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Economic impact of *Prosopis juliflora* on agropastoral households of Dire Dawa Administration, Ethiopia

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This study was undertaken to empirically evaluate the impact of a controversial alien species called *Prosopis juliflora* invasion on the livelihood of agropastoral households selected from rural Dire Dawa Administration of Ethiopia. One hundred and fifty five respondents were randomly drawn from both invaded and non-invaded rural areas of the Administration with similar pre-invasion characteristics. The major analytical concern of the study is to estimate the impact of *P. juliflora* invasion on agropastoral households' farm income using propensity score matching technique. After controlling for differences in demographic, socioeconomic and institutional characteristics of the sampled households, it was found that, on average, invasion by P. *juliflora* has significantly decreased annual income of the agropastoral households from livestock and their products sale by 780.74 Birr (28.82%) and increased average annual income from crop sale by 839.31 Birr (25.85%) though not statistically significant. Based on these results, the study recommends efficient use and/or eradication of *P. juliflora* to reverse its adverse effects on the agropastoral households in Dire Dawa Administration.

Key words: *Prosopis juliflora,* invasive alien, agro-pastoralists, propensity score matching (PSM), Dire Dawa Administration.

INTRODUCTION

Prosopis juliflora (P. juliflora), an ever green tree native to South America, Central America and Caribbean was first introduced to many tropical areas in the 1970s and 1980s as a response to the global concern of deforestation, desertification and fuel wood shortages. It is fast growing, nitrogen-fixing and tolerant to arid conditions and saline soils. In Ethiopia, it was first introduced in the Afar region in the 1970s by the Ministry of Agriculture from India in an effort to improve water and soil conservation and fight desertification (EARO and HDRA, 2005). In Ethiopia, *juliflora* has covered an area of one million hectares and more than 12,000 hectares in Dire Dawa Administration (BoARD, 2009). It has now been expanded to the south-eastern and south-western parts of the country reducing the farm land, choking out local plant species and drastically reducing the grazing land and now considered as the national number one invasive plant (EARO and HDRA, 2005). The tree was found to have both positive and negative effects on the livelihood of the invaded community and the environment. As to the positive effects, *P. juliflora* is a multipurpose tree/shrub whose wood is used for firewood, charcoal, posts, poles, and a sawn timber; its pods can be used as a livestock feed and for making human foods; and environmental services

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provided by nitrogen fixation, shade, shelter, live and dead fencing, erosion control, soil improvement and reclamation are remarkable. Secondary products from this tree includes honey (as a bee forage), edible exudate gums, fibres, tannins, foliage for fodder, mulch, biopesticides and medicines, and other uses for wood and pods such as particle board, wood chips for energy generation, pods for ethanol production, galactomannan gums from the seeds and other specialist products (Pasiecznik, 1999; Pasiecznik et al*.,* 2001; Hailu, 2002).

The negative effects include reduced crop fields and grazing areas, invasion into wetlands that reduces their value for watering and dry season grazing, invasion into the lakeshore areas making fishing more difficult, consumption of seed pods that damage teeth of goats; sharp, strong and poisonous thorns that cause wounds to livestock and human beings. Increased disease incidence associated with microclimate change due to invasion and reduced utilities from indigenous herbs, trees and wild animals were also cited as the negative effect of the tree. Besides, the invasion blocked paths to water points, grazing areas and between villages and served as shelter for predators (Shakeleton et al., 2006; Easther and Brent, 2008; Zeila, 2008).

People's perception about the costs and benefits of *P. juliflora* depend on their livelihood strategy. Rural poor who cannot afford alternative energy sources value the tree for fuel and fodder production. Similarly, ranchers, pastoralists and agropastoralists whose main livelihood strategy is keeping livestock and farming view it negatively because it invades pastures and farm lands (Saxena, 1997).

In India and counties of its origin (South America, Central America and Caribbean) *P. juliflora* was called a "poor man's tree" or a valuable tree from which considerable people's in the drylands make their living. For example, in the native range Americas, all parts of the tree are valued, supplying raw materials and supporting local trade in processed goods. In Africa and Asia, however, it remains under-used and is often regarded as an invasive weed and calls it a "devil tree". Studies in these regions of the world show that the possible benefits of the plant have been dramatically outweighed by the multiple negative impacts associated with its invasion and propose its eradication through possible means. This might be related to the fact that the indigenous knowledge surrounding its wise management and use was not introduced along with the tree and lack of appropriate technologies that reduce its spread by increasing its utilization (DFID, 2005).

According to Hailu (2002), the potentially deleterious effects and the valuable prospect of *P. juliflora* in Ethiopia in particular or in tropics in general should be the subjects for more research efforts, management systems and debates among researchers, governmental and non-governmental organizations, and other stakeholders. *P. juliflora* is now a serious topic in Ethiopia, especially in Afar region and Dire Dawa administration (DDA). In Ethiopia, the spread of invasive plant species in national parks, lakes, rivers, power dams, and urban green spaces is a growing concern and it is causing huge economic and ecological losses (Hailu et al., 2004; Kassahun et al., 2005; Senayit et al., 2004).

Empirical studies on the economic impact of the invaded households are scanty. A study by Ndhlovu (2011) on the impact of *P. juliflora* (mesquite) invasion and clearing on ecosystem structure, function and agricultural productivity found that in heavily grazed rangeland *P. juliflora* invasion and clearing can signifycantly change rangeland vegetation composition, with invasion leading to greater alien species cover and lower indigenous species richness, while clearing leads to lower alien species richness and cover and greater indigenous species richness and cover. However, invasion seems to have no effect on alien species richness and overall indigenous species cover. Clearing appears to facilitate the spontaneous restoration of alien species cover and indigenous species richness within four to six years but not species composition, alien species richness and indigenous species cover. In addition, his results also indicate that *P. juliflora* invasion can lower rangeland plant canopy and basal cover and grazing capacity while clearing, even under heavy grazing, can substantially raise them. Clearing however does not seem to facilitate the restoration of rangeland plant canopy and basal cover and grazing capacity to pre-invasion levels within four to six years after clearing.

A study by Mulindol and Sang (2004) on the farmers' perceptions and the impact of *P. juliflora* on food security in Kenya show that about 6.0% of each household's piece of farmland had been reduced by the plant denying each household an annual yield of about 600 kg of maize. In addition, the plant was associated with about 38% of all the livestock deaths in the region. An analysis of the costs and benefits associated with the plant revealed that benefits were outweighed by the costs justifying the farmers' demand for total eradication of the plant. However, institutions (property rights, customary authority) and the incentives that they produce may limit the range and effectiveness of the possible responses farmers may give in a probe. The plant was found to be a critical component of environmental conservation in the area and as government policy regarding use of forest products undergoes reforms, farmers' attitudes towards the plant may be found to change in the short-run.

Esther and Brent (2008) conducted a study on the livelihood effects, costs of control, and local perceptions of the invasive tree, *P. juliflora*, on rural residents in the Lake Baringo area of Kenya. Their results show that *P. juliflora* potential benefits have not been captured and few people in the Lake Baringo area realize net benefits from the widespread presence of the tree. Strong local support for eradication and replacement appears to be well justified. Moreover, they noted that sustainable

Table 1. Variables definition and measurement.

Variable	Type and definition	Measurement
Treatment variable		
Invasion by *P. juliflora*	Dummy, invasion by *P.juliflora*	1 for invaded households and 0 otherwise
Outcome variable		
Income from livestock sale	Continuous, annual income from livestock sale	Birr
Income from crop sale	Continuous, annual income from crop sale	Birr
Explanatory variable		
Age	Continuous, age of household head	Years
Education	Dummy for illiterate household head	1 if the household head is illiterate and 0 otherwise
Irrigation	Dummy for access to irrigation	1 if a household head has access to irrigation and 0 if not
Sex	Dummy for sex of household head	1 if the household head is female and 0 if male
Credit	Dummy for access to rural credit service	1 if the household head has access to credit service and 0 if not
Experience	Household head's farm experience	Years
Safety net	Dummy for access to safety net program	1 if the household head is engaged in safety net program and 0 otherwise
Drought	Dummy for effect of drought	1 if the household's income from livestock and crop production decreased as compared to the normal year and 0 if not
Off/non-farm activities	Dummy for engagement of the household head in off/non-farm activities	1 if the household head is engaged in off/non-farm activities and 0 otherwise
Distance to market	Continuous	Market distance from residential area in kilometers

utilization may require considerable investment in the development of new commercial enterprises.

Even though *P. juliflora* could be both beneficial and harmful to the local communities, there are no empirical studies in the country and elsewhere in the world which tested its livelihood impact using rigorous econometric techniques like propensity score matching (PSM). This study aims at filling this research gap.

The major objective of the study was to measure the impacts of *P. juliflora* invasion on the rural livelihoods of DDA, through a comparative assessment of invaded and non-invaded households' income generated from livestock and crop production using propensity score matching (PSM) method suitable for impact assessment when there is no base line survey.

METHODOLOGY

Study area

The study was conducted in DDA, the second most *P. juliflora* infested area in Ethiopia next to the Afar National Regional State. Dire Dawa is the second most urbanized city in the country next to Addis Ababa. DDA is organized into 38 rural and 9 urban Kebeles. It has a flat monotonous topography and predominantly pluvisols soil type with extremely high temperature and erratic rainfall. It belongs to the lowland agro ecology (less than 1500 masl with a total annual rainfall ranging between 500 and 650 mm) (IDP, 2006). The study area is located to the west of Dire Dawa city and it covers a total area of 26,437 ha which is nearly 20% of the area of the Administration. It has an estimated population of 17,800 which is nearly 16.5% of the rural population in the Administration (BoARD, 2009). Agriculture (both crop and livestock production) is the main stay of the economy in the study area. Subsistence mixed farming is practiced by 93% of the farm households (Table 1). Selling of firewood is the most non-farm income generating activity in the study area.

Sampling methods and sample size

Out of the 38 rural Kebeles[1] in the Administration, all the four *P. juliflora* invaded Kebeles and three non-invaded Kebeles with similar demographic, socioeconomic and geographic characteristics were purposively selected. A total of 155 households (71 from the *P. juliflora* invaded Kebeles and 84 from the non-invaded Kebeles) were randomly selected based on probability proportion to sample size.

Data sources and types

Both primary and secondary data were collected from different sources. Primary data were collected through semi-structured questionnaires, focus group discussions, story tells, transact walks

[1] Kebele refers to the smallest administrative division in the country.

with elders, and key informants interview. Secondary data pertinent to the study were collected from district, zonal and national agricultural offices.

Data analysis

In this study both descriptive and econometric methods were used to analyze data.

Descriptive statistics

Descriptive statistics like mean, standard deviation, minimum, maximum, percentages, frequency, tables and graphs are used to describe the socio-economic, demographic and institutional characteristics of the sampled households.

Propensity score matching technique

Invasion by *P. juliflora* of the agropastoral communities was not randomized. Consequently, we used propensity score matching (PSM) developed by Rosenbaum and Rubin (1983) to assess if invasion by *P. juliflora* has a significant negative impact on the livelihood of the invaded communities. PSM uses a statistical model to calculate propensity of invasion on the basis of the set of observable characteristics. Invaded and non-invaded households are then matched on the basis of similar propensity scores. The idea behind the PSM approach is to find control observations (that is, invaded households) having initial observable characteristics similar to the invaded households, to serve as valid surrogates for the missing counterfactuals.

This involves estimating a Logit model that predicts the probability that each household is invaded as a function of observed household and community characteristics using a sample of invaded and non-invaded households. The model specification is checked to test equality of the means of these observed characteristics across the invaded (treatment sample) and non-invaded (control sample).

In the impact estimates, the estimated probability of being invaded, or "propensity score", from this model is used to determine the closeness (the "match") of treatment observations to neighboring non-invaded observations with similar values of the propensity score. The impact estimate is constructed as the average difference in the outcome of each invaded and a weighted average of non-invaded outcomes, using the difference in propensity scores to construct the weights. Non-invaded households with propensity scores nearest to the treatment observation receive the highest weight.

PSM provides reliable estimates of *P. juliflora* invasion impact provided that (1) a comparable group of agropastoral households is available, and (2) there is access to carefully collected household survey data with many variables that are correlated with invasion and the outcome variables (Heckman et al., 1998a).

The treatment sample was designed to include an appropriate control group. The control sample is drawn exclusively from the DDA who are not invaded by *P. juliflora*. Also, the survey includes a large set of variables affecting household welfare and invasion. These variables include measures of household head age, gender and schooling, household size and other demographic characteristics, asset levels, distance to markets, indicators of social networks and exposure to economic shocks.

This approach assumes that after controlling for all pre-invasion observable household and community characteristics that are correlated with invasion and the outcome variables, non-invaded households have the same average outcome as invaded households would have had if they were not invaded. PSM provides biased estimates of invasion impact if, for any chosen outcome, it is not feasible to control for enough observable characteristics so that this assumption holds. Having control households from the same communities as treatment helps to reduce the risks of such bias by providing a similar distribution of unobserved community characteristics such as access to markets or local economic shocks.

It is also assumed that for each invaded household and for all observable characteristics, a comparison group of non-invaded household with similar propensity scores exists. Heckman et al. (1998a) emphasize that the quality of the match can be improved by ensuring that matches are formed only where the distribution of the density of the propensity scores overlap between treatment and comparison observations, or where the propensity score densities have "common support." Common support is improved by dropping treatment observations whose estimated propensity score is greater than the maximum or less than the minimum of the comparison group propensity scores. Similarly, comparison group observations with a propensity score below the minimum or above the maximum of the treatment observations are also dropped.

The balancing property of the logit specification is tested to ensure that sample of invaded households and the sample of non-invaded households have similar mean propensity scores and observables at various levels of propensity scores (Becker and Ichino, 2002). Hence, the results are presented based on specifications that passed the balancing tests. Related to the balancing property of p-score is the conditional independence assumption (CIA), which states that the existence of *P. juliflora* is random and uncorrelated with household income, once the set of observable characteristics, X, are controlled for. Sensitivity analysis was also undertaken to check if the influence of unobserved variables on the selection process is so strong to undermine the matching procedure.

Variables definitions and measurement

The variables hypothesized to be related to invasion and outcome variables were identified through review of relevant literature and authors' knowledge about the study area.

RESULTS AND DISCUSSION

Here, descriptive and econometric model results are presented.

Descriptive results

Household characteristics

The results presented in Table 2 show that there are statistically significant differences between invaded and non-invaded households with respect to distance to market centers. Results show that compared to non-invaded households, invaded households are closer to market centers.

The results presented in Table 3 show that there are statistically significant differences among households in the invaded and non-invaded areas in terms of access to credit and off/non farm income generating activities. This shows that invaded households have better access to credit and off/non-farm activities may be because they

Table 2. Sample households' characteristics for continuous variables.

Variable	Invaded sample (N=71)	Non-invaded sample (N=84)	Total sample (N=185)	t-value
	Mean(Std)	Mean(Std.)	Mean(Std)	
Age	42.92(8.77)	40.80(10.14)	41.77(9.56)	-1.45
Distance to market	6.49(0.30)	5.68 (0.28)	6.05 (0.21)	-1.98**
Farm experience	21.23(1.06)	19.07 (0.90)	20.06(0.69)	-1.56

**Means significant at 5% probability level.

Table 3. Sample households' characteristics for discrete variables.

Variable	Category	Invaded sample (N=71)		Non-invaded sample (N=84)		Total sample		χ^2
		N	%	N	%	N	%	
Sex	Male	48	67.61	56	66.67	104	67.10	0.02
	Female	23	32.39	28	33.33	51	32.90	
Education	Illiterate	58	81.69	64	76.19	122	78.71	0.69
	Literate	13	18.31	20	23.81	33	21.29	
Irrigation	Yes	9	12.68	16	19.05	25	16.13	1.15
	No	62	87.32	68	80.95	130	83.87	
Credit	Yes	40	56.34	34	40.48	74	47.77	3.88**
	No	31	43.66	50	59.52	81	52.23	
Safety net	Yes	59	83.10	64	76.19	123	79.35	1.12
	No	12	16.90	20	23.81	32	20.65	
Drought	Yes	69	97.18	81	96.43	150	96.77	0.07
	No	2	2.82	3	3.57	5	3.23	
Off/non- farm	Yes	35	49.30	55	65.48	90	58.06	4.14**
	No	36	50.70	29	34.52	65	41.94	

**Means significant at 5% probability level.

are closer to the cities as compared to non-invaded households. However, invaded and non-invaded households are similar in terms of other variables such as sex, educational status, irrigation access, drought incidence, and participation in safety net program. The survey results indicate that the majority of the households in the study area illiterate, have no irrigation access, are members of the safety net program and are affected by drought.

Perception of agropastoralists about P. juliflora

Nearly, 31% of the respondents in the *P. juliflora* invaded kebeles knew the bush for the last 11 to 15 years, whereas 67.61% are aware of it in the last five to ten years. However, almost all of the respondents (98.59%) mentioned that they felt the severity of the invasion in the last five to seven years. Around 59% of the surveyed agropastoral households in the invaded areas perceived *P. juliflora* as undesirable species while only 5.63% considered it as beneficial and the rest 35.22% stated it as both beneficial and harmful.

As to the adverse effect of *P. juliflora,* respondents mentioned decrease in grazing land and forage availability (60.56%), decline in ground water potential (9.86%), loss of biodiversity (7.04%) and others (9.86%)[2]. This implies *P. juliflora* invasion has significantly affected the grazing land and forage availability and consequently livestock production. Even though there are variations among invaded Kebeles on the proportion of grazing areas covered by *P. juliflora*, all the surveyed households reflected that pasture areas have been shrunk after its introduction. Most of the surveyed households perceive that half to three fourth of their grazing lands was lost due to *P. juliflora* invasion.

All the sampled households agree that forage/fodder cover of grazing areas were reduced in the past ten to fifteen years. The most important factors often mentioned for the decline in forage /fodder covers were recurrent drought and *P. juliflora* invasion. Most of the respondents and some elders in the focus group discussion stressed that the invasion threatened some grass species which

[2]Others refer to the poisonous nature of its thorns, alleliopathic effects of its leaves and the allergic reactions of its pollen.

Table 4. Coping mechanisms of the households against the invasion.

Coping mechanism	Percentage (yes)
Use it as income source	76.06
Livelihood diversification	5.63
Eradicate it	9.86
No action	8.45
N	71

Source: Own survey.

their cattle. Results also show that nearly thirty[3] different grass species were perceived to be threatened by *P. juliflora* in the four invaded Kebeles. This situation has put heavy pressure on the remaining pasture which according to Esther and Brent (2008) leaves the pastoral and agropastoral community under frequent conflict with their neighbors.

For agropastoralists in the study area, the importance of the species was found to be abundance driven. Most sampled households (77.42%) from the invaded area use it as a source of fuel wood and charcoal. About 16% use it for live fencing, 3.23% as a feed for livestock and the rest (3.22%) use it for a combination of the above purposes. This implies the importance of the invasive species as a source of fuel wood and/or charcoal either for domestic consumption or as a source of income to buffer the declining income due to crop failure or declining livestock productivity. Furthermore, results from focus group discussion show that even though its test is somewhat bitter, it is good bee forage and yields honey with some medicinal values.

Coping strategies against P. juliflora invasion

Table 4 summarizes the different coping strategies that the surveyed households in the invaded area adopt against the invasion by *P. juliflora*. Among the coping strategies, using the plant as a source of income or domestic fuel consumption took the lion's share (76.06%) followed by eradication (9.86%), no action (8.45%) and livelihood diversification or engaging in different off/non-farm income generating activities (5.63%).

The most important coping mechanism practiced by the agro-pastoral households in the invaded areas was selling of fuelwood and charcoal collected from this tree. The average annual household's income generated from fuel wood/charcoal sale in the invaded areas was 2881.00 Birr. Results show that 76.06% of the sampled households use the plant as a source of fuel wood/-charcoal. This constitutes around 26% of the average annual income of the households in the invaded areas. Only small proportion of the households (9.86%) controls the invasion by cutting either in groups or individually. However, respondents mentioned *P. juliflora's* fast regenerating or coppicing nature and its ability to cover a large area in a short period of time is discouraging. Some of the respondents noted bitterly that no other aid is worthwhile than eradicating it, as it regenerates in the afternoon when cut in the morning.

Even though some of the respondents in the invaded areas are not ignorant about its adverse effects, they prefer not to take any action mainly in fear of the thorny nature of the species and that selling of firewood is a taboo.

Econometric results

The econometric method used to evaluate the economic impact of invasion by *P. juliflora* is the Propensity Score Matching (PSM) method. The main purpose of using PSM model is to answer the question "what is the income generated from crop and livestock production of the invaded households would be, had these households not been invaded by *P. juliflora*?" which requires observing outcomes of a household with-and-without invasion. PSM first estimates the propensity scores by running binary choice models (Logit/Probit), drop observations outside the common support region, match observations based on propensity scores, calculate the invasion effect for each pair of matched observations and finally calculate the average of these difference6s.

Propensity scores

Logistic regression model is used to estimate propensity scores of invaded and non-invaded households. The Pseudo R^2 value of 0.32 (Table 5), indicates that the estimated model performs well for the intended matching exercise. In other words, the low Pseudo R^2 value shows that the explanatory variables are not influenced by *P. juliflora* invasion and hence, selection into treatment was close to random. The estimated coefficients from Logit regression (Table 3) indicates that access to irrigation, off/non-farm employment and distance to the market significantly and negatively affect households' probability of being invaded by *P. juliflora* while education, credit and drought affects it positively. These results show that households which are invaded by *P. juliflora* are the ones nearest to the town and hence have more access to off/non-farm activities and less access to irrigation. Moreover, they are more educated, have better credit access and are highly affected by drought.

Imposing a common support condition

As shown in Table 6, the estimated propensity scores

[3]Some of these grass species include Serdu, Balbalessa, Hadhawa, Hollagabis, Metasedi, Buran, Daremo, Cawismacaan, Nafriy, Kundi, Agar, Gumer, Deberduli, Cashcade Andekis, Shakume, Maddhbur, Dunfure,Wechere, etc.

Table 5. Logit results of invasion by *P. juliflora*.

Variable	Coefficients	Standard error	Z-value
Age	0.014	0.021	0.68
Sex	-0.189	0.366	-0.52
Education	4.356**	1.372	2.18
Irrigation	-2.176**	0.981	-2.22
Off/non-farm activities	-1.862***	0.422	-4.41
Distance to market	-0.108***	0.025	-4.34
Credit	0.607*	0.351	1.73
Experience	-0.246	0.361	-0.68
Safety net	0.608	0 .440	1.38
Drought	1.083*	0.629	1.72
Constant	-5.694**	1.903	-2.99
Number of observation	155		
Pseudo R^2	0.32		
LR $\chi2$ (10)	51.3		
Prob> $\chi2$	0.024		
Log likelihood	-82.243		

Source: Own estimation result; ***, ** and * means significant at the 1, 5 and 10% probability levels, respectively.

Table 6. Distribution of estimated propensity scores.

Group	Obs.	Mean	Std. Dev.	Min	Max
Total households	155	0.46	0.132	0 .18	0 .83
Treatment households	71	0.49	0.13	0.26	0 .83
Control households	84	0.43	0.126	0.18	0.74

vary between 0.26 and 0.83 (mean = 0.49) for *P. juliflora* invaded (treatment) households and between 0.18 and 0.74 (mean = 0.43) for non- invaded (control) households. The common support region would then lie between 0.26 and 0.74. In other words, households whose estimated propensity scores are less than 0.26 and larger than 0.74 were not considered for the matching exercise.

Choosing the best matching estimator

As shown in Table 7, alternative matching estimators were tried in matching the treatment and control households in the common support region. The final choice of a matching estimator was guided by different criteria such as equal means test, low pseudo-R^2 and large matched sample size as suggested by Smith and Todd (2001).

Based on these criteria, the results indicated that nearest neighbor matching (NNM) with replacement and kernel matching with 0.1 band width are the two best estimators for the data. In order to select the best one from these two estimators, a balancing test of covariates, before and after matching was implemented.

Balancing test

After matching, two types of balancing tests were employed, one is a simple t-test and the other is Hotelling’s T-squared test, to check for the similarity of household characteristics between the two groups. The Hotelling’s T-squared tests suggest that differences in household characteristics between the treatment and control groups are jointly insignificant both before and after matching. In the individual covariates balancing tests (Table 8), the number of variables with no statistically significant mean difference is ten in case of Kernel matching (KM) while it is nine in NNM. Hence, KM is preferred as the best estimator of average treatment effect, because it satisfies all the three matching performance criteria mentioned previously. Consequently only the outcomes from KM were used to estimate the impacts of *P. juliflora* invasion on households’ income generated from livestock and crop production.

Plausibility of the overlap and unconfoundedness assumptions

As can be seen from Table 8, the value of Pseudo R^2 is

Table 7. Performance of the matching estimators.

Matching estimator	Performance criteria	
	Pseudo-R^2	Matched sample size
Nearest neighbor matching (NNM)		
Neighbor with replacement	0.013	146
Neighbor without replacement	0.018	142
Caliper matching (CM)		
Radius 0.01	0.018	142
Radius 0.25	0.022	144
Radius 0.5	0.022	144
Kernel matching (KM)		
With no band width	0.018	142
Band width of 0.1	0.013	146

Source: Own estimation result.

fairly low after matching showing that the unconfoundedness assumption is plausible. Moreover, the study uses pscore graph to test the plausibility of the overlap assumption. As can be seen from Figure 1, the distribution of propensity scores of both treatment and control indicates the existence of unmatched observations in both the treated and untreated groups before common support condition is imposed. However, as can be seen from Figure 2, after matching the data using the KM, the common support condition has trimmed out a total of nine observations from the model (two from treatment and seven from control households which lie in the off-support regions) implying that the overlap assumption is also plausible for this estimator.

Treatment effect on the treated (ATT)

The estimation result presented in Table 9 provides a supportive evidence of statistically significant negative effect of the invasion on households' average annual income from livestock sale. However, the effect of the invasion on households' average annual income from crop production was not statistically significant even though the effect was shown to be positive.

After controlling for differences in demographic, socioeconomic and institutional characteristics of the invaded and non-invaded households, it was found that, on average, the invasion has significantly decreased annual income from livestock and their products sale by 780.74 Birr (28.82%) and increased average annual crop production by 839.31 Birr (25.85%) though not significant
The estimated significant negative effect on annual income from livestock and their products sale in invaded households might be attributed to reduced grazing land and loss of palatable grass species due to *P. juliflora* invasion. In addition, the heavy dependence of livestock on *P. juliflora* pod for survival, as it is abundantly found even during drought period might have resulted in *P. juliflora* borne health hazards which adversely affects livestock production and productivity (Esther and Brent, 2008; Mugasi et al., 2000; Pasiecznik et al., 2004; Al-Hmaid and Warrag, 1998; Gavali et al., 2003).

On the contrary, the estimated positive difference in average annual income from crop production in the invaded households is believed to arise from fertility improvement by *P. juliflora* and its contribution to soil and water conservation, which was mentioned by participants of the focus group discussion. This result is also in line with most of studies conducted on the contribution of *P. juliflora* to soil fertility.

Testing sensitivity to the specification of the propensity score

The proposed sensitivity analysis is conceptually related to the practice of assessing sensitivity of estimates by comparing the results obtained from discarding one or more observed covariates from the analysis (Dehejia and Wahba, 1999; Smith and Todd, 2001).

Table 10 presents the sensitivity of the estimates to the choice of specification by dropping in succession access to irrigation and drought in the covariates specification. The result revealed that the estimates are not particularly sensitive, compared to the estimates in the full specification of covariates. Hence, we choose the full specification estimates because it succeeded in balancing all the observed covariates, conditional on the estimated propensity score.

CONCLUSION AND RECOMMENDATIONS

Even though the majority of the sampled households use *P. juliflora* as a source of fuel wood for sale or home consumption, they perceive it as undesirable species that

Table 8. Balancing test.

Variable	Sample before matching	Sample after NNM	Sample after KM
Age			
Mean (treatment)	42.92	42.45	42.45
Mean (control)	40.80	38.79	42.54
t-test	0.18	0.68	0.95
Sex			
Mean (treatment)	0.68	0.63	0.67
Mean (control)	0.67	0.67	0.68
t-test	0.90	0.59	0.95
Experience			
Mean (treatment)	21.23	20.48	20.48
Mean (control)	19.07	16.70	20.65
t-test	0.12	0.01**	0.90
Off/non-farm activities			
Mean (treatment)	0.49	0.51	0.54
Mean (control)	0.65	0.48	0.51
t-test	0.04**	0.73	0.75
Education			
Mean (treatment)	0.18	0.18	0.18
Mean (control)	0.24	0.27	0.19
t-test	0.40	0.22	0.89
Drought			
Mean (treatment)	0.97	0.97	0.97
Mean (control)	0.96	0.99	0.96
t-test	0.79	0.56	0.83
Safety net			
Mean (treatment)	0.83	0.82	0.82
Mean (control)	0.76	0.88	0.82
t-test	0.29	0.34	0.93
Irrigation			
Mean (treatment)	0.13	0.13	0.13
Mean (control)	0.19	0.06	0.13
t-test	0.28	0.15	0.95
Credit			
Mean (treatment)	0.56	0.48	0.54
Mean (control)	0.41	0.40	0.50
t-test	0.049**	0.36	0.71
Distance to market			
Mean (treatment)	6.49	0.48	6.18
Mean (control)	5.68	0.40	6.21
t-test	0.049**	0.36	0.96
Hotelling's test	0	0	0
Pseudo R^2	0.320	0.013	0.013
N (treatment)	71	69	69
N (control)	84	77	79

*, ** and *** means significant at10, 5 and 1% probability level respectively.

has to be eradicated. An empirical test using PSM method also found a statistically significant negative effect of invasion by *P. juliflora* on the income from livestock and their products sale which is the main livelihood of agropastoralists. This result justifies eradication or increased use that limits its spread.

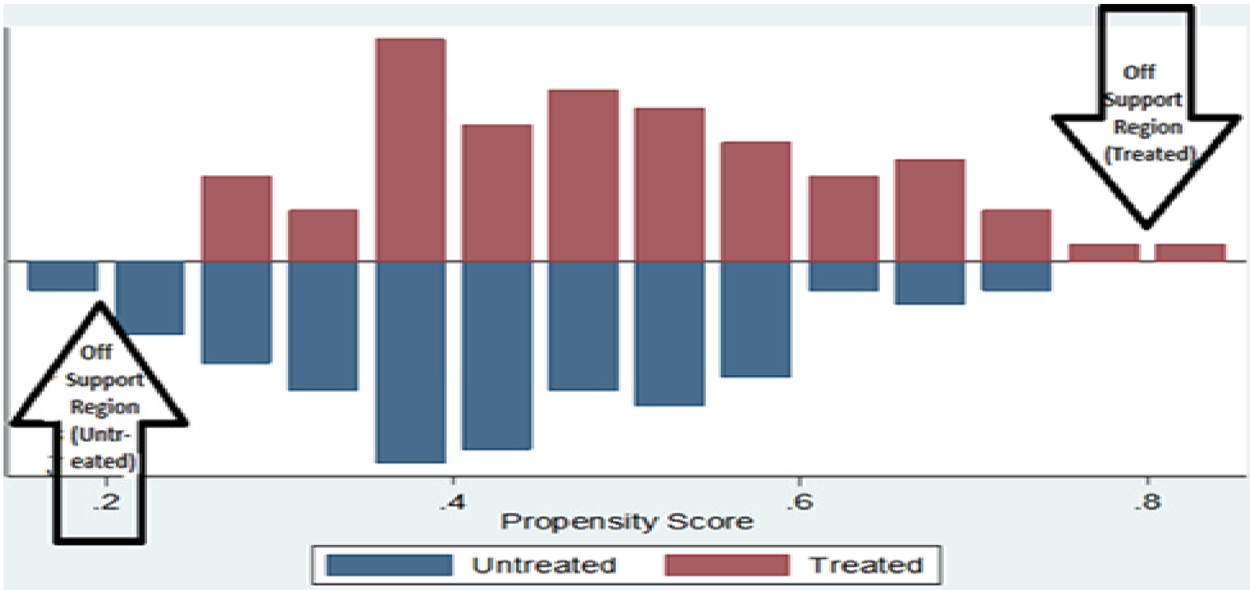

Figure 1. Distribution of p-scores of treated and untreated households before common support.

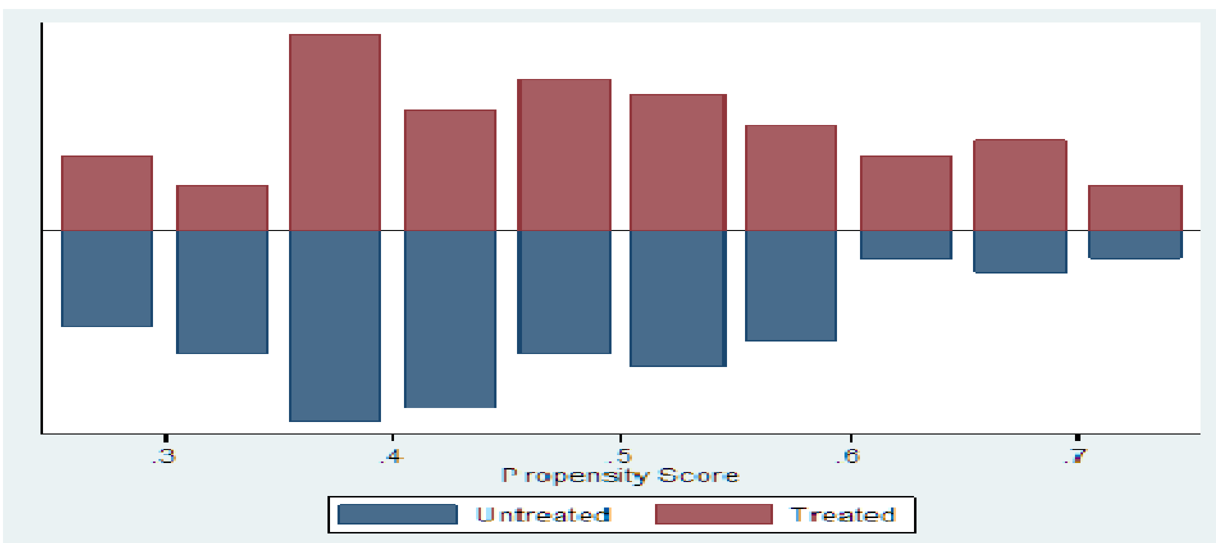

Figure 2. Distribution of p-scores of treated and untreated households after common support.

However, experiences around the world show that eradication is ineffective, costly and a futile management option. Studies from around the world indicate that through appropriate short, medium and long term-interventions the adverse effects of *P. juliflora* can be reversed. That means, promoting its utilization in a planned and regulated way through adoption of appropriate and sustainable management practices is beneficial.

Recently the production and productivity of livestock in the arid and semi-arid areas have been declining due to recurrent drought and enhanced desertification. Hence, increased use of *P. juliflora* that limits its negative effects could be an alternative livelihood means for pastoral and agropastoral households. This can be achieved through active involvement and proactive participation of the private sectors in *P. juliflora* product development and marketing and, introduction of a package of new technologies that would improve fuelwood production and pods processing for livestock and human food.

The study results show that households in the invaded area have a record of better harvest by clearing the lands covered by *P. juliflora*, converting some of the invaded grazing lands into crop land (especially sorghum). This

Table 9. Average treatment effect on the treated (ATT).

Variable	Treated	Control	ATT	t-value
Income from livestock sale	515.55	1045.96	-530.41	-2.04**
Income from crop sale	3246.55	2407.24	839.31	1.2

Table 10. Sensitivity of matching with replacement to the specification of the estimated propensity score.

Specification	Obs.	Outcome variable							
		Income from livestock sale		Income from milk sale		Income from livestock and milk sale		Income from crop sale	
		ATT	St. Err.	ATT	St. Err.	ATT	St. Err.	ATT	St. Err.
Full specification	146	-530	260.02	-250	354.4	-781	489.4	839.3	698.7
Dropping irrigation	149	-527	284.61	-263	456.7	-790	741.8	945.71	874.34
Dropping drought	153	-573	271.97	-290	381.2	-864	661.4	1008	778.06

is because gullies and degraded areas were covered with good soil when invaded by *P. juliflora* due to its ability to control gully erosion and soil retaining capacity. Improving the poor infrastructure (roads, communication) in pastoral and agropastoral areas which prevent interested entrepreneurs from investing and relaxing government's ban on charcoal movement on the invaded areas are important for the efficient use of *P. juliflora* products in the study area. So let us all try our best to tap at least some of the apparent benefits of this "poor's man tree" and turn the threats caused by the invasion into an opportunity.

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