (68.0)	12 (66.7)	14 (70.0)	11 (78.6)	17 (81.0)
Shade tree	23 (52.3)	4 (16.0)	8 (44.4)	9 (45.0)	9 (64.3)	6 (28.6)
Fuelwood	36 (81.8)	19 (76.0)	17 (94.4)	18 (90.0)	14 (100)	21 (100)
Homestead fence	37 (84.1)	19 (76.0)	13 (72.2)	17 (85.0)	11 (78.6)	21 (100)
For barn construction	37 (84.1)	20 (80.0)	13 (72.2)	17 (85.0)	10 (71.4)	17 (81.0)
For house construction	12 (27.3)	7 (28.0)	7 (38.9)	4 (25.0)	4 (28.6)	12 (57.1)
Walking stick	4 (9.1)	2 (8.0)	2 (20.0)	–	–	6 (28.6)
For making traditional bed (*Olo'ytaa*)	2 (4.5)	–	–	–	–	1 (4.8)
Effects of *P. juliflora*						
Wet- and dry-season grazing land invasion	38 (86.4)	19 (76.0)	18 (100)	20 (100)	11 (78.6)	17 (81.0)
Transhumance	37 (84.1)	19 (76.0)	18 (100)	19 (95.0)	11 (78.6)	20 (95.2)
Traditions and institutions	34 (77.3)	19 (76.0)	17 (94.4)	19 (95.0)	10 (71.4)	20 (95.2)
Competition for labor	35 (79.5)	20 (80.0)	16 (88.9)	17 (85.0)	11 (78.6)	21 (100)
Thorn punctures (both livestock and inhabitants)	38 (86.4)	19 (76.0)	18 (100)	19 (95.0)	11 (78.6)	21 (100)
Settlement areas invasion	36 (81.8)	22 (88.0)	18 (100)	18 (90.0)	12 (85.7)	21 (100)
Graveyard invasion	29 (65.9)	7 (28.0)	5 (27.8)	–	–	–
Shelter to predators	20 (45.5)	16 (64.0)	13 (72.2)	17 (85.0)	10 (71.4)	21 (100)
Shelter to rustlers	13 (29.5)	9 (36.0)	2 (11.1)	1 (5.0)	3 (21.4)	–

The numbers in brackets show the proportion

their way to grazing site. Once they get in to the deep thicket, it is very difficult to get them out. The other effect is, for example, there are cattle who know their home/place: even if you leave them on grazing field, they will come back to the village by their own before sunset. This is no longer happening after *P. juliflora* invasion. They cannot locate their home, everywhere is *P. juliflora* and cattle get 'confused' (Respondent number 55; 35 years old).

Along with the invasion, 71 % of the respondents said that predators are nearer to their village than before in the hideout created by *P. juliflora*. According to them, nocturnal predators like hyena eats trapped livestock even during the day.

Fig. 2 Small stock barn and traditional Afar thatch house frame made from *P. juliflora* in the Middle Awash area

P. juliflora invasion and forage/fodder availability

Invasion of *P. juliflora* into grazing areas and cattle tracks were among the most mentioned inconveniencies created by *P. juliflora* on pastoral community (Table 1). Majority of the surveyed households assumed that they have lost more than half of their grazing lands due to the invasion (Table 3). According to the result, a significant proportion of the respondents think that half to three fourths of their grazing lands are invaded by the plant (Table 3; $\chi^2 = 24.28$, $p = 0.007$). In addition to shrinkage of grazing lands, the change in grass cover of *P. juliflora*-encroached areas was also mentioned as a problem. All of the respondents claimed that forage/fodder cover of grazing areas has reduced in the past 10 to 15 years. The key reasons given were *P. juliflora* invasion and erratic nature of rain the area is experiencing. Most of the respondents and elders in the group discussion stressed that the invasion has also threatened multipurpose indigenous trees/bushes.

Durfu (*Chrysopogon plumulosus*), *isissu* (*Cymbopogon pospischilii*), *melif* (*Andropogon canaliculatus*), *denkito*

Table 2 Logit *P. juliflora* as a source of income model: maximum likelihood result (response variable, $Y = 1$ if a household uses *P. juliflora* as a source of income, $Y = 0$ otherwise)

Explanatory variable	Coefficient	Std. error	Marginal effect
Age of household head	−0.045	0.023[a]	−0.010
Primary school dummy (1 = yes, 0 = no)	−0.002	0.534	−0.001
Polygamy status (1 = yes, 0 = no)	0.657	0.742	0.152
Family size	−0.095	0.104	−0.022
Livestock asset	0.018	0.018	0.004
Change in livestock asset	−0.011	0.006[a]	−0.003
Division in which household is located (reference is Worer)			
Amibara (1 = yes, 0 = no)	0.541	0.713	0.126
Awash Arba (1 = yes, 0 = no)	0.552	0.671	0.128
Halaideghe (1 = yes, 0 = no)	−1.461	0.865[a]	−0.339
Gewane (1 = yes, 0 = no)	1.169	0.666[a]	0.271
Sideha-Faghe (1 = yes, 0 = no)	−0.337	0.783	−0.078
Constant	1.481	0.993[a]	0.344
Number of observations		142	
LR(G)		20.83[a]	
Log likelihood		−63.36	

Marginal effect shows a change in probability in using *P. juliflora* as a source of income for a unit change in an explanatory variable
[a]Significant at 5 %

(*Eragrostis cylindriflore*), and *ayti-adoita* (*Terapogon cenchriformis*) were frequently mentioned grasses to have been affected by *P. juliflora* invasion in the whole basin, whereas the invasion's effect on *sitabu* (*Vossia cuspidata*) and *gedoyyta* (*Cyprus* spp.) were specific to Gewane only (Table 4). Among the indigenous trees, *Adaito* (*Salvadora persica*), *e'ebto* (*Acacia tortilis*), *ada-doita* (*Acacia senegal*), *adengali* (*Cadaba rotundifolia*), and *kasalto* (*Acacia nilotica*), which are browseable trees, were the most affected ones (Table 4).

P. juliflora invasion and Afar traditions

A high proportion of the respondents felt that *P. juliflora* invasion has undermined some traditions and institutions of Afar pastoralists (Table 1). In Afar culture, there is a high degree of reciprocity—if a household loses its livestock asset due to rustling, epidemics, or other agents, the risk is divided among the whole clan; thereby, the household gets some stocks for rebuilding its stock asset. However, nowadays, the possibility for risk division is very rare as each household is under pressure of losing its livestock asset due to narrowed dry- and wet-season grazing lands caused by *P. juliflora* encroachment.

P. juliflora and Afar pastoral livelihoods

For Afar pastoralists, pasture and livestock are key components of their livelihoods. Livestock asset comparison was made between "before" and "after" *P. juliflora* invasion within a household (Fig. 4). The current livestock

Table 3 Perceived proportion of grazing lands invaded by *P. juliflora* on the six villages of the Middle Awash area

Invasion proportion	Villages						χ^2
	Amibara	Awash Arba	Gewane	Halaideghe	Sideha-Faghe	Worer	
Less than half invaded	2 (11.1)-	0 (0.0)-	0 (0.0)-	0 (0.0)-	2 (8.0)-	1 (2.3)-	
	–	–	–	–	–	–	–
Half to two thirds invaded	4 (22.2)	4 (28.6)	2 (10.0)	1 (5.0)	2 (8.0)	14 (31.8)	
	3.15	2.76	4.14	3.94	4.53	8.47	9.10
Two thirds to three fourths invaded	8 (44.4)	3 (21.4)	4 (19.0)	11 (55.0)	7 (28.0)	7 (15.9)	
	4.87	4.09	6.13	5.84	6.72	12.56	10.43
Three fourths and above invaded	4 (22.2)	7 (50.0)	15 (71.0)	8 (40.0)	14 (56.0)	22 (50.0)	
	8.18	7.15	10.73	10.22	11.75	21.97	4.75

$\chi^2 = 24.28$, $p = 0.007$. The χ^2 test did not include the "less than half invaded" row as their expected count was less than 5. The numbers in brackets show the proportion; values in the second row of each cell show the expected count from χ^2 test

Table 4 Plant species perceived to be threatened by *P. juliflora* invasion in the Middle Awash area

Grass/herbs			Tree/bush		
Vernacular name	Scientific name	Frequency of respondent	Vernacular name	Scientific name	Frequency of respondent
Ayti-adoyta	*Terapogon cenchriformis*	77 (54.2)	Adadoita	*Acacia senegal*	81 (57.0)
Bonket	*Tribulus zeyher*	35 (24.6)	Adaito	*Salvadora persica*	93 (65.5)
Delaita	*Setaria acromelaena*	41 (28.9)	Adengali	*Cadaba rotundifolia*	79 (55.6)
Denkito	*Eragrostis cylindriflore*	49 (54.8)	E'ebto	*A. tortilis*	86 (60.6)
Durfu	*Chrysopogon plumulosus*	97 (68.3)	Gerento	*A. oerfota*	67 (47.2)
Halal	*Ipomoea sinensis*	38 (26.8)	Gerssa	*Dobera glabra*	47 (33.1)
Irareyta	*Cyndon dactylon*	69 (48.6)	Hedayto	*Grewia tenax*	44 (31.0)
Isissu	*Cymbopogon pospischilii*	96 (67.6)	Kasalto	*A. nilotica*	76 (53.5)
Ka'ato	*Sedge species*	35 (24.6)	Mederto	*Cordia Sinensis*	25 (17.6)
Melif	*Andropogon canaliculatus*	78 (54.9)			
Serdoita	*Cenchrus cilaries*	39 (27.5)			
Anterba[a]	*Ipomoea aquatica*	6 (28.6)			
Gedoyta[a]	*Cyprus* spp.	18 (85.7)			
Sitabu[a]	*Vossia cuspidata*	19 (90.5)			

The numbers in brackets show the percentage of respondent which considered plant species to be threatened
[a]Grasses grown at swampy grasslands found at Gewane and their proportion is relative to respondents from Gewane

holding of individual household was about 20 % of what they had before *P. juliflora* invasion. The Wilcoxon signed-rank test (T^+) showed that the reduction is highly significant for all livestock categories within a household. The main reasons given for the reduction in livestock assets were shortage of pasture due to *P. juliflora* invasion (48 %) followed by recurrent drought (40 %) and disease (10.6 %). Those who mentioned drought as a major factor also said that *P. juliflora* invasion aggravated the rain shortage problem. According to them, before *P. juliflora* invasion, they used to have enough dry pastures on the field even during drought season. Besides, a disease which is locally called *Armeko*, characterized by twisted neck and dental disfiguration, caused by eating *P. juliflora* pod was accused for fueling the problem. Each household, on average, lost about 6.5 sheep/goats and 7 cattle in the past 10 years due to a complexion caused by the pod. The continual reduction of livestock asset a household experienced made it very difficult to depend on sole pastoralism driving them to look for additional means of stay.

Factors affecting diversification of livelihoods as a response to the declined livestock assets was assessed using logit model (Table 5). Accordingly, household head age, level of education, change in livestock asset, location, and perceived size of grazing land invaded by *P. juliflora* significantly affected a household decision to diversify its source of income or to change lifestyle ($G = 36.23$, $p = 0.009$). The probability of diversifying livelihood was about six times higher for a household having some level of education than an uneducated one. As per the result, young-headed households were more likely to have diversified livelihood than old-headed households. Households that lost much livestock asset due to *P. juliflora* invasion had relatively less diversified sources of income than those who did not. On the other hand, realization of the proportion of grazing land abandoned by *P. juliflora* invasion significantly drove households to diversify their livelihood. On top of these, location dummies showed that households at Amibara and Halaideghe had lesser tendency to diversify their livelihoods relative to households at Worer, which probably be due to the presence of a number of governmental and private organizations (as source of employment for rural villages) closer to Worer.

Discussion

Majority of the pastoralists realized the presence of *P. juliflora* in the Middle Awash area about 30 years ago. In all the surveyed villages, pastoralists use *P. juliflora* as homestead hedge/fence and for fuelwood. However, most women complained about pricking by the thorn during fuelwood collection and also the deterring smoke *P. juliflora* wood has while using it for cooking, especially when the wood is wet. On top of these, according to the respondents, structures of fence, house, or barn made from *P. juliflora* (Fig. 2) collapse sooner than those made from indigenous sources like *adengali* (*C. rotundifolia*), *e'ebto* (*A. tortilis*), and *kasalto* (*A. nilotica*). The reason given was that wood from *P. juliflora* is very susceptible to wood-boring insects which makes structures made from it collapse sooner. Most of the uses of *P. juliflora* were abundant driven; otherwise, according to the respondents, they would prefer to use indigenous plants.

Table 5 Logit diversification of livelihood strategies model: maximum likelihood result (response variable, $Y = 1$ pastoralism and/or others, $Y = 0$ pastoralism only)

Explanatory variable	Coefficient	Std. error	Marginal effect
Age of household head	−0.036[b]	0.025	−0.006
Primary school dummy (1 = yes, 0 = no)	1.744[b]	0.717	0.314
Polygamy status (1 = yes, 0 = no)	−0.202	0,802	−0.036
Family size	0.139	0.133	0.025
Livestock asset	0.025	0.023	0.005
Change in livestock asset	−0.903[b]	0.034	−0.163
Perceived size of grazing land invasion (1 = above 2/3 is invaded, 0 = 2/3 or less is invaded)	0.987[b]	0.639	0.178
Division in which household is located (reference is Worer)			
Amibara	−1.790[a]	0.854	−0.322
Awash Arba	−0.257	0.889	−0.046
Halaideghe	−2.483[a]	0.789	−0.447
Gewane	0.132	0.911	0.024
Sideha-Faghe	−1.051	0.838	−0.189
Constant	1.318	1.169	0.204
Number of observations		142	
G		36.23[a]	
Log likelihood		−51.31	

Marginal effect shows a change in probability in diversifying a household's livelihood for a unit change in an explanatory variable
[a]Significant at 5 %
[b]Significant at 1 %

P. juliflora invasion has affected fodder/feed availability on grazing lands of the Middle Awash area. Studies showed that encroached grazing lands have low stocking capacity and reduced herbage yield (Mugasi et al. 2000; Moleele et al. 2002; Angassa 2005). In the case of *P. juliflora*, its effect on grazing lands can reach to an extent of turning pasture lands into totally unusable bush lands (Getachew 2002; Hailu et al. 2004). Apart from its effect on grazing lands, *P. juliflora* pod causes twisted neck and dental disfiguration (called *Armeko*) of cattle and goat/sheep resulting in livestock losses. *Armeko*, based on the respondents, is severe during drought season as the livestock heavily depend on *P. juliflora* pods for survival. Similar problem was also reported by Esther and Brent (2005). Tabosa et al. (2006) observed that prolonged consumption of *P. juliflora* pod affects cranial nerves, controlling neck muscle, of cattle. In spite of these effects, the pod is nutritionally rich (Benedito 1988; Pasiecznic et al. 2004; Esther and Brent 2005), and livestock can depend on it to survive drought season (Ellis and Swift 1998). Nevertheless, the experience of the Afar pastoralists is, unless the pod is mixed with other feeds, solely dependent on *P. juliflora* pod during drought can be lethal for livestock.

It is true that for pastoralists, livestock and pasture are key components of their livelihoods. As a result, factors affecting accumulation of livestock assets and access and claim to grazing lands have direct implication on pastoralists' sustained existence (Chambers and Conway 1991). As the scale of encroachment of invasive species increases, its effect on the supply of ecosystem goods and livelihood activities also increases (Siges et al. 2005; Gemedo et al. 2006; Shackleton et al. 2006; Angassa and Oba 2008). In the Middle Awash area, majority of the households perceived that more than half of their grazing land is occupied by *P. juliflora*. During the survey, I also realized that a significant proportion of grazing lands were already encroached by the plant as shown in Fig. 3. The invasion forms impermeable, dense thickets, reducing grass cover of grazing lands. Despite this, it was the extended fodder/forage source areas which would guarantee the existence of pastoralism in their fragile ecosystem.

Fig. 3 *P. juliflora* encroachment at Bedlu-Ale grazing land, Middle Awash area

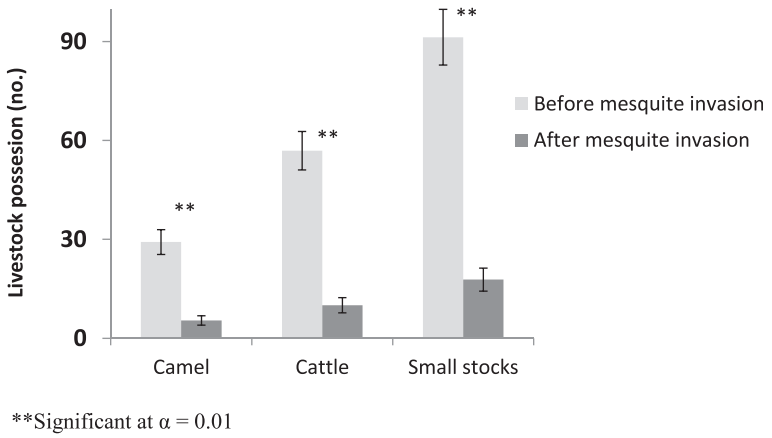

Fig. 4 Livestock asset of individual household, before and after *P. juliflora* invasion in the Middle Awash area

The other problem associated with *P. juliflora* invasion is its hindrance on transhumance, a seasonal migration for search of feed. However, transhumance is one of the risk management strategies used by pastoralists to maintain their livestock asset. Transhumance allows marked recovery of grazing lands due to de facto "protected" grazing and also enables optimum utility from the grazing lands (Western and Nightingale 2002). Following the introduction of *P. juliflora* to the Middle Awash area, grazing lands of different seasons have been invaded, limiting transhumance to a maximum. The limitation in transhumance has in turn resulted in overgrazing of remained pasture sources leaving pastoralists with low number of stocks. Similar problems were also reported in Kenya and India (Gavali et al. 2003; Esther and Brent 2005). As a result, the pastoralists' resilience to environmental uncertainties is impaired by raising their ecological vulnerability (Swallow 1994; Mariara 2005).

Generally, the accumulation of livestock asset by pastoral communities helps them to minimize and absorb risks (Swallow 1994; Little et al. 2001; Moritz 2013). Pastoralists keep their most valuable livestock and sell the others for absorbing risk, and at the end, they sell their most valuable animals to ensure their survival (Swallow 1994). When it comes to Afar pastoralists, it appears that they were better off before *P. juliflora* invasion (Fig. 4). According to Seid (1994), a purely pastoral household in the Middle Awash area needs on average 80 small stocks, 41 cattle, and 27 camels to meet the needs of the household, which may guarantee to rebuild stocks after drought or other shocks. Nonetheless, the average current holdings of livestock (5.4 camels, 10 cattle, and 17.8 small stocks; Fig. 4) are by far lower than what was mentioned by Seid (1994), implying that total dependency on livestock rearing as a sole source of livelihood is difficult nowadays.

The *P. juliflora*'s effect on the life-supporting unit of pastoralist, grazing land, has made sole dependency on pastoralism less likely. Measures, such as cultivation of land, share cropping, formal employment in mechanized farms and other organizations, and engaging in casual labor and small trade have been taken by Afar pastoralists to secure their livelihoods. Pastoralists use various adaptive risk management strategies to enhance their resilience and secure their livelihoods when sole dependency on livestock is in question (Swallow 1994; Little et al. 2001).

Conclusions

In conclusion, in the Middle Awash area, *P. juliflora* is a strong competitive bush with low beneficial traits for Afar pastoralists. The bush has reached a level to impair the pastoral livelihoods in different ways like (a) reducing pasture availability; (b) inhibiting mobility; (c) having poisonous thorn for both the people and their livestock; (d) having pods posing health hazard for livestock; and (e) threatening traditions and institutions. The effects mentioned are interlinked and interacting with one another to heavily test pastoral way of life in the Middle Awash area putting them extremely vulnerable to environmental uncertainties.

Additional file

Additional file 1: Group discussion checklist and household survey questionnaire used in the study.

Competing interests

The authors declare they have no competing interests.

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