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Economic Valuation of Parthenium Weed Control Measures, in Gurage Zone, SNNPR of Ethiopia

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I. Introduction

Worldwide in general in Ethiopia in particular, agriculture holds many future challenges to adapt with such as global warming [1], resource shortages and invasive alien plant species [2]. Invasive alien plant species (IAPS) are plants that are non-native to an ecosystem and which may cause economic or environmental harm or adversely affect human health (The Convention on Biological Diversity, 2009). IAPS may also be termed as weeds, that is, plants that are objectionable or interfere with the activities and welfare of people [3]. Invasive species are of concern because of their capability of spreading fast, their high competitiveness and ability to colonize new areas within short periods. The nature and severity of the impacts of these species on society, economic life, health and national heritage are of global concern [4].

Globally, the cost of damage caused by invasive species has been estimated to be $1.5 trillion per year – close to 5% of the global GDP [5]. In developing countries, where agriculture accounts for a higher proportion of GDP, the negative impact of invasive species on food security as well as on economic performance can be even greater. Virtually all ecosystem types on the planet are affected by invasive species and they pose one of the biggest threats to biodiversity worldwide. They reduce yields of agricultural outputs both crop and livestock, forest land, fishery, decrease water availability and contribute to spread of disease. As a result, IAPS contributes to social instability and economic hardship, placing constraints on sustainable development, economic growth, poverty alleviation and food security [6].

Ethiopia is among the developing African countries affected by IAS. This is reflected in the fact that IAS has been clearly identified as one of the emerging problems facing the country over the last two decades [7]. Several alien species are spreading at alarming rate, and threatening agricultural lands, rangelands, national parks, lakes, rivers, power dams, and urban green spaces - causing huge economic and ecological losses [8]. Foremost among these invasive plant species is Parthenium *hysterophorus L.* (Parthenium), which is an emerging problem in Ethiopia; the weed has been spreading throughout the country after it was first noticed around Dire Dawa in 1980's [9] and [10].

The impacts of Parthenium are numerous and are most profound on agriculture, environment and human health. Studies in some other parts of the world have shown that impact of Parthenium invasion on animal and human health as well as the economic loss in agriculture [6]. Crop losses are caused primarily through allelopathic effects over and above its ability to compete for nutrients and moisture and these losses are

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often proportionally higher than expected from a similar crop weed. Another mechanism by which Parthenium impacts upon crop productivity is through its ability to cover crops in pollen, which prevents seed set with resulting losses in yields of up to 40% [11]. Which indicates the existence of Parthenium is a growing danger to small-scale farmers. If it is not controlled on time, it will occupy the land alone.

Under controlled experiments, at high densities, yields showed a 97 percent decline [12]. Estimates show that between one and two million hectares of farming land (up to 2 per cent of the land area) is affected in Ethiopia [10]. Furthermore, it increases production costs and thereby lowers the profitability of farm enterprises and driving farmers to poverty. In addition to direct competition for resources and allelopathic effects, Parthenium causes health hazard to humans and animals. In general there is fear that the rapid and uncontrolled expansion of the weed may considerably weaken the carrying capacity of the grazing land [13]. While the adverse impacts of Parthenium weed on native habitats have become an issue of global concern, there remains a gap in the understanding of the weed in many areas of the world including Ethiopia [14]. The weed is currently invading almost all regions of the country at an alarming rate [15]. Attempts have been made both at national and regional levels to mitigate this problem which has a direct causal effect to declining agricultural productivity and food insecurity. However, problems have been more serious and critical than ever before and threaten many people's lives in the country as well as in the study area.

Though, there are no precise data available on the current infestation level of Parthenium weed in the region its distribution is widely increasing with its detrimental effect on agricultural productivity and production as it can be seen from ground reality. In the study area (Gurage zone) almost all kebeles are highly invaded by Parthenium. Consequently, people are now facing challenges and problems due to the spreading of the weed. Much of the studies conducted on Parthenium focused on biological aspects such as distribution, diversity, biological control etc. Effort has not been made to assess farmers' perception of the socio-economic impact of Parthenium and the interrelated socio-economic and physical factors that determine farmers' participation in the preventive and control measures at household level.

The major problems encountered in the past and current control activities were related with wrong perception towards the problem, poor participation of community members because of the externalization of the issue, lack of sustainability of control programs, lack of enforcement mechanisms, resource limitations, unavailability of a recommended package of control techniques; shortage/unavailability of information, shortage of trained manpower, lack of an institutional set up for designing and implementing Parthenium control programs and lack of proper national attention to control Parthenium, poor coordination among stakeholders [14].

Formulation of control measure strategies for environmental protection from such kind of invasive weeds demands the participation of farmers (in terms of their willingness to contribute) from the very beginning. Accordingly, identification of factors that influence farmers' WTP for control measures of Parthenium weed, can help policy makers, practionaires and other stakeholders to take appropriate action in formulating strategies that curb the problem of invasion by Parthenium with active participation of farmers. Hence, this study was initiated to estimate the value farmers' are willing to pay for the control measure of Parthenium weed, and identify factors determining farmers' willingness to pay for control measure of Parthenium weed in Gurage zone, SNNPR of Ethiopia.

II. Research Methodology

a) *Description of the study area*

This study was undertaken in Abeshige and Kebena districts of Gurage zone in SNNPR of Ethiopia. Abeshge district is situated between 8.19'- 8.43' North latitudes and 37.45'-38.89' East longitudes. The topography of Abeshge district varies from 1001-2000 masl. The annual average temperature ranges from 15.5 - 25 ^{o}c while the total annual rainfall varies between 801mm and 1400mm. These situations resulted in a diverse agro-ecology which is suitable for the production of various annual crops (such as *teff*, maize and sorghum), perennial crops (such as coffee and khat) and livestock. The district covers a total area of 559 km^2. The district has an estimated population of 68,598 of which 36,240 are male and 32,358 are female. The district consists of 26 kebeles, of which constitutes only two of them are urban. On the other hand, Kebena district is situated between 8.22' - 8.39' North latitudes and 37.72' - 38.13' East longitudes. The topography of Kebena district varies from 1501-2000 masl. The annual average temperature ranges from 17.6 – 20^{o}c while the total annual rainfall varies between 1201mm and 1400mm. These situations resulted in a diverse agro-ecology which is suitable for the production of various annual crops (such as *teff*, barley, maize and sorghum), perennial crops and livestock. The district covers a total area of 298 km^2. The district consists of 23 rural based administrative kebeles. The district has an estimated population of 58,496 [26].

b) *Sampling procedure and methods of data collection*

The study employed multi stage purposive and random sampling techniques to draw a representative sample. At the first stage, the two districts (Abeshige and Kebena) were selected purposively. At the second stage, four kebeles (Sunika Dinicho,

Katibare, Tatesa Weshribe and Odobera) from Kebena and five kebeles (Darge, Mida Tedele, Nacha Qulit, Hudad 5 Ena 6 and Gibe) from Abeshige districts were purposively selected. Finally, on the basis of probability proportional to size (PPS) of the number of farmers in each selected kebeles, a total sample size of 320 farmer households (160 from each selected districts) were randomly drawn.

Both primary and secondary data sources were used in this study. The Primary data was collected using Focus Group Discussion (FGD) and structured questionnaires. The FGD was conducted using some purposively and randomly selected key informants and households from the above selected kebeles in both districts to determine the appropriate threshold value/price. To elicit farmers' responses on the amount of WTP, the study used a contingent valuation method (CVM) involving a single bound with open ended follow up question [27].

c) Methods of data analysis

i. *Descriptive analysis*

a. Estimating Aggregate Maximum WTP Value

An important issue related to the measurement of welfare using WTP is aggregation of benefit [28]. Accordingly, the maximum figures for the WTP reported by the respondents can simply be averaged to produce an estimate of Mean Maximum WTP:

$$\text{Mean MWTP} = \sum y_i/n \qquad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where: n is the sample size and each **y** is a reported WTP amount by the surveyed farmers

b. Estimating Total Maximum WTP

The estimation of total social benefits from the environmental protection (Parthenium weed control measures in this case) is conventionally carried out by estimating the aggregate of individual WTP [29]. Accordingly, it was calculated using the following formula:

$$WTP_{total} = WTP_{hh} * HH * R_{wtp} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where: WTP_{total}, is the total amount of WTP that households in both districts are willing to pay per year; WTP_{hh}, is the mean annual household WTP; HH denotes the total number of households in both districts and R_{wtp}, is the percentage of respondents' willing to pay.

ii. *Econometric Analysis*

Since the value of dependent variable (Maximum WTP for the control measure of Parthenium weed) in this study is all positive values, the Ordinary Least Square method [30]. will not yield consistent estimates. A widely used approach, the Tobit model [31] was developed to alleviate the problems caused by OLS. In this study, therefore, Tobit model is employed to identify factors determining the decision and the amount that a household is willing to pay for the control measure of Parthenium weed in the study area.

The general form of Tobit Model, when lower limit is censored to zero, can be defined as:

$$y_i^* = \beta X_i + u_i \qquad \text{For, } i = 1, 2, \ldots\ldots, n$$

$$y_i = y^* \; if \; y_i^* > 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$y^* = 0 \; if \; y_i^* \leq 0$$

$$\text{With } u_i \sim N(0, \sigma^2)$$

Where:

$$\boldsymbol{y_i} = the\ observed\ maximum\ WTP\ for\ the\ control\ measure\ of\ parthenium\ weed;$$

$\boldsymbol{y^*}$ = *the latent or unobserved willingness to pay for control measure of Parthenium weed;*

$\boldsymbol{X_i}$ = *a vector of explanatory variable (socio-economic, demographic and institutional factors) and* $\boldsymbol{\beta}$ = *a vector of unknown parameters*

$\boldsymbol{u_i}$ = *residuals that are independently and normally distributed with mean zero and a common variance,* σ^2.

The Tobit coefficients do not directly give the marginal effects of the explanatory variables on the dependent variable [32]. Hence, one has to compute the derivatives of the estimated Tobit model to predict the effects of changes in the exogenous variables. Thus, a change in $\mathbf{X_i}$ (explanatory variables) has two effects. It affects the probability that the observation will fall in that part of the distribution and it affects the conditional mean of Y_i^* in the positive part of the distribution. Following the works of [33] similar approach is used in this study.

III. Results and Discussion

a) Results of the Descriptive Analysis

Out of the total 320 sampled households taken in both districts, about 224 respondents were willing (WTP) and 96 were not willing to pay (NWTP) for the control measure of Parthenium weed.

Table 1: Descriptive statistics result of households demographic, socio-economic and institutional characteristics in both districts (N=320)

Variables category								
Dummy variables		WTP (224) Frequency	%	NWTP (96) Frequency	%	Total (320) Frequency	%	χ^2-value
SEXHH	Male	208	65	40	12.5	248	77.5	- 0.702
	Female	16	5	56	17.5	72	22.5	
OFFARINC	Yes	120	37.5	8	2.5	128	40	16.182***
	No	104	32.5	88	27.5	192	60	
PASTAWERPP	Yes	72	22.5	48	15	120	37.5	5.614***
	No	152	47.5	48	15	200	62.5	
LANDTENURE	Yes	66	20.6	84	26.3	150	46.9	2.406
	No	158	49.4	12	3.75	170	53.1	
IMPACT	Yes	149	46.6	18	5.6	167	52.2	9.398***
	No	75	23.4	78	24.4	153	47.8	
ASSISTANCE	Yes	80	25	10	3.1	90	28.1	4.211**
	No	144	45	86	26.9	230	71.9	
ATITUDTOPAY	Yes	48	15	66	20.6	114	35.6	-0.170
	No	176	55	30	9.4	206	64.4	
MEMBSHIP	Yes	161	50.3	28	8.7	196	59	4.890**
	No	63	19.7	68	21.3	131	41	

Continuous variable	WTP (224) Mean	WTP (224) StD.	NWTP (96) Mean	NWTP (96) StD.	Total (320) Mean	Total (320) StD.	t-value
AGEHH (in years)	42.95	5. 39	48.12	1.88	45.1	5. 52	7.586***
EDULHH (in years of schooling)	7.25	0.52	4.28	1.87	5. 87	2. 83	2.524**
FAMSIZHH (in adult equivalent)	5.39	1.98	2.5	0.52	5.25	2.04	5.818***
LIVSTOWN (in TLU)	5.46	0.71	2.62	0.44	5.32	1.71	4.202*
LANDSIZE (in ha)	4.08	0.74	2.5	0.59	3.25	1.41	-4.625

***, **,*show significance level at 1%, 5% and 10% probability levels, respectively.

Source: Survey data result, 2017.

As it is shown in the above table (in Table 1) the descriptive result showed that the willing and not willing households differed significantly from each other in age, education, family size, livestock ownership, engagement in any off/non-farm sources of income, past awareness on prevention technology methods, impact of Parthenium weed encountered, assistance (training and extension service) and membership of the households in cooperative organizations.

b) Estimating the Maximum Mean and Total WTP value

The mean maximum WTP amount for 320 households was found to be 168.52 birr per annum per household. The aggregate maximum WTP was calculated by multiplying the mean MWTP by the total 320 sampled household respondents. Following the formula and procedure (in equation 3), the aggregate Maximum WTP for Parthenium weed control measures was computed to be 53,926.4 birr per year. Similarly, following the formula and procedure (in equation 4) the total maximum amount that households' (6,742 households' in both districts) are willing to pay per year for the control measure of Parthenium weed was found to be 795,313.288 birr per year.

c) Results of Econometric Analysis

Prior to running the Tobit model, the hypothesized explanatory variables were checked for the existence of multicollinearity and heteroscedasticity. The Tobit model shown below (in table 2) estimates the parameters of the variables which are expected to determine the probability to affect farmer Maximum WTP and the intensity level/amount of payment for the control measure of Parthenium weed.

From the Tobit model output indicated in the Table 2 below, it is observed that seven variables (age, education, live stock ownership, off farm income, past awareness, assistance and membership) were significantly influenced the probability of households' maximum WTP and intensity of payment among individuals. Since, direct interpretation of the Tobit model output (presented in Table 2) is not straightforward, the study used three set of marginal effects (only the significant variables incorporated) for interpretation and report purpose: the effect on the probability of a positive WTP, the effect on conditional WTP (among willing respondents) and the effect on unconditional WTP (among all willing and unwilling respondents), which is presented in Table 3.

Table 2: MLE of the Tobit model for Factors Affecting Farmers' WTP in both districts

Variables	Coefficients	t-ratio
Sex	-24.92	-0.65
Off farm income	78.491	2.97***
Past awareness	79.687	1.74*
Impact of land tenure	-37.536	-0.94
Impact of Parthenium	58.84	4.19
Assistance	124.011	3.6***
Attitude to pay	1.967	0.31
Membership	13.097	3.28***
Age	-4.487	-2.26**
Education	73.102	2.31**
Family size	5.632	0.59
Live stock ownership	16.989	1.75*
Total land size	-9. 3218	-9.19
Cons	84.686	0.80
Number of observation	320	
Prob > chi2	0.0000	
Pseudo R2	0.3146	
LR chi2(13)	413.72	

***, **,*, shows significance level at 1%, 5% and 10% probability levels, respectively

Source: Survey data result, 2017.

According to the result of the Tobit model marginal effect showed below (in table 3) age has a negative and significant influence on the probability of maximum WTP. The result implies that as a household becomes older, the probability of willingness to pay for the control measure of Parthenium weed will decrease by 0.07%, ceteris paribus. This might be because aged farmers at later age lack resources (money) even though it is hard to generalize, if aged people had money they may not be interested to pay or invest in environmental protection, since such investment may take long time before its maturity to give return [8] and [14].

Table 3: Marginal effects of the explanatory variables

Variables	The Change in the probability of WTP as independent variable X_i changes: $\frac{\partial F(Z)}{\partial X_i}$	The change in amount of WTP with respect to a change in an explanatory variable among willing respondents: $\frac{\partial E(y_i/y_i^* > 0)}{\partial X_i}$	The marginal effect of an explanatory variable on the expected value of the dependent variable (change among all) is: $\frac{\partial E(Y_i)}{\partial X_i}$
Age	-.0007**	-4.193**	-4.440**
Education	.0128*	67.735**	72.193**
Live stock ownership	.0026*	15.883*	16.820*
Off farm income	.0112**	73.654***	77.725***
Past awareness	0121*	74.457*	78.851*
Assistance	.0127***	118.276***	123.165***
Membership	.0241 **	5.408***	11.316***

****, **,*, shows significance level at 1%, 5% and 10% probability levels, respectively*

Education had a positive and significant relationship with maximum amount of WTP at 10% probability level. This suggests that, as households become more educated the probability of willingness to pay for the control measure of Parthenium weed will increase by 1.28%, ceteris paribus. The result is in line with the findings of [34], [35] and [36].

A unit increase in the number of livestock (in TLU) an individual owns will increase the probability of willingness to pay by 0.26% (at 10% probability level).

This might be due to the fact that the number of Livestock holding could be a proxy for wealth under Ethiopian farmers' condition. When the wealth of a household increases, the Willingness to pay will also

increase (Animut, 2007). The implication might be as Parthenium is observed to have an adverse and different kind of impact on livestock production and productivity. Therefore, farmers who owned a large number of livestock are more likely to be WTP and invest more on the control measures of this weed.

As households' engaged in any off/non-farm sources of income/employment, the probability of maximum WTP increases by 1.12% (at 5 % probability level of significance). This is in line with the basic economic theory, which states that individuals demand for most goods or services depends on income [37].The other possible explanation for this result is, this is because income sources from any off-farm activities would contribute to the improved welfare of the households and able them to relieve different financial constraints [38] and thereby increases their WTP. In addition, the study result is in line with the findings by [39].

Households' awareness on the impact and in the available option on the effective control and prevention method of Parthenium weed known and undertaken in the past, which is a proxy for management or control technology awareness, found to affect the probability of farmers' maximum amount of WTP positively and significantly (at 10% probability level). The result implies that as a household becomes aware, the probability of WTP for the control measure of Parthenium weed will increase by 1.21%, ceteris paribus.

As it is indicated the variable assistance (in the form of extension service and training) increases the probability of WTP by 1.27 % at 1% probability level of significance. Extension provides farmers with information related to better agricultural farming practices and technologies while protecting their natural resource which improves their knowledge and thus awareness of the need to protect and manage the resource [40].With regard to training; a study by [41] showed that it was positively associated with willingness to pay. As farmers received any form of assistance in the prevention and control measures had positively influenced farmers' maximum WTP amount by birr 118.28 and 123.16 among willing and the entire sample respondents, respectively.

IV. Conclusion And Recommendation

The study estimated the economic value farmers' are willing to pay for the control measure of Parthenium weed and examined the factors that determine their maximum WTP amount of money for the control measures of Parthenium weed in Abeshige and Kebena districts, Gurage zone. To achieve the above mentioned objectives both primary and secondary data were used. The Primary data were collected from 320 randomly sampled farmer households' from the two districts (160 from each) using a structured questionnaire. To elicit the maximum amount farmers are WTP the study used a single bound with open ended follow up CVM. The data obtained was analyzed using both descriptive and econometric methods. Accordingly, the result of the study showed that about 224 respondents were willing and 96 were not willing to pay for the control measure of Parthenium weed. The result of the estimated mean maximum WTP value of controlling Parthenium weed was found to be 168.52 birr per year per household. In addition, the total maximum willingness to pay from the total population in both districts (6, 742 households) was estimated to be birr 795,313.288 birr per year.

The simultaneous Tobit analysis result indicated that, age, education level, livestock ownership, off/non-farm sources of income, past awareness, assistance and membership in any form cooperatives were found to significantly affect farmer households' willingness to pay. Thus, these factors have important policy implications in that due emphasis should be given to these important policy variables. Accordingly, it can be concluded that understanding and addressing of these factors is a necessary and first step before designing and implementing the most effective measures/ strategies to control or eradicate Parthenium weed in the study area.

Therefore, based on the results obtained the following important policy recommendations can be suggested to control or eradicate Parthenium weed in the study area:

- The study first and foremost, underlined the crucial importance of creating and raising or improving farmer households' awareness and knowledge about the adverse impact of Parthenium weed through different outreach methods and instruments so as to promote their maximum willingness to pay for the most effective strategies/packages to control or eradicate this weed.
- There is also a need to linkage creation and collaboration development between and/or among all concerned body's and stakeholders and designing and implementing integrated Parthenium weed controlling packages with full participation of farmer households' in the study area.
- In addition, making, implementing and strengthening of policies and strategies that encourages or promotes farmers to form or join farmer associations (particularly in the form of cooperatives) and that support the expansion and promotion of off-farm sources of income/ employment are among others will be a step in the right direction in this regard.
- Furthermore, farmers' capacity building programs to asset formation or accumulation should be strengthened.
- Finally, priority also should be given to urgently continue with the control or eradication of

Parthenium weed, to avoid future costs which may result if the control of this weed remains suspended.

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