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Impact of *Prosopis juliflora* on Pastoral Communities of Bale Zone Oromia Region, Ethiopia

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Abstract: Prosopis juliflora, an evergreen shrub, is one of the most invasive alien species causing economic and environmental harm in arid and semi-arid areas. It is spreading rapidly in the rangelands, croplands and forests and in particular is threatening pastoral and agro-pastoral livelihoods. Prosopis has invaded parts of wildlife reserves and National Parks threatening biodiversity. There are several factors favoring its rapid distribution in the environment. Its ability to adapt wide range of climatic condition, effective dispersal mechanism, its allelopathic effect, prolific nature, having large seed bank in the soil environment, fast growing and vigorous coppicing ability are among the principal factors. Prosopis has the capacity to decrease the composition and diversity of plant species and it has adverse effects on crop yield, as well as animal and human health. Despite its negative effects, the tree has potential uses such as fuel, charcoal, fodder, food, bio-char, bio- control, windbreaks, shade, construction and furniture materials, and soil stabilization. It can be also be used against different disease and ameliorated environmental conditions through carbon sequestration. On the other hand, manual, mechanical, chemical and biological control methods as well as control by utilization have been pointed out as an effective control ways and management of this weed. There is urgent need to develop management strategies that are environmentally friendly and economically viable to bring them under control. Therefore, objective of this is explore the distribution, impacts, benefits and as well as the possible management approaches against Prosopis.

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Key words: Allelopathy; beneficial effects; distribution; impact; Prosopis juliflora.

1. Background of the study

Prosopis juliflora has been identified as Ethiopia's number one priority invasive weed. This assessment was made by EARO, working with other national and international organizations at the beginning of a new programme to deal with the problem of invasive plants in Africa. Many call for its eradication, but why, when it is also a very useful and valuable tree? We can control it by making more use of it, developing businesses and helping those who live in areas where it is found. Invasive alien species are non-indigenous plants, animals and microorganisms that have been deliberately or accidentally introduced to new areas beyond their native ranges, and which then spread beyond cultivation and human care to impact biodiversity. Invasive alien species can alter vital ecosystem processes such as fire, hydrology and nutrient cycling, kill, suppress, compete with or displace native species and communities, or alter gene pools through hybridization (Chornesky & Randall 2003).

In areas where they spread, invasive can destroy natural pasture, displace native trees and reduce grazing potential of rangelands. They compete for and reduce productivity of croplands. Plants like the water hyacinth also block water ways for irrigation, navigation, electricity generation, fishing and livestock watering.

Decline in rangeland resources and livestock productivity are among the most pressing problems worldwide (Oba *et al*., 2000). Increased grazing pressure and decline in the productivity of rangelands are a major threat to livestock production (Angassa, 2014) biodiversity (Angassa and Oba, 2010; Angassa 2012) and local livelihood rangelands are ecologically unstable with high variability of rainfall and fluctuating forage productivity.

Consequently, the livelihood of billions of pastoralists living in the dry rangelands of the world is at risk due to the deteriorating condition of rangelands. In Ethiopia, rangelands consist of mainly native vegetation (grass, forbs and woody plant species), which are major sources of feed for grazing and browsing animals (Gemedo *et al.,* 2006).

Despite all of these merits, rangeland productivity is threatened by various factors. Rangeland degradation and reduction in the capacity of grazing lands are a serious problem with considerable impact on the livelihood of pastoral communities in Ethiopia. Reduction in the capacity of rangelands due to increased population pressure and invasion of undesirable plant species has been identified as a major concern in the rangelands of the country (Angassa and Oba, 2008, 2010).

Currently, the rangelands of the country are characterized by the invasion of bush encroachment with a general decline in forage production (Oba, 1998). The rangelands may have limited capabilities in providing reasonable animal sustenance and production due primarily to adverse environmental conditions including low and seasonal rainfall, varying degrees of soil fertility, soil erosion, inadequate forage availability, lack of proper management of grazing lands number of livestock (Alemayehu, 2005).

The Ethiopian rangelands are presently undergoing extensive deterioration both in quantity and quality (Ahmed, 2003; Amaha, 2006; Belaynesh, 2006; Desalew, 2008). Improper rangeland management may result in serious land degradation, reduced biodiversity, and decline in the nutritive values of forage plants and the gradual replacement of indigenous grasses by unpalatable species (Alemayehu, 2004; Amaha, 2006; Teshome, 2007).

According to Mekuria and Yami (2013), rangeland condition is a reflection of specific indicators such as plant species composition, vegetation cover (basal cover), forage production, land condition (soil erosion and compaction) and management practices at a particular land system. Decline in rangeland condition may be explained in terms of reduction in vegetation covers and palatable species, as well as increases in unpalatable plant species. Further signs of declines in rangeland condition may include: depletions in soil quality and nutrients due to various forms of soil erosion, soil compaction and deterioration of plant regeneration capacities of the soil seed banks that make restoration of degraded rangeland more difficult. Such sign of declines may be induced by continuous grazing without rest and lack of conservation measures (Angassa, 1999; Gemedo *et al.,* 2006; Teshome, 2007; Desalew, 2008). Livestock feed supply from natural pasture is characterized by seasonal fluctuation in total dry matter (DM) production and nutritional quality because of the distinct seasonal variation in plant growth, in relation to the annual rainfall pattern.

1.1 Rational of the study

In Bale zone Rangeland, southeast Ethiopia; where pastoralism and Agro-pastoralism are the main land use systems and livestock are the main assets of the community. Pastoralists own different animal types including grazers and browsers irrespective of the condition of rangeland. According to Friedel (1991) assessment of a rangeland that composed of different vegetation component must incorporate three parameters of assessments (i.e., the herbaceous layer, soil and tree-shrubs layer). In the past, some attempts have been made by many scholars to determine rangeland condition of the country. However, compared with the vast rangeland areas of the country, there are only very limited studies; for example, in south Ethiopia (Angassa, 1999; Oba *et al.,* 2000, Gemedo *et al.,* 2006, Solomon *et al.,* 2006), in middle Rift valley (Amsalu and Baars, 2002, Abule *et. al.,* 2007) in East Ethiopia (Amaha, 2006) in south east Ethiopia (Teshome, 2007). Identifying the existing forage species of the natural pasture and their nutritive value is the primary task in designing and implementing appropriate management interventions such as livestock feeding strategy.

Therefore, this study will focus on to investigate the effects of different methods of bush encroachment control on rangelands vegetation in Bale zone, southeast Ethiopia. The information will help to effectively integrate natural resource conservation schemes with livestock production activities in an effort to efficiently and sustainably utilize the available pastoralist resource.

1.3 objective of the study

Therefore, the specific objectives of the study will be:

(1) To assesses the rangeland condition in relation to grazing pressure areas;

(2) To investigate the species composition in enclosure vs. open rangelands in the study area; and

(3) To identify possible controlling mechanism of invasive species in the study area.

2. Materials and Methods

2.1 Description of the study area

Bale (*Afan Oromo*: Baale) is one of the zones in the Oromia Region of Ethiopia. Bale is named for the former kingdom of Bale, which was in approximately the same area. Bale is bordered on the south by the Ganale Dorya River which separates it from Guji, on the west by the West Arsi Zone, on the north by Arsi, on the northeast by the Shebelle River which separates it from West Hararghe and East Hararghe, and on the east by the Somali Region.

The highest point in the Bale Zone, and also the highest point in Oromia, is Mount Batu (4,307 m), one of the Urgoma Mountains. Other notable peaks of the Urgoma include Mount Tullu Dimtu, Mount Darkeena and Mount Gaysay. Rivers include the Wabe and the Weyib; notable lakes include Garba Guracha and Hora Orgona. Points of interest in the Zone include Sheikh Hussein named for the tomb of a Moslem saint—the Bale Mountains National Park, and the Sof Omar Caves. Towns and cities in Bale include Dodola, Ginir, Goba and Robe.

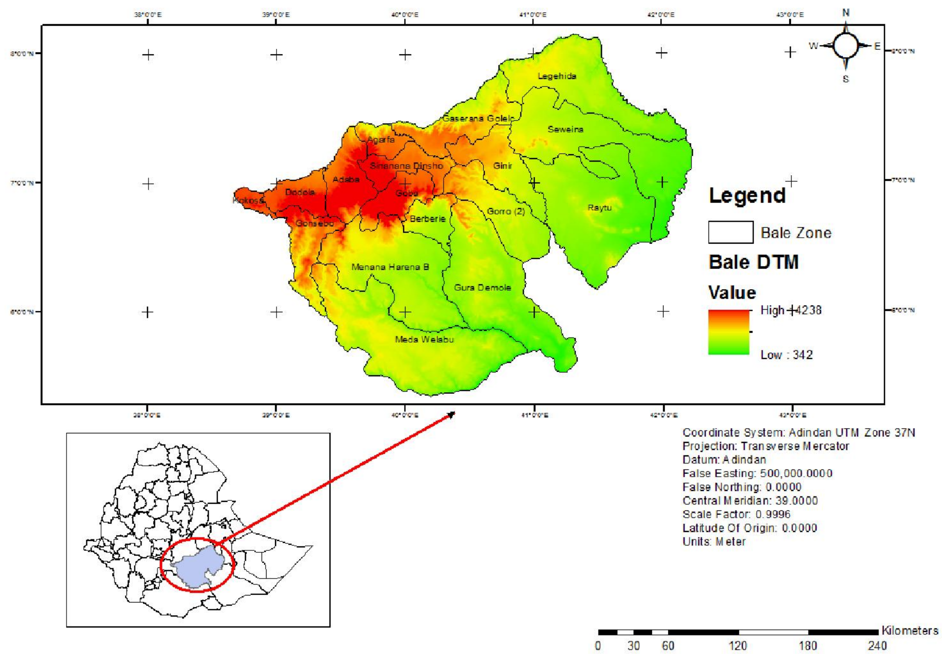

Figure 1. Bale Zone

The Central Statistical Agency (CSA) reported that 5,130 metric tons of coffee were produced in this zone in the year ending in 2005, based on inspection records from the Ethiopian Coffee and Tea authority. This represents 4.46% of the Region's output and 2.2% of Ethiopia's total output.

2.2 Demographics

Based on the 2007 Census conducted by the CSA, this Zone has a total population of 1,402,492, an increase of 15.16% over the 1994 census, of whom 713,517 are men and 688,975 women; with an area of 43,690.56 square kilometers, Bale has a population density of 32.10. While 166,758 or 26.20% are urban inhabitants, a further 44,610 or 3.18% are pastoralists.

A total of 297,081 households were counted in this Zone, which results in an average of 4.72 persons to a household, and 287,188 housing units. The three largest ethnic groups reported were the Oromo (91.2%), the Amhara (5.7%) and the Somali (1.44%); all other ethnic groups made up 1.66% of the population. Oromiffa was spoken as a first language by 90.46%, Amharic was spoken by 7.11% and Somali by 1.05%; the remaining 1.38% spoke all other primary languages reported. The majority of the inhabitants were Muslim, with 81.83% of the population having reported they practiced that belief, while 16.94% of the population professed Ethiopian Orthodox Christianity and 1.04% were Protestant.

The 1994 national census reported a total population for this zone of 1,217,864 in 250,586 households, of whom 603,895 were men and 613,969 women; 130,307 or 10.7% of its population were urban dwellers at the time. The four largest ethnic groups reported in Bale were the Oromo (88.93%), the Amhara (7.65%), the Somali (1.39%), and the Sidama (0.88%); all other ethnic groups made up 1.15% of the population. Oromiffa was spoken as a first language by 87.5%, 9.5% Amharic, 1.51% spoke Somali, and 0.88% spoke Sidamo; the remaining 0.61% spoke all other primary languages reported.

The majority of the inhabitants were Muslim, with 76.7% of the population having reported they practiced that belief, while 19.02% of the population said they professed Ethiopian Orthodox Christianity, 2.77% held traditional beliefs, and 1.15% were Protestant. According to a May 24, 2004 World Bank memorandum, 11% of the inhabitants of Bale have access to electricity; this zone has a road density of 11.4 kilometers per 1,000 square kilometers (compared to the national average of 30 kilometers);

the average rural household has 1 hectare of land (compared to the national average of 1.01 hectare of land and an average of 1.14 for the Oromia Region); and the equivalent of 1.0 head of livestock. 19.5% of the population is in non-farm related jobs, compared to the national average of 25% and a regional average of 24%. Concerning education, 66% of all eligible children are enrolled in primary school and 21% in secondary schools. Concerning health, 53% of the zone is exposed to malaria and none to Tsetse fly.

2.3 Methodology and Approaches

The consultant will employ a combination of desk review, quantitative and qualitative methods/approaches that will include inter alia the following: desk review of relevant project documentation including funding proposal and log frame, conduct individual and group discussions with project staff (operational and admin), consult with individual consortium partners, discuss with local implementing partners and local DM institutions, conduct field visits to all the targeted woredas and hold discussions with stakeholders and beneficiaries (e.g. through Key Informant Interviews (KIIs) and focus group discussions (FGDs), ensure that women's voices are sufficiently heard e.g. by splitting KIIs and FGDs into gender groups, and analyse project monitoring tools and training tools.

Initially, a reconnaissance survey will have conducted and there will be contacts with the local leaders and development agents (DAs). Both vegetation and socio-economic data will be collected to capture important information in order to address the specific objectives of the study. Then, we established a total of 50 circular sampling plots of 500 m2 (radius 12.56 m) to gather data on vegetation variables (Limenih et al., 2003). We excluded villages and agricultural lands from sampling. Sampling plots will systematically be placed along transect lines.

The socio-economic data will be collect using a structured questionnaire survey with 215 households encountered on the transect lines of the vegetation study. The questionnaire will be translated into *Afaan Oromo*, the Oromo language, pre-tested and adjusted subsequently. Then, twenty trained enumerators will use to conduct the socio-economic survey with close supervision of the principal investigator. Special attention will be given to capturing information on the impact of *invasive species* on rangeland resources, as well as on local livelihood systems.

Furthermore, key informant interviews, focus group discussions and personal observations will be used to gain an in-depth understanding of specific conditions related to the species. Knowledgeable key informants will be selected with the help of DAs and PA administrators. These informants will be mainly elderly men, women, religious leaders and decision makers in the community especially of the Abba Gada (Legesse, 1973, 2000; Watson, 2003). Additionally, an interview with 27 individuals involving DAs, PA administrators and experts from woreda and zone Pastoral Development office will be conducted. Furthermore, a total of ten focus group discussions (FGD) each comprising 7 to 10 participants will be undertaken, while FGD's participants included: Abbaa Gada, DAs, development experts and knowledgeable community representatives (Watson, 2003). We will employ checklists with important topics to facilitate discussion during key informant interviews and focus group discussions.

2.4 Data Analysis

Data will have analyzed by various techniques. The quantitative data will be analyzed using MINITAB version 13. The importance value index (IVI) that indicates the importance of species in an ecosystem will be calculated as follows (Kent and Coker, 1992):

Relative density = Number of individuals of species× 100
Total number of individuals
Relative dominance = *Dominance of species × 100
Total dominance of all species
Relative Frequency = Frequency of species × 100
Frequency of all Species

*Dominance is defined as the mean basal area per tree times the number of species.

The importance value index for each woody species is the sum of its relative abundance; relative dominance and relative frequency will used to evaluate the importance of woody species. The information collected through vegetation surveys will be analyzed using MINITAB version 13. The invasive woody species ratio (IWSR) was computed to assess whether *A. drepanolobium* is an invasive species or not. The ratio is defined as the density of species regarded as invasive divided by others regarded as non-invasive (i.e. a ratio of > 1.0 is an indication of a high invasive threat, while < 1.0 represents a lesser threat of encroachment) (Angassa and Oba, 2008a). Qualitative data obtained through key informant interviews and focus group discussions will summarized and analyzed using comparative analyze methods.

3. Results

3.1 Descriptive results

Prosopis is now a serious topic in Ethiopia, especially in Afar and Dire-Dawa. It has invaded large areas of mostly grazing land in these regions and elsewhere, and is the national No. 1 invasive plant. As already noted, this study is based on data collected from a total of 450 sample households, of which 250 households belong to the four Kebeles invaded by

Prosopis and the remaining 200 households belong to the three non-invaded rural Kebeles of the administration. As indicated in the survey, the average age of respondents in Prosopis-invaded Kebeles was 42.49 years, whereas it is 38.58 years for the non-invaded Kebeles. Average family size of the households in Prosopis-invaded Kebeles was 6.302 persons or 5.578 in adult equivalent while that of the non-invaded households was 6.270 persons or 5.407 in adult equivalent. t test results for differences in age distribution was significant with a t value of −3.694, and family size between the two groups was insignificant (t = −0.135).

Proximity of households to market centre, the city and main road of Giner were also assessed, and the result showed that the average distances of the invaded and non-invaded households from the city were 3.824 and 13.736 km, respectively, while their corresponding distances from the main road were 1.840 and 2.475 km. t test results showed that there is a significant difference at 1% and 10% level of significance (t = 20.614 and t = 1.918), in proximity of households to market centre and main road, between the two groups, respectively.

A closer look at economically active family members in the sampled households (15 to 65 years old) showed that the treatment group of households (invaded households) had relatively larger active family members, accounting to about 3.411 persons, than the control group of households which was found to be about 2.790 persons.

This implies that, on average, the households from the invaded Kebeles have relatively more labour force than those households from the non-invaded Kebeles. However, the treatment group of households showed a slightly lower average dependency ratio (1.030) than households from the control group (1.056). This implies that every economically active person in the Prosopis invaded households and non-invaded households had to support more than one economically inactive person. Farm experience of the sampled households was also assessed, and the result showed that, on average, Prosopis-invaded households had 26.109 years of farm experience while non-invaded had an average of 20.135 years' farm experience. t test results, indicated that there is a significant difference in farm experience of household heads at 1% level of significance (t = −6.202) between the two groups.

Livestock holding, as a wealth variable, indicates the capacity of agro-pastoral household to involve in high-return income sources. As shown in the table below, livestock holding in TLU was 5.033 for the treatment group and 4.610 for the control group. This implies that livestock per capital in the invaded areas was higher than that in the non-invaded areas, even if the t test result presented in Table 3 shows the difference is insignificant (t = 1.308).

As is the case in the majority of farm households in the country, land is one of the scarce factors of production in the study area. Land holdings of sampled households varied from no farm land (1.7%) to greater than 1 ha (30.2%) out of which 20.2% belonged to the treatment (invaded) areas and the remaining 10% belonged to the control (non-invaded) group. This implies that the largest share (49.1%) of the households in the study area own less than one hectare of farm land.

Survey results also showed that 3.1% from the control (non-invaded) group and 2.4% from the treatment group held less than 0.5 ha of farmland. About 10.9% from the control and 11.1% from the treatment group owned 0.5 ha of farmland, while 10.2% of households in the control group and 10.4% of households in the treatment (invaded) group owned 1 ha of farmland. The small size of plots or farmlands accompanied with some environmental stresses in the study areas further aggravated the already existing agricultural practice and of course adversely affected crop production.

As far as educational status of the respondents is concerned, nearly 80% and 66% of households from Prosopis-invaded and non-invaded Kebeles were illiterate, respectively. Only 19.80% from the invaded and 34% from the non-invaded Kebeles attended primary education. The result of chi-square test showed that there was a significant difference in the educational status of household heads at1% level of significance between the two groups ($\chi 2$ = 10.311). As the result indicates, majority of households who are invaded by Prosopis were illiterates.

Survey results showed that, out of the total 450 sampled households, 85% and 15% were male headed and female headed, respectively. The results also indicated that 88% and 12% of Prosopis-invaded households and 82% and 18% of non-invaded households were male headed and female headed, respectively. t test result for differences in gender of the household head between the two groups was significant (t = −2.963). In both Prosopis-invaded and non-invaded areas, it was observed that 64.4% and 50.5% of the respondents were engaged in food for work or the so-called safety net programme, respectively.

This implies that more than half of the households are not in a position to feed themselves from income generated from crop and livestock production. Besides, the average number of food secured and food insecure households was assessed based on the calorie intake levels of sample respondents, and the results revealed that 59.5% of the respondents in non-invaded areas and 49.6% of the respondents in the invaded areas were food insecure. This means that in both cases, there is almost food uncertainty. The result of the chi-square test showed that there is a significant difference among the two groups in number of food secured people at 5% level of significance ($\chi2 = 4.048$).

In the study area, both perennial and annual crops are grown through rain-fed and irrigation agriculture. Subsistence mixed farming is the dominant farming type constituting 81.25% of the households in the study area. Irrigation accounts for about 27.72% of the households in the control (non-invaded) areas and only 8.8% in the treatment (invaded) areas. The chi-square test was also undertaken to check whether there is a significant mean difference in households' access to irrigation between the two groups. The result showed that the difference was significant at 5% ($\chi2 = 6.544$).

In the study area, it was observed that 41.2% of the respondents in the invaded areas and 33.66% of the respondents in the non-invaded areas have access to rural credit service. As can be seen from, the chi-square test result indicated that there is insignificant difference in access to rural credit service between the two groups.

As far as cooperative membership is concerned, nearly 71.6% from Prosopis-invaded Kebeles and 46.50% from the non-invaded Kebeles are not members of cooperative respectively. The result of chi-square test showed that there was a significant difference in household heads' membership to a cooperative, at 1% level of significance between the two groups ($\chi2 = 25.604$).

The results show that there were significant differences between the two groups of sample respondents with respect to expenditure on education, milk income, income from livestock sale, income from Prosopis, average annual income from crop production, food and non-food expenditure, health expenditure and calorie per day per Adult-Equivalent (AE). However, there were no statistical significant differences between the two groups of sample households with respect to off-farm income. The explanation for the significant outcome variables are presented below. Expenditure on education includes money spent on exercise books, pens, pencils, uniform, school fees and other education materials of the previous year. The mean education expenditure of the total sample households is Birr 465.119 (USD 24.162) per annum.

The average education expenditure for Prosopis-invaded and non-invaded households is Birr 562.644 (USD 29.228) and Birr 366.620 (USD 19.045), respectively. The t test result shows that there is statistically significant difference among the two groups at 1% probability level. The quantity of milk from the households who own livestock was estimated on the basis of the number of milking animals and the amount of milk that the average cows, goats, sheep and camels produced. Explicit costs including annual average cost for medication and supplementary feed cost were also considered with the assumption that income from milk production is equal to domestic consumption plus sale.

The descriptive result shows that there is significant difference between the two groups of households in that the mean income from milk production by Prosopis-invaded and non-invaded households is Birr 656.990 (USD 34.129) and Birr 941.050 (USD 48.886), respectively. The t test result reveals that there is statistically significant difference between the two groups at 5% probability level. According to the respondents, reduced pasture availability (caused by mesquite invasion) and frequent rain shortage caused the problem. Pasture availability is of course one of the factors determining milk productivity.

A comparative study conducted by Mugasi et al. (2000) showed that livestock reared under relatively highly encroached grazing fields yielded less milk than those reared under less encroached fields.

3.2 Income from livestock sale is the sum of money households

In areas of Ethiopia where Prosopis has invaded, the environment is very hot, with limited rainfall and saline soils. Few plants can thrive here, but these conditions are conducive for Prosopis. There are no natural enemies, pests or diseases. Also, the Prosopis trees introduced to Ethiopia are particularly bushy, thorny and weedy. The life style of the nomadic local people has helped, as the animals eat the pods and travel long distances, disseminating seeds to new areas through droppings. There is also little knowledge or experience on how to manage and utilise these trees, and there have been few policies or strategies in place for quick action.

obtained from sale of live livestock. The mean income from livestock sales in Prosopis-invaded and noninvaded households is Birr 1719.946 (USD 89.348) and Birr 2161.128 (USD 112.266), respectively. The t test result reveals that there is statistically significant difference between the two groups at 10% probability level. This study is in line with Pasiecznik (1999) which reported that mesquite invasion forms impermeable, dense thickets. The same source also stated that the invasion reduces grass cover of grazing lands and consequently affects stocking density. Income from fuel wood and charcoal is a sum of money households obtained from fuel wood collection and charcoal making.

The mean income from fuel wood and charcoal in Prosopis-invaded and non-invaded households is

Birr 1235.460 (USD 64.180) and Birr 561.200 (USD 29.153), respectively. The t test reveals that there is statistically significant difference in income generation from firewood collection and charcoal making. Explicit costs such as costs for fertilizer, pesticides, seeds and labour, taking a minimum wage of Birr 20 per day, was used in the calculation of net income from crop production. These quantities were converted to values (Birr) using households' self-report of sales price. Based on this estimation, the mean annual income generated from crop production in Prosopis-invaded households is Birr 3053.03 (USD 158.599) while it is Birr 2215.006 (USD 115.065) for non-invaded households.

There is a significant difference in income generated from crop production between invaded and non-invaded households, and the t value of −3.944 suggests that this variable is significant at 1% probability level. This study is also in line with Haji and Mohammed (2013) who confirmed that Prosopis is attributed to have resulted in increased crop yields by 29%. Prosopis have positive effects on the soil layer (Ilukor et al. 2014). These positive soil characteristics can be used for consecutive planting of native species on cropping fields. In some studies, the physico-chemical property of soil under mesquite canopy was found to be better than the adjacent open field (e.g. El Fadl, 1997, cited in Esther and Brent 2005) which may be due to nitrogen fixation, leaf litter addition and change in soil structure due to deep tap root system (Pasiecznik et al. 2001).

An effort has also been made to study the expenditure pattern among the households which is presented below. Total household expenditure includes food and non-food expenditure of households in the previous year. The mean total household expenditure of invaded and non-invaded households is Birr 9879.327 (USD 513.212) and Birr 6429.45 (USD 333.997), respectively.

The t test result reveals that there is a statistically significant difference between the two groups at 1% probability level. Health expenditure is a sum of money spent for medication by the household for family members and their animals. The mean health expenditure of Prosopis invaded and non-invaded households is Birr 243.158 (USD 12.6316) and Birr 153.170 (USD 7.957), respectively. The t test result reveals that there is statistically significant difference between the two groups at 1% probability level. Findings of the study show that invaded households and non-invaded households had calorie intake of 2704.443 and 1859.7 cal per AE, respectively. As already mentioned, two weeks' data on available food for sample households' consumption, from purchase and/or stock, were converted to kilocalories and the figures were divided by the total AE in each households AE.

Finally, the computed kilocalorie per AE in each household was compared with the minimum subsistence energy requirement per AE per day, 2,100 kcal. Invaded households' calorie intake is higher than non-invaded households. Although education expenditure, income from fuel wood collection and charcoal making, income from crop production, food and non-food expenditure, health expenditure and calorie per day per AE of the invaded households were higher than those of non-invaded households, milk income and income from livestock sale in the invaded households were less than those of non-invaded households.

However, this does not mean that the mean difference is exclusively because of the invasion of Prosopis. Since comparisons are not yet restricted to households who have similar characteristics, it is impossible to attribute the difference in the above variables between the two groups exclusively to Prosopis invasion. Therefore, to handle this shortcoming, a further analysis was conducted using propensity score matching techniques to strengthen the findings.

3.3 Sensitivity analysis

In this section, the issue whether or not the final evaluation results are sensitive with respect to the choice of the balancing scores is addressed. Matching estimators work under the assumption that a convincing source of exogenous variation of treatment assignment does not exist. Likewise, sensitivity analysis was undertaken to detect if the identification of conditional independence assumption was satisfactory or affected by the dummy confounder or the estimated Average Treatment Effect on the Treated (ATT) is robust to specific failure of the CIA. Sensitivity analysis using the bounding approach was employed, and this involves calculating upper and lower bounds, using the Wilcoxon signed rank test. These rank tests test the null hypothesis of no-treatment effect for different hypothesized values of unobserved selection bias. reveals the sensitivity result of outcome ATT values to the dummy confounder.

Regarding milk income, off-farm income, income from crop production and income from Prosopis, the average treatment effect on the treated is found to be insensitive to the dummy confounder. Similarly, education expenditure, food and non-food expenditure and calorie per day per AE were also found to be robust or insensitive to the dummy confounder. This shows how strongly an unmeasured variable influences the selection process in order to undermine the implications of matching analysis.

4. Conclusions and Recommendation

4.1 Conclusions

In this study, cross-sectional data from Prosopis-invaded and non-invaded Kebeles of rural parts of Bale Zone were used to explore the impacts of Prosopis invasion on households' welfare. The main question that this research attempted to answer was, 'what would be the livelihoods of Prosopis-invaded households had they not been invaded by Prosopis?' Answering this question requires observing outcomes with and without the Prosopis invasion for the same household. However, it is impossible to observe the same object in two states simultaneously. In other words, the fundamental problem in any social programme evaluation is the missing data problem. While the programme evaluator observes the factual for an object, it is impossible to observe the counter-factual for the same object. This study used the propensity score matching technique to eliminate the possible sample selection bias since the data were from a survey study. Kebeles were grouped into two strata. Stratum one, which represent the treatment group, consists of four Kebeles that are severely invaded by Prosopis. The other three Kebeles which are not invaded by Prosopis are categorized under stratum two representing the control group.

The present study is a comparison between Prosopis invaded Kebeles forming four in number and Prosopis non-invaded Kebeles numbering three. As expected, a household's invasion by Prosopis was determined by a combination of factors.

These are age of the household head, family size of the household, dependency ratio, access to irrigation water, TLU and engagement in food for work programme. Finding a reliable estimate of the Prosopis impact thus necessitates controlling for all such factors adequately. In doing so, propensity score matching has resulted in 240 treated households to be matched with 200 controlled households. In other words, a matched comparison of all outcome variables was performed on these households who shared similar pre-intervention characteristics except the Prosopis. The resulting matches passed a variety of matching quality tests and were fit for addressing the main objectives of this study.

After controlling for other characteristics, it has been found that Prosopis invasion had significantly boosted the Prosopis-invaded household, over the non-invaded households on education expenditure by Birr 213.053 (37.23%), average annual income from crop production by Birr 529.43 (11.93%), off-farm income by Birr 3831.295 (63.53%), food and non-food expenditure by Birr 2607.103 (26.35%) and physical food consumption by 805.421 cal per AE (30.12%). On the other hand, Prosopis invasion reduces milk income of the Prosopis invaded household by Birr 410.667 (60.64%) over the non-invaded households. Although this study tried to capture some aspects of the Prosopis invasion in the rural Bale zone, more aspects of Prosopis invasion such as more benefits and social costs were not examined, making the total economic evaluation incomplete.

4.2 Recommendations

Based on our results, we provide the following recommendations for the sustainable management and control of Prosopis in the Bale zone.

First, any projects or programmes that aim to tackle the challenges of Prosopis invasion and optimize the positive impacts of this species need to consider the Prosopis invasion effects explicitly, as there is huge market failure and externalities relative to the Prosopis invasion. Moreover, active involvement of the local community is important in the design and success of Prosopis invasion control/eradication programmes. So raising awareness of the local community about the pros and cons of Prosopis effects on households' welfare will play a great role for the success of community-based Prosopis invasion control/ eradication programmes. Hence, before trying to mobilize the community in control/eradication of Prosopis invasion, an awareness creation activity has to be done.

Second, age of the household head was found to be positively related to the probability of Prosopis invasion. Therefore, encouragement must be given to older household heads on the control/eradication of Prosopis invasion. In other words, development agencies and policy-makers should target Prosopis control/eradication technologies on the basis of age.

Third, households with large family size found to have lesser probability to be invaded by Prosopis because the family could have contributed higher labour force invasion can be an opportunity. Projects/programmes that work on efficient family labour allocation and family planning need to be encouraged in maintaining and minimizing household size to the level of household income capability. The implementation of family planning programmes should be supported with the current health-extension package of giving high emphasis on local people's perception of household size and on their attitudes towards family planning facilities.

Fourth, livestock rearing is the most important economic activity for the agro-pastoral households in the study area. Projects like dairy cow credits, sheep and goat credits, camel credit and fattening need to be supported through establishment of organized credit facilities, together husbandry skill and knowledge training for improvement of livestock management to increase family income can gain capacity to control/ eradicate Prosopis invasion. Management of herds (stocking and restocking) and utilization of improved feed and fodders in combination with Prosopis as a feed source need to be given due attention. Side by side, the extension service needs to give due attention to problems of animal health and critical feed shortage. In addition, necessary inputs should be provided on time, as per the requirement of the farmers.

Fifth, food security programmes are positively related to Prosopis invasion. Therefore, government and NGO intervention with regard to food aid and different food security programmes and projects have to take into consideration the negative impacts of Prosopis invasion. Since some invaded households gain a good source of income, promoting Prosopis utilization in a planned way through adoption of appropriate and sustainable management is advisable in the study area.

Sixth, the study results also indicated that access to irrigation was negatively related to Prosopis invasion. Therefore, in order to address the Prosopis invasion problems in the study area, attention should given by GOs and NGOs to developing small-scale irrigation or water harvesting technology, by organizing farmers into watershed cooperatives.

Seventh, due to the fact that the local communities in the invaded area have a record of better harvest in lands cleared of Prosopis, converting some of the invaded grazing lands into cultivable land (especially sorghum) is also another point of recommendation. Last, but not the least, further research is needed on the total economic valuation of Prosopis invasion on the administration so as to gain more insight into the impact of Prosopis invasion.

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