

**TOTAL ECONOMIC VALUATION OF *PROSOPIS JULIFLORA*
INVASION IN RURAL DIRE DAWA ADMINISTRATION, ETHIOPIA**

PhD DISSERTATION

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**Total Economic Valuation of *Prosopis Juliflora* Invasion in Rural Dire
Dawa Administration, Ethiopia**

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DEDICATION

This dissertation work is dedicated to my wife Elsabeat Mulugeta for taking care of my lovely daughters Liliya Negussie and Wintana Negussie during my study leave and to my mother Roman Berehe for nursing me with affection and love and for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this Dissertation is my own work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis and completion of this Dissertation. Any scholarly matter that is included in the Dissertation has been given recognition through citation.

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Finally, this thesis presents only my empirical and academic expositions and does not reflect the opinions of Haramaya University nor that of my advisors and examiners. Any error in this thesis is my own.

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LIST OF ACRONYMES AND ABBERVATIONS

BoARD	Bureau of Agriculture and Rural Development
CA	Conjoint Analysis
CBA	Cost Benefit Analysis
CE	Choice Experiment
CI	Confidence Interval
CV	Contingent Valuation
DBDC	Double Bounded Dichotomous Choice
EARO	Ethiopian Agricultural Research Organization
HDRA	Henry Double Day Research Association
HPM	Hedonic Price Method
IAS	Invasive Alien Species
ISSG	Invasive Species Specialist Group
IUCN	International Union for the Conservation of Nature and Natural Resources
KM	Kernel Matching
LR	Likelihood Ratio
NGO	Non-Governmental Organization
NN	Nearest Neighbor
PSM	Propensity Score Matching
RBP	Recursive Bivariate Probit
REP	Random Effect Probit
SBDC	Single Bounded Dichotomous Choice
SLM	Sustainable Land Management
SUBVP	Seemingly Unrelated Bivariate Probit
TEV	Total Economic Value
TLU	Tropical Livestock Units
WTA	Willingness to Accept

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TOTAL ECONOMIC VALUATION OF *PROSOPIS JULIFLORA* INVASION IN RURAL DIRE DAWA ADMINISTRATION, ETHIOPIA

ABSTRACT

Invasive Alien species (IAS) are considered to be one of the most serious challenges worldwide to mankind, biodiversity and environment. But, studies widely agree that actions to eradicate and control the effects of invasive alien species focused largely within developed countries. However, in poor, fragile and vulnerable developing countries, invasive alien species cause similar or worse problems, for development as well as conservation of biodiversity. Addressing the problem of invasive alien species is currently urgent because the threat is growing daily, and the economic as well as environmental impacts are severe. This study aims to empirically estimate the total economic value of Prosopis juliflora (hereafter referred as 'Prosopis') invasion in Dire Dawa administration. Data were collected through a survey of 450 agro-pastoral households (250 from Prosopis invaded and 200 from non-invaded area). Both stated and revealed preference methods were used because impacts of Prosopis are both tangible and intangible. Applying the total economic valuation approach, the study found that the current costs of the Prosopis invasion in Dire Dawa administration are higher than the benefits. The Gini-coefficient shows that on-farm income as a whole accounted for 22.5%, while nonfarm income accounted for 73.5% of total income inequality in the Administration. The study further shows that while on-farm income inequality is decreasing, non-farm income inequality is increasing in rural Dire Dawa Administration. Applying a double bounded contingent valuation method, the study found that WTP for eradication measures is significantly influenced by bid level, income of the households, age of the household head, gender, physical injury incidence, size of land holding and attitudes towards payment. Moreover WTP for control measures is influenced by bid level, occupation, family size, livestock owned, participation in non-farm income earning activities and attitudes towards payment. Results indicate that eradication and control of Prosopis invasion offers 224.30 and 107.49 Birr per household, respectively. The importance of Prosopis is perceived negatively by the households with a mean value of almost 4 out of 5 rating scale. Results obtained from the PSM model reveal that Prosopis invasion has led to an increased education expenditure, average annual income from crop production, non-farm income, food and non-food expenditure and physical food consumption, whereas Prosopis invasion reduced income generation from the sale of milk products. Among the coping strategies used by households living in invaded areas, utilizing Prosopis either as a source of income or domestic consumption took the lion's share (61.2%). The clear implication is that controlling Prosopis through utilization is the most preferred management option in the study area.

Keywords: Invasive alien species, Total Economic Valuation, PSM, WTP, Stakeholder analysis, Dire Dawa Administration, Ethiopia

1. INTRODUCTION

1.1. Background of the Study

Ethiopia's natural resource base is the foundation of an economic development, food security and other basic necessities of its people. Smallholder agriculture is the dominant sector that provides over 77 percent of the total employment, the lion's share of foreign exchange earnings and approximately 42 percent of the Gross Domestic Product (GDP) (ATA, 2015). The sector is also a frontline victim of different environmental shocks including invasion of noxious plant species. According to Stefan (2005), the impacts of the invasive species on livelihoods are most likely more pronounced in developing nations because the majority of the populations in those countries consist of small-scale farmers who are dependent on natural resources for their survival.

Invasive species are plants of all taxonomic groups whose introduction and/or spread outside their natural past or present distribution threaten the environment such that the well-being of humans will ultimately be affected (CBD, 2010). According to D'Antonio and Kark (2002), such plants are mostly characterized by high ecological adaptability and vigorous growth even in harsh climate to cover huge acreages. These natures of the species will undoubtedly affect people's livelihoods by threatening their means of stay like grazing areas, farmlands, and fisheries, either by reducing its productivity or completely denying access. This further worsens the living conditions of resource poor rural people of developing countries. According to Anderson (2005), the annual economic damage due to invasive plant species in USA was USD 24 billion.

According to Pimental (2001), around USD 1.5 trillion annual global economic damage is caused by problems associated with bio-invaders. One of the top 100 bio-invaders rated in 2004 by Invasive Species Specialist Group (ISSG) was *Prosopis* species (Lowe *et al.*, 2004).

Prosopis is one of the invasive species that are native to South America, Central America and the Caribbean. In the United States, it is well known as mesquite. It is fast growing, nitrogen-fixing and tolerant to arid conditions and saline soils. Under the right conditions, *Prosopis* can produce a variety of valuable goods and services: construction materials,

charcoal, soil conservation and rehabilitation of degraded and saline soils (Sunil *et al.*, 2015). Concern about deforestation, desertification and fuel wood shortages in the late 1970s and early 1980s prompted a wave of projects that introduced *Prosopis* and other hardy tree species to new environments across the world. *Prosopis* has survived where other tree species have failed and in many cases became a major nuisance. *Prosopis* species have invaded over 4 million hectares in Africa (Witt, 2010).

In Ethiopia, it was first introduced to the Afar region from India in the 1970s by the Ministry of Agriculture in an effort to improve water and soil conservation and fight desertification (EARO and HDRA, 2005). *Prosopis* was also introduced and cultivated in Ethiopia for shade, timber, forage, food and medicine (Hunde and Thulin, 1989). It escaped cultivation and spread to farmlands, irrigation areas and rangelands. Since its introduction, *Prosopis*' invasion has escalated markedly from time to time and it has become one of the top three invasive species in Ethiopia and has been declared by the Environmental Policy and the National Biodiversity Strategy and Action Plan as noxious weed (Yibekal, 2012). *Prosopis* has now invaded most of the pastoral and agro-pastoral areas of Afar Regional State and Dire-Dawa administration. In Ethiopia, *Prosopis* has covered an area of one million hectares and more than 12,000 hectares in Dire Dawa Administration (BoARD, 2009). In the Middle Awash, about 30,000 hectare of grass land, rangelands, water points and croplands are estimated to be invaded by *Prosopis* (Zeray, 2008). *Prosopis* is now a serious agenda item in Ethiopia, particularly in Afar Regional State and Dire-Dawa Administration. It has become a serious challenge to pastoralists, agro-pastoralists, regional government and city administration, researchers, academia, development practitioners and policy makers at various levels. Following its fast spread and encroachment of the grazing land in vast (agro) pastoral areas, the Government of Ethiopia has recently moved to the extent of producing and issuing a national strategy for the control and management of *Prosopis*. Hence, it becomes imperative to undertake research on total economic value of *Prosopis* invasion in Dire Dawa administration.

1.2. Statement of the Problem

Invasive species threaten important ecosystems with serious repercussions on human wellbeing and economic development of societies. The impact of invasive species is more critical in the developing world where livelihood is primarily dependent on agriculture (Chenje and Mohamed-Katerere, 2006). Apart from their direct effect on livelihood, invasive species are one of the five drivers of biodiversity loss together with habitat loss, over exploitation, climate change, and pollution (Millennium Ecosystem Assessment, 2005). *Prosopis* is an invasive species that has become the national number one invasive species in Ethiopia (EARO and HDRA, 2005).

Currently, *Prosopis* poses a threat to indigenous biodiversity in Ethiopia in general, and in Dire-Dawa Administration in particular. In Dire Dawa Administration, more than 12,000 hectares (about 9.6% of the total area) of land are estimated to be occupied by *Prosopis* (BoARD, 2009). Areas that are currently invaded by *Prosopis* were important sources of forage for livestock keeping, which in turn are the mainstay for the Dire-Dawa administrative council's pastoral and agro-pastoral households. The invasion by *Prosopis* reduces grass availability and stocking density. The invasion also leads to shrinkage of the pastoral and agro-pastoral lands and will, therefore, threaten sustained existence of the agro-pastoral system in the area.

Some of the negative impacts of *Prosopis* are partially offset by its services such as firewood, live fencing and charcoal and carbon storage service (Yohannes *et al.*, 2014). Other positive impacts of this plant include increasing crop productivity (Jema and Abdu, 2013), improving temperature and humidity – positive microclimate impacts (Choge and Muthike, 2014; Ilukor *et al.*, 2014). Improving crop productivity can occur as a result of the fact that the plant improves soil texture and soil organic matter by increasing nitrogen and phosphorus, and lowering soil pH (El Fadel, 1997).

Despite some positive attributes, communities in Ethiopia and elsewhere are becoming increasingly concerned about the negative impacts of *Prosopis* which include the impact of this invasive tree on beneficial native species; encroachment onto paths, villages, homes, water sources, crop and pasture land; and injuries on animals and human beings (Mwangi and Swallow, 2008; Maundu *et al.*, 2009). *Prosopis* has a belligerent invasive

nature, infesting pastureland, irrigated cultivated lands and irrigation canals causing irreversible displacement of natural pasture grasses as well as native tree species (Kassahun *et al.*, 2005). All these factors contribute to increased pressure on the remaining pasture and increased vulnerability of pastoralists and agro-pastoralist to the recurrent moisture stress they are experiencing.

Peoples in the dry lands are demanding the eradication of *Prosopis* (Zeila *et al.*, 2004); however, experiences around the world show that eradication is ineffective, costly and a futile management option once established (Pasiecznik, 1999; Zeila *et al.*, 2004). Studies from around the world indicate that through appropriate short, medium and long term interventions, the adverse effects of *Prosopis* can be reversed. That means, promoting its utilization and eradication in a planned and regulated way through adoption of appropriate and sustainable management practices is beneficial.

The existence of *Prosopis* in an area needs to be valued based on its positive and negative effects on the local population and ecosystems in order to tie it into the local decision-making processes and livelihoods. Therefore, it is necessary to examine how *Prosopis* in combination with all available natural resources impacts on the local rural household socio-economies. An extensive survey of literature has however, mirrored that there is no a single study conducted in Ethiopia that maps the social factors and many aspects of economic value of cost and benefit resulting from *Prosopis* invasion.

This study, therefore, attempts to address the prevailing knowledge gap and enhance understanding about the social and economic effects of *Prosopis* invasion and the value of *Prosopis* invasion in Dire Dawa Administration through use of empirical and intuitive approaches.

1.3. Research Questions

The present study attempts to address the following key research questions.

1. How much value do agro-pastoral households attach to the different commodities and services obtained from the *Prosopis*? What is the total economic value of *Prosopis* invasion?

2. What is the perception of different stakeholders about control/eradication of *Prosopis*?
3. How much do agro-pastoralists be willing to pay for control/eradication of a unit area of *Prosopis*?
4. What are the factors determining households' willingness to pay for control/eradication of a unit area of *Prosopis* and its extent?
5. Does the invasion of *Prosopis* have an impact on the income, consumption and expenditure of the households? If so, what is the impact of *Prosopis* invasion on the income, consumption and expenditure of agro-pastoral households of the study area?
6. What is the pattern and effect of households' income obtained from *Prosopis* on income inequality among the households?
7. What are the coping strategies of the households against *Prosopis* invasion?

1.4. Objectives of the Study

An overarching objective of the study is to empirically estimate the total economic value of *Prosopis* invasion in Dire Dawa administration.

The specific objectives of the study are:

1. to estimate the total economic value of *Prosopis* invasion;
2. to examine how the economic benefits and costs/losses of *Prosopis* invasion are distributed among sample households;
3. to estimate households' willingness to pay for control/eradication of *Prosopis*;
4. to identify the determinants of households' willingness to pay for control/eradication measures of *Prosopis*;
5. to measure the impact of *Prosopis* invasion on income, consumption and expenditure of agro-pastoral households of the study area; and
6. to assess households' perceptions to and coping strategies against the effects of *Prosopis* invasion in the study area.

1.5. Significance of the Study

Herders and farmers are facing challenges and benefits from invasive species, like *Prosopis*. Hence, assessing the impact of such species on the rural livelihoods in general

and agro pastoral households' in particular using total economic valuation concept have a paramount importance for herders, farmers and policy makers to make valuable decisions on the selection and use of contextual management strategies.

Through this research, woody IAS management strategies are identified for the study areas. In addition to updating the existing woody IAS distribution data, the research has also generated valuable information on the important indicators of ecosystem conditions and services in the study areas. This has been allowed by establishing a baseline against which future ecosystem assessments can be compared. The findings of this research do also inform the development of practical mitigation strategies at all scales as the process has been underpinned by an active engagement with policy-makers. Findings may also lead to the development of a policy environment that is conducive for widespread application of Sustainable Land Management (SLM) approaches towards the mitigation of negative impacts of invasive alien species. These will have direct manifestations on the pastoral and agro-pastoral livelihoods.

The research has also attempted to add to the empirical literature on the area and provided a basis for further empirical study on the subject in Ethiopia. The study is also expected to serve as a springboard for further research, extension and development schemes that would benefit the pastoral and agro-pastoral population. Furthermore, the research results could benefit all development partners including organizations concerned with community development, researchers, and development policy makers.

1.6. Scope and Limitations of the Study

The study focused on the assessment of total economic valuation of *Prosopis* invasion in rural Dire Dawa Administration, east Ethiopia. Undertaking original environmental valuation research requires high cost. The study had implemented the questionnaire survey in order to collect primary data from Dire Dawa administration.

A number of invasive species are found in the study area. This requires a full-scale total economic valuation research that would require more time, efforts and several alternative services. But due to the nature of TEV this study is only limited to the investigation of *Prosopis* species only which has colonized most of pastoral and agro-pastoral lands. There are several techniques that are used for valuation of the natural resource, but for the

purpose of this study, stated and revealed preference methods based on the concept of total economic value were used to assess the economic impacts of *Prosopis* invasion on agro-pastoral livelihoods in Dire-Dawa Administration. The fact is that evaluation of the impact of *Prosopis* invasion on biodiversity and ecosystem services can only be partial, because many of the impacts have non-market values, and the available data, in many cases, is feared to be inadequate. Akin, identifying and capturing these values using stated or revealed preference methods is somewhat problematic, because IAS often cause changes in the population or health of an environmental asset, rather than its complete destruction (Cook and Proctor, 2007).

Eliciting such marginal values is yet to be attempted. The results from this work should be taken as a mean estimate of the total impacts associated with the *Prosopis* species in Dire-Dawa Administration. Also, it should be clear from the very outset that a number of assumptions were made to build the cost-benefit model. And, the resulting ratios are indicative values to be used for planning purposes only. These cannot be taken as the absolute values. Another limitation of this study emanates from use of cross-sectional data as it does not allow to capture the inter-temporal variations in perceptions, values and impacts, *inter alia*.

1.7. Organization of the Dissertation

This dissertation contains five main chapters. The remaining part of the dissertation is organized as follows. Relevant literatures related to the study area are reviewed in chapter two. Chapter three focuses on sampling design, methods of data collection, analytical techniques and description of the study area. In chapter four, results obtained from the descriptive statistics and econometric models are presented and discussed. Finally, chapter five presents summary, conclusion and recommendations.

2. LITERATURE REVIEW

This chapter presents conceptual and operational definitions, theoretical, methodological, analytical frameworks, and review of the empirical literature.

2.1. Conceptual and Operational Definitions

2.1.1. Invasive alien species and *Prosopis* as an invasive alien species

A species is considered an “alien invasive species” when it spreads beyond its natural area of distribution and moreover causes harm or is likely to cause harm to the environment, people, economy or human health (Executive Order, 1999).

Invasive Alien Species (IAS) out-compete native organisms for food and habitat, spread through their new environment, increase their population and harm ecosystems in their introduced range (Liba and Gretchen, 2009). They cause ecological, economic and social impacts and are key drivers of global change. They inflict serious damage on ecosystem goods and services which are the lifeline of the human enterprise (Ross *et al.*, 2014).

In economic terms, the costs of invasive alien species are significant. Total annual costs include losses to crops, pastures, livestock, water and forests, as well as environmental damages. These costs have been estimated to be in the hundreds of billions of dollars and possibly more than one trillion. This does not include other values like losses in biodiversity or ecosystem services (Pimentel *et al.*, 2001).

The multifaceted problems of IAS have been at the top of policy agenda throughout the world. How to control, eradicate and prevent IAS are the main challenging questions that need to be addressed in policy design (Emerton and Howard, 2008). The policy challenge posed by IAS in developing countries is particularly serious as they arise in complex social, economic and political problems prevalent in these countries (Chenje and Mohamed-Katerere, 2006). Invasive alien species pose a complex policy problem especially when they have both beneficial and harmful aspects. A very good example of such a species is *Prosopis* which is now a policy dilemma for many countries where it is introduced. The issue of this invasive species in Ethiopia is particularly interesting as the

invasion is on internationally important biodiversity sites of the country and its bearings on the susceptible livelihoods of pastoralists and agro-pastoralists.

Prosopis is one of the top 100 bio-invaders identified by ISSG in 2005. It is ever green to semi ever green, flat topped crown, thorny with a bushy appearance of spreading branches touching to the ground (Muthana, 1988). Its height ranges from 3-12 meters and rarely reaches around 20 meters depending on genetics, population and environment. The trunk's diameter reaches up to 1.2 meters (Zeila *et al.*, 2004).

Prosopis has a very wide soil and site adaptability from sand dune to clay soil, from saline to alkaline soil; altitude less than 200 meters up to greater than 1500 meter above sea level, and mean of precipitation amount ranging from 50 to 1500 mm. Nowadays it is very common in Africa, Asia and Australia (Pasicznik *et al.*, 2004). According to Kassahun (2005), *Prosopis* in Ethiopia is generally described as short, multi-stemic (6-8 basal stems) with spreading canopy of twisted branches. In Afar region, it ranges from bush to tree reaching up to 15 meters height and an average diameter of 0.2 meters (Ameha, 2006).

2.1.2. Concepts of total economic value

Economic values are anthropocentric notions and are based on situations of choice. The economic definition of value is rooted in the idea that many resources are scarce. That means that the demand for those resources is great relative to their availability. There is never enough resource like land or labor to do all the things that all individuals might wish. Because resources are scarce, it is necessary to make choices about how society will use what is available. These choices are often based on complex trade-offs; thus, value is revealed in how individuals and society collectively choose to allocate these resources.

The economic concept of value has its foundation in neoclassical welfare economics. Welfare economics is the science of determining how available resources may be best used to promote human welfare. It seeks to develop better procedures (without prejudice towards either the public or the private sector) for allocating the total resource base (labor, capital, land, etc.) among potential uses and users in order to meet individual and group needs. Individuals need material resources to improve their economic well-being, a healthy environment to maintain their physical well-being, and psychologically satisfying experiences to maintain their mental wellbeing (James and Lee, 1971).

The basic premises of welfare economics is that the purpose of economic activity is to increase the well-being of the individuals who make up a society, and that each individual is the best judge of his/her own welfare. This welfare depends not only on the individual's consumption of private goods and of goods and services produced by the government, but also on the quantities and qualities they receive of nonmarket goods and service flows from the resource-environment system, e.g. health, visual amenities and opportunities for outdoor recreation.

It follows that the basis for deriving measures of the economic value of changes in resource-environmental systems is their effect on human welfare. The anthropocentric focus of economic valuation does not preclude a concern for the survival and well-being of other species. Individuals may value the survival of other species not only because of the uses people make of them (for food or recreation, for example), but also because of an altruistic or ethical concern. The latter can give rise to non-use values (Freeman, 1993).

The term total value, synonymous with true WTP or WTA, arose in environmental economics with the awareness that substantial portions of WTP or WTA were not accounted for in the measure of economic value obtained using market prices or revealed preference techniques. In this sense, WTP and WTA estimates derived using those approaches are defective since welfare gains or losses may be overlooked if passive use value is decisive (Freeman, 1993).

According to Barbier (1994), the concept behind the total economic value of a natural or human-modified ecosystem essentially involves considering its full range of characteristics as an integrated system, its resource stocks or assets, flows of environmental services and the attributes of the system as a whole. Often, total value is reported as the sum of use value and non-use values or passive values (Perman, 2003; Tietenberg, 1996). Measure of ecosystem values should in fact be captured through TEV under non-use values and use values. Since TEV seeks to elicit social preferences it can be said to encompass psychological values and indeed, as Nijkamp *et al.* (2006) note, psychological value is strongly correlated with the total economic value, because both measure social preferences.

The contents of a TEV analysis vary slightly from case to case and from analyzer to analyzer, partly because it is a demanding task which requires large amounts of data and is both expensive and time consuming. The valuation work aims at identifying, quantifying and monetizing or describing: (a) the direct use values, (b) the indirect use values, and (c) the non-use values. Direct use values refer to the purposeful use of bio-resources to gain an economic benefit or utility. Bio-resource goods can be consumed by households which hunt, collect or grow them, use them as raw materials, or trade in them. Other use values, related to recreational activities, are for instance, sport fishing and hunting, ecotourism, and bird-watching. Indirect use values are associated with functions of the ecosystem that maintain the stability and productivity of the environment. On a wider scale, values also include the environmental services of watersheds in the hydrological cycle, and the contributions of forests and other types of vegetation to the atmospheric balance and climate regulation. Bio-resources can also be valued for the aesthetic, cultural, spiritual, or recreational benefits they provide. There are also so-called option values for such utilization, which may not be alternatives in active use but ones that can be taken into use at a later occasion (Dixon and Pagiola, 1998; Abeygunawardena *et al.*, 1999).

The non-use values include existence values, which represent the value of the satisfaction an individual derives from the knowledge that a given element of biodiversity exists, irrespective of whether that individual expects to use or benefit from it directly. There are also bequest values, where goods or services are saved for future generations to experience. Additionally, there are intrinsic values, which relate to ethical, moral, or cultural perceptions, for instance, including expectations that giant pandas should still exist or that a given type of ecosystem can still be found intact on the Earth (CBD, 2003).

In general, the TEV of control/eradication of *Prosopis* can be defined as a combination of use and non-use values. Use value includes direct and indirect use value. Non-use value includes existence and bequest value, since option value could be classified mainly under non-use value. This study dealt with the TEV of *Prosopis* control/eradication. Accordingly, in this study the household's WTP is investigated with a view to improve the functional services obtained from pastoral and semi-pastoral land, for current and future generations.

2.1.3. Social value, insurance value and output value

The term ‘social value’ refers to the value of a particular community or the cultural values and norms of society at large, but can also be used to refer to the public interest, values for public goods, ‘altruistic’ values and feigned altruistic values, the values that people hold in social situations, contribution to welfare or well-being, the willingness-to-pay (WTP) of a group, the aggregated WTP of individuals, or values derived through a social process. According to Kennedy *et al.* (1995) social values are about natural resources, on the one hand, values deriving from the ‘social system’ and, on the other, as the wider norms expressed through laws, political action, media and other institutions. Kennedy *et al.* (1995) suggested two layers of social values: a cultural first layer that influences a second layer of contextual values in relation to natural resource management.

The insurance value of ecosystems is closely related to the system’s resilience and self-organizing capacity. The notion of resilience relate to the ecosystems’ capacity to absorb shocks and reorganize so as to maintain its essential structure and functions, i.e., the capacity to remain at a given ecological state or avoid regime shifts (Holling, 1973; Walker *et al.*, 2004). Securing ecosystem resilience involves maintaining minimum amounts of ecosystem infrastructure and processing capability that allows 'healthy' functioning. Such minimum ecological infrastructure can be approached through the concept of “critical natural capital” (Deutsch *et al.*, 2003; Brand, 2009). The status of critical natural capital and related insurance values are sometimes recognized by the precautionary conservation of stocks, or setting safe minimum standards.

Output value is the aggregated value of the ecosystem service benefits provided in a given state, akin to the concept of TEV. Benefits corresponding to the “output value” of the ecosystem can span from disparate values such as the control of water flows by tropical cloudy forests or the mitigation of damages from storms and other natural hazards by mangroves. The elicitation of these kinds of values can generally be handled with the available methods for monetary valuation based on direct markets, or, in their absence, on revealed or stated preferences techniques (Gren *et al.*, 1994; Turner *et al.*, 2003; Balmford *et al.*, 2008).

2.1.4. Willingness to pay/willingness to accept

Economic valuation is concerned with how to estimate the impact of changes in ecosystem services on the welfare of individuals and is based on the principles of utilitarianism. If ecosystem changes result in individuals' judging that they are worse off, one would like to have some measure of the loss of welfare to these individuals. Alternatively, if the changes make people better off, one would want to estimate the resulting welfare gain.

The basic concept used by economists to measure such welfare gains and losses is rooted in the utilitarian notion that for any individual, the different sources of value that affect the individual's utility are potentially substitutable; that is, the individual is willing to trade a reduction in one source of value for an increase in another in a manner that leaves his or her overall utility unchanged. The essence of this approach is to value a change by determining what people would be willing to trade (i.e., to receive or to give up) so they would be equally satisfied or happy with or without the change.

Each measure looks at potential trade-offs between money and the good or service being valued that leave utility unchanged from some base level. They differ, however, in the base level of utility that is maintained when the hypothetical trade-off is made. In valuing an improvement in environmental quality or services, Willingness to pay (WTP) considers the maximum sum of money a respondent would be willing to pay for an increase or to prevent a harmful effect (e.g. environmental degradation) in an environmental amenity. Willingness to accept (WTA) considers the minimum sum of money a respondent would require to forgo an improvement or to accept a harmful effect (e.g. degradation) in an environmental amenity (Hanemann, 1991). WTP takes as its reference point the absence of the improvement while WTA takes as its reference point the improvement, and WTP is constrained by income while WTA is not (Freeman, 1993). However, for many environmental goods and services, the two can be substantially different. In particular, Hanemann (1991) has shown that when valuing changes in the quantities of goods or services available for which there are no close substitutes (including many ecosystem services); the two measures of value can yield quite different results. For environmental improvements, the amount an individual is willing to accept to forgo that improvement

will normally be greater than the amount he or she would be willing to pay to ensure it ($WTA > WTP$).

Traditionally, economists have been fairly indifferent about the welfare measure to be used for economic valuation: willingness to pay (WTP) and willingness to accept compensation (WTA) have both been acceptable. By and large, the literature has focused on WTP.

However, the development of stated preference studies has, fairly repeatedly, discovered divergences, sometimes substantial ones, between WTA and WTP. These differences still would not matter if the nature of property rights regimes were always clear. WTP in the context of a potential improvement is clearly linked to rights to the status quo. Similarly, if the context is one of losing the status quo, then WTA for that loss is the relevant measure (Little and Mirrlees, 1974).

By and large, environmental policy tends to deal with improvements rather than deliberate degradation of the environment, so there is a presumption that WTP is the right measure. The problems arise when individuals can be thought of as having some right to a future state of the environment. If that right exists, their WTP to secure that right seems inappropriate as a measure of welfare change, whereas their WTA to forego that improvement seems more relevant. In practice, the policy context may well be one of a mixture of rights, e.g. a right to an improvement attenuated by the rights of others not to pay “too much” for that improvement (Little and Mirrlees, 1974).

2.1.5. Welfare change

A change in environmental quality can affect individual welfares through any of the following four channels: change in the prices they pay for goods bought in markets; change in the price they receive for their factors of production; change in the quantities or qualities of nonmarket goods; and change in risk individual face (Freeman, 1986).

The individuals' utility function is not observable. There is no direct way of measuring individuals' gain or loss from policy change. The indirect methods are used to measure welfare change resulted from policy change, such as welfare gain due to improved environmental service. In estimating monetary values for environmental resources we are

concerned with how changes in the provision of environmental public goods impact upon individual's utility. Traditionally the welfare gain or loss from such changes of provision have been approximated by changes in consumer surplus; the area underneath the ordinary (Marshallian) demand curves and above the price level (Just *et al.*, 1982; Johansson, 1987).

The Marshallian demand curve tracks the 'full price effect' which occurs when the provision of a good changes. Typically it has been used to show how much the quantity consumed of normal good increases when its price falls. A practical problem, therefore, arises in estimating the Marshallian demand curve for an un-priced environmental public good. Without private property characteristics, such as rival consumption and excludability, a good cannot be traded in a market and the price/consumption information required to estimate the Marshallian demand curve will not be directly observable. One solution is to estimate the Marshallian demand curve via a surrogate market, using incurred travel costs as a proxy for the recreational value of an open-access leisure site. However, a more fundamental theoretical problem remains in that the presence of income effects mean that consumer surplus itself can give an inaccurate measure of the welfare change resulting from a change in good provision.

In the case of environmental public goods, the individual is usually faced with a quantity rather than a price constraint, the good often being un-priced. Furthermore, these goods often have much higher income elasticities than those associated with many market goods (Bateman and Turner, 1992). Consequently, large income effect arising from a change in quantity provision may undermine the consumer surplus measure of welfare change. In order to move from the ambiguity of consumer surplus to a theoretically more accurate measure of welfare change we therefore need to compensate for the income effect by holding real income constant, that is moving from using the ordinary Marshallian demand curve to the compensated (Hicksian) demand curve (Bateman and Turner, 1992).

The Hicksian approach evaluates welfare change as the money income adjustment necessary to maintain a constant level of utility before and after the change of provision. Two such welfare change measures are feasible for such an approach. The 'Compensating Variation' (CV) is the money income adjustment (welfare change) necessary to keep an

individual at his initial level of utility throughout the change of provision, while the 'Equivalent Variation' (EV) is the money income adjustment (welfare change) necessary to maintain an individual at his final level of utility throughout the provision change (Hicks, 1943).

2.1.6. Economy-environment interdependence

Basically the economy and the environment have a two way relationships, while one side depicts the flow of resources and energy to the economic system; the other depicts the flow of waste product back to the environment.

Economic activity takes place within, and is part of, the system which is the earth and its atmosphere. This system we call 'the natural environment', or more briefly 'the environment'. This system itself has an environment, which is the rest of the universe. The economy and the environment nexus is a two-way relationships and interdependence (Common, 1995).

Economic activity depends upon and affects the natural environment. The fact that the economic process continually depends on the natural world for both the generation of raw material 'inputs' and absorption of waste 'outputs' is simply taken for granted. More specifically, natural ecosystems are viewed simply as a 'gift of nature' ready to be exploited by humans and in strict accordance to the laws of demand and supply. As O' Neill and Kahn (2000) put it, the environment is viewed as 'the constant and stable background for economic activities.

The human economy is a subsystem of the biosphere. In a natural ecosystem, everything is related to everything else. Hence, survival of the biosphere requires recognition of the mutual interdependencies among all the elements that constitute the biosphere. Strictly from an ecological viewpoint, then, the human economy cannot be viewed in isolation from natural ecosystem or the biosphere (Georgescu-Roegen, 1993). Instead, the economy is a subsystem of the natural environment, which is both a source of its raw material inputs and as a 'sink' for its waste (output). Human economy as a subsystem of the biosphere has very profound implications – especially for the issue of 'optimal' scale, the size of human economy relative to the natural ecosystem.

As discussed by Common (1995), economic activity located within the environment and involving production and consumption, both of which draw upon environmental services. Not all of production is consumed. Some of the output from production is added to the human-made, reproducible, capital stock, the services of which are used, together with labor services, in production. Production using a third type of input, resources extracted from the environment. Production gives rise to wastes inserted into the environment. So does consumption. Consumption also uses directly a flow of amenity services from the environment to individuals without the intermediation of productive activity.

The natural environment is viewed as having four distinctive functions. It is the source of basic raw materials for the human economy (resource base). It functions as a repository and eventually a decomposer of the waste materials emanating from the production and consumption sectors of the human economy. Natural environment also provides humans with valuable amenities services. Finally natural environment provide Life support system.

We all want to protect the purity and vitality of our air and water, and the natural landscape. However, despite our desire to do so, as long as we are engaged in transforming material inputs (land, labor, capital, and raw materials) into economic goods, we cannot avoid creating residuals (the second law of matter and energy). These residuals (low entropic matter–energy) of the economic process are commonly referred to as pollution. Pollution then, is an inevitable by-product of economic activities (Ahmed, 2004).

Furthermore, by the first law of matter and energy, we know that this residual has to go somewhere. That ‘somewhere’ comprises the various media of the natural environment – air, water and/or the landscape. It is in this way that the natural environment is used as a repository for wastes generated through the economic process. In general, however, disposal in this way should pose no problem if done in moderation. This is because the natural environment has a decomposer population which, given adequate time, will transform the waste into harmless material, and/or return it as a nutrient to the ecosystem. This self-degrading ability of the natural environment is commonly referred to as its assimilative capacity. It should not be surprising, then, that from the viewpoint of

environmental management, the quality of a particular environmental medium (air, water, land) is determined by its capacity to assimilate (degrade) waste (Perman, 2003).

Amenity services flow directly from the environment to individuals. The biosphere provides humans with recreational facilities and other sources of pleasure and stimulation. Swimming from an ocean beach does not require productive activity to transform an environmental resource into a source of human satisfaction, for example. Wilderness recreation is defined by the absence of other human activity. Some people like simply lying out of doors in sunshine. The role of the natural environment in regard to amenity services can be appreciated by imagining its absence, as would be the case for the occupants of a space vehicle. In many cases the flow to individuals of amenity services does not directly involve any consumptive material flow. Wilderness recreation, for example, is not primarily about exploiting resources in the wilderness area, though it may involve this in the use of wood for fires, the capture of game for food and so on. A day on the beach does not involve any consumption of the beach in the way that the use of oil involves its consumption. This is not to say that flows of amenity services never impact physically on the natural environment. Excessive use of a beach area can lead to changes in its character, as with the erosion of sand dunes following vegetation loss caused by human visitation (Perman, 2003).

2.1.7. Environmental impact and its drivers

Understanding the factors that cause changes in environment and environmental function is essential to designing interventions that capture positive impacts and minimize negative ones. The environmental impacts of economic activity can be looked at in terms of extractions from or insertions into the environment. In either case, for any particular instance the immediate determinants of the total level of impact are the size of the human population and the per capita impact. The per capita impact depends on how much each individual consumes, and on the technology of production (Perman, 2003). Different research studies also demonstrated that population and affluence (per capita GDP) are the primary determinants of a wide variety of national environmental impacts (Dietz and Rosa, 2012; York *et al.*, 2010).

During the late 1960s and early 1970s, debates began about the factors that lead humans to have adverse effects on the biophysical environment. A number of “root” causes were asserted: religion (White, 1967), common property institutions (McCay and Jentoft, 1998), and capitalism and colonialism (O’Connor, 1988). But none of these hypotheses of dominant cause could sustain empirical scrutiny. According to Dietz and Rosa (1994), the drivers of environmental impacts are multiple rather than single causes. After IPAT formulation ($\text{Impacts} = \text{Population} \times \text{Affluence} \times \text{Technology}$) they acknowledging that there are multiple human drivers of environmental change, their effects are multiplicative rather than additive, increases in one driver can sometimes be mitigated by changes in another driver, and assessing the effects of human drivers requires both theory and empirical evidence.

IPAT continues to be used in discussions of the drivers of environmental change (Waggoner and Ausubel, 2002), and the IPAT accounting framework finds productive use in industrial ecology (Chertow, 2001). However, formulations that build on IPAT are emerging. A variety of studies demonstrate that population size has an effect on impacts but sometimes is less important than other factors (Palloni, 1994; Rudel and Roper, 1997; York *et al.*, 2003). A substantial literature examines the effects of affluence on environmental impact (reviewed in Stern 1998; Nordstrom and Vaughan, 1999), including a number of analyses that suggest that such effects depend strongly on context (Roberts and Grimes, 1997).

Over the last decade, the approach has been further refined in many assessment models by adding such factors as specific socio-political, biophysical, and cultural drivers. But these top-down approaches to environmental change still rely heavily on highly aggregated drivers, the value of which has recently been questioned (van Beers and de Moor, 2001; Young, 2002). But perhaps the most important recent advance in understanding is the clarification of a broader variety of interacting drivers that become more important in the local context.

There is no clear hierarchy of drivers that encompasses cause and effect. Individuals and societies try to influence their environment and fulfil their needs by evaluating expected

outcomes. If undesired impacts are foreseen, mitigating decisions can be made (OECD, 1979).

Recent advances in integrated assessment (Alcamo *et al.*, 1998; Stafford-Smith and Reynolds, 2002) and comprehensive analyses of environmental problems (Ostrom *et al.*, 2002) have shown that analyzing causes of environmental change requires a multi-scale and multidimensional assessment of major components of the system and their dynamics and interactions. An appreciation of the feedbacks, synergies, and trade-offs among these components in the past improves understanding of current conditions and enhances the ability to project future outcomes and intervention options.

2.1.8. Inter-temporal distribution

Inter-temporal issues play a particularly central role in environmental problems because the time scale of many environmental processes is radically longer than conventional economic time scales. Global warming and loss of biodiversity provide perfect illustrations: global warming may well have its main impacts on human societies one hundred or more years the costs of loss of species diversity in terms of simplification of ecosystems and loss of genetic variability are likely to be felt most strongly by generations quite remote from us.

This is not to say that there will be no short-run impacts from these phenomena: there will, but they are likely to be dwarfed by consequences that will become apparent only over very long periods. So to assess and evaluate properly these anthropogenic changes in the biosphere we need to look relatively far into the future-possibly a century at least (Heal, 2001). Environmental assets such as watersheds, species diversity, rangelands, marine ecosystems, and climate regimes, are assets that are in principle very long-lived. They have functioned as they do today for millennia, and if well managed will continue to do so equally far into the future. In this they are rather different from the assets that humans construct, and that we are used to valuing. These typically have life spans measured in years or decades. So to appreciate fully the contributions that environmental assets can make to human welfare we need a very long view. This does not sit easily with the economist's standard practice of discounting the future at a real rate. Inter-temporal distribution is at the heart of the choice of a utility discount rate (Heal, 2001).

Many of the issues involve choices with consequences that extend over time. Such choices are said to have an ‘inter-temporal’ dimension. Where we deal only with current consequences we are doing an ‘intra-temporal’ analysis and thus utilitarianism as the ethical basis for intra-temporal normative economics. Most economists also approach normative inter-temporal issues on the basis of utilitarianism (Perman, 2003).

2.2. Theoretical Framework

Studies using single theories omit crucial explanatory variables and, hence, might be misleading. Economic models of WTP have proven to be incomplete, that is, they have restricted explanatory power and need to be supplemented by psychological and sociological models. Furthermore, a general finding is that factors influencing WTP are different for “in-principle WTP” on the one hand and “amount of WTP (given in-principle WTP)” on the other. One drawback of studies of these types is that they normally focus on a single theory and, hence, their results may be misleading (Wall *et al.*, 2007). Hence, it becomes important to use an integrated theoretical approach while dealing with complex issues like the one under consideration in the present study.

2.2.1. Economic valuation theory

This thesis discusses the major tenets of economic valuation of natural resources. Measuring values involves the use of economic theory and technique. Current decision-making processes often ignore or underestimate the value of ecosystem services. Decision-making concerning ecosystems and their services can be particularly challenging because different disciplines, philosophical views, and schools of thought assess the value of ecosystems differently. A review on the approaches to valuation makes it possible to identify two well-differentiated paradigms for valuation: biophysical methods, constituted by a variety of biophysical approaches, and preference-based methods, which are more commonly used in economics (Brander *et al.*, 2010).

Biophysical valuation uses a “cost of production” perspective that derives values from measurements of the physical costs (e.g., in terms of labor, surface requirements, energy or material inputs) of producing a given good or service. In valuing ecosystem services and biodiversity, this approach would consider the physical costs of maintaining a given ecological state.

Biophysical valuation methods use a “cost of production” approach, as did some value theories in classical economics (e.g., the Ricardian and Marxist embodied labor theory of value). Biophysical approaches assess value based on the intrinsic properties of objects by measuring underlying physical parameters (Patterson, 1998). Just like biophysical approach, non-utilitarian value paradigm holds that something can have intrinsic value that is; it can be of value in and for itself irrespective of its utility for someone else. From the perspective of many ethical, religious, and cultural points of view, ecosystems may have intrinsic value, independent of their contribution to human well-being. Current decision-making processes often ignore or underestimate the value of ecosystem services (Rashid *et al.*, 2005). Biophysical measures are generally more useful for the valuation of natural capital stocks than for valuation at the margin of flows of ecosystem services. This is particularly true when ecosystem services have no direct biophysical expression as in the case of some cultural services. In particular, biophysical measures can be especially useful for calculating depreciation of natural capital within a strong sustainability framework (which posits that no substitution is possible between human-made and natural resources) (Brander *et al.*, 2002).

Classical economics see value as arising from the labour power embodied (directly and indirectly) in output, a view which found its fullest embodiment in the work of Karl Marx. Neoclassical economists explained value as being determined in exchange, so reflecting preferences and costs of production. The concepts of price and value ceased to be distinct. Moreover, previous notions of absolute scarcity and value were replaced by a concept of relative scarcity, with relative values (prices) determined by the forces of supply and demand. This change in emphasis paved the way for the development of welfare Economics (Perman, 2003).

Preference-based methods which depend on neoclassical theory rely on models of human behavior and rest on the assumption that values arise from the subjective preferences of individuals. This perspective assumes that ecosystem or environmental values are commensurable in monetary terms, among themselves as well as with human-made and financial resources, and that subsequently, monetary measures offer a way of establishing the tradeoffs involved in alternative uses of ecosystems and environmental goods.

Within the neoclassical theory, ecosystem services that are delivered and consumed in the absence of market transactions can be viewed as a form of positive externalities. Framing this as a market failure, the environmental economics has developed a range of methods to value these “invisible” benefits from ecosystems, often with the aim of incorporating them into extended cost-benefit analysis and internalising the externalities. In order to comprehensively capture the economic value of the environment, different types of economic values neglected by markets have been identified, and measurements methods have been progressively refined. In fact, valuation of non-marketed environmental goods and services is associated with a large and still expanding literature in environmental economics.

The neoclassical theory assumes that individuals assign values to the environment (with the distinction among "use", "altruistic", "bequest" and "existence" values) and that underlying these values are exogenously given individual preferences (Norton, 1987; Turner *et al.*, 1994). Since markets do not exist for environmental goods and services, the theory calls for the estimation of their values. The use value derives from the actual and direct use of the environment; the altruistic value is the value individuals place on other people having a clean and unexploited environment; the bequest value is the value that the current generation places on the availability to future generations of a clean and unexploited environment; and the existence value is the value attached to the knowledge that the species exists and will continue to exist, independent of any use (Norton, 1987; Turner *et al.*, 1994).

Ecosystems and the services they provide have value to human societies because people derive utility from their use, either directly or indirectly (use values). Within this neoclassical framework concept of value, people also give value to ecosystem services that they are not currently using (non-use values). Non-use values, usually known as existence values, involve the case where humans ascribe value to knowing that a resource exists even if they never use that resource directly. These often involve the deeply held historical, national, ethical, religious, and spiritual values people ascribe to ecosystems the values that the MA recognizes as cultural services of ecosystems (Rashid *et al.*, 2005).

The economic approach is not the only way to assign values to natural and environmental resources. A fundamental distinction between the way in which economics and other disciplines such as ecology use the term value is the economic emphasis on human preferences. Thus, the functionality of economic value is between one entity and a set of human preferences. If an ecosystem is degraded so that it supports a lower number of organisms, an ecologist would characterise this degraded area as less valuable for those organisms than a non-degraded area. In economic terms, however, a polluted area has less value than an otherwise equivalent non-polluted area only if some individual members of society prefer non-polluted to polluted areas (Lipton *et al.*, 1995). If no one cares that there are fewer organisms in the polluted area, then there is no difference in economic value. Typically, however, some members of society will display a preference for an environment that is less degraded.

As mentioned earlier, this study aims primarily at the total economic value of *Prosopis* invasion on agro-pastoral households of Dire Dawa Administration. To address such types of issues, the concept of total economic value is widely used by economists (Pearce and Warford, 1993). The TEV typically disaggregates the value of ecosystems into direct and indirect use values and non-use values. Consequently, the premises of neoclassical welfare economics was adopted and used in the present study as a guiding theory and for deducing valuation measurements.

2.2.2. Random Utility Theory (RUT)

For the analysis of individual preference for the improvements of the environmental conditions that caused by Invasive Alien Specie based on random utility theory. The theory postulates that utility derived by individuals from their choice is not directly observable, but is a latent construct that exists in the consumer's mind so that indirect determination of preferences is possible (Manski and Lerman, 1977; Phaneuf *et al.*, 2009). RUT thus, provides a link between the deterministic model and a statistical model (McFadden, 1974).

It further assumes that this latent utility can be partitioned into two components: a systematic or representative utility and a random, unexplainable component. This random component arises both because of the randomness in the individuals' preferences and

because the attributes do not cover all of the individuals' preferences. If we consider random sampling of the respondents, then it can be interpreted as a random term. Because of this random component, the problem is inherently stochastic and an individual's preferences cannot be understood perfectly.

This naturally leads to formulation of expressions for probability of choice. Based on the repeated observations of the choices, one can examine how the levels of various attributes affect the probability of choice. Furthermore, the random utility theory assumes a utility maximization principle, i.e., if an individual chooses one alternative over another, then the utility from the chosen alternative is greater than that from the unselected alternative.

This study therefore utilizes RUT for application of CE and CV in valuation of biodiversity loss, carbon sequestration and other environmental services. The CV and CE share a common theoretical framework: the random utility model (RUM) (Thurstone, 1927; McFadden, 1973).

2.2.3. Attitude theory

A. Theory of Reasoned Action (TRA)

The theory of reasoned action was developed to predict individual volitional behavior. According to TRA, actual behavior is preceded by behavioral intentions. In the causal chain, behavioral intention is a composite of attitudes towards this specific behavior and subjective norms.

Ajzen and Fishbein (1980) suggest that attitudes are viewed as overall evaluations. They define that an attitude toward any concept "is simply a person's general feeling of favorableness or unfavorableness of that concept." In the theory of reasoned action, the concept of interest is implementation of a specific behavior, on which the attitude focuses, in order to be able to predict the behavior. This intention to act is a function of two determinants, "one personal in nature and the other reflecting social influence" (Ajzen and Fishbein, 1980). The attitudinal component is termed attitude toward the behavior or act (i.e., an evaluation of the behavior as favorable or unfavorable) and the normative component is termed subjective norm (i.e., the perceived social pressure to perform or not to perform the behavior). The relative importance of these two determinants in predicting

intention to act is expected to vary with the type of behavior, situation, and based on individual differences (Ajzen and Fishbein, 1973). Variables other than attitude toward the behavior and subjective norm are assumed to influence intention to act and behavior indirectly through these two determinants.

The theory of reasoned action incorporates a feedback mechanism, reflecting the fact that attitudes, beliefs, norms and expectations are influenced by behavioral experiences. Because of this process of dynamic adjustment, predicting behavior under novel conditions or predicting a unique type of behavior is more difficult than predicting customary behaviour (Ajzen and Fishbein, 1980).

B. Theory of Planned Behaviour (TPB)

The theory of planned behavior expands the applicability of theory of reasoned action also to behaviours that cannot be assumed to be dependent only on volitional control (Ajzen and Madden, 1986; Ajzen, 1991). TPB includes a new control factor in explaining behavioral intention, namely perceived behavioral control. This refers to the actor's evaluation of the perceived ease or difficulty of performing the specific action. Perceived behavioral control often reflects past experience and anticipated impediments and obstacles based on second hand information.

The theory of planned behavior is a memory-based model to understand individual evaluations and behavior. It is based on a long research tradition in social psychology focusing on attitudes as predictors of behavior, i.e. on an attitude-behavior framework. An attitude can be defined as a disposition to respond favorably or unfavorably to a commodity or event (Fishbein and Ajzen, 1975). The theory of planned behaviour (Ajzen, 1991) is a well known and widely used approach in social psychology to explain and to predict behaviour (Eagly and Chaiken, 1993; Armitage and Conner, 1999). According to the theory a person's intention to perform a behaviour is the immediate determinant of any behaviour "... including the behaviour paying money for a good ..." (Ajzen *et al.*, 1996). Intentions are assumed to capture the motivational factors that influence a behaviour. They are, as Ajzen (1991) writes, indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour.

According to Ajzen (1996), the intention to perform a behavior is the immediate determinant of the behavior in question including “the behavior of paying money for a good” (Ajzen *et al.*, 1996). The theory proposed three conceptually independent determinants of intention to perform a behavior, or behavioural intention: attitude toward the behavior, subjective norm, and perceived behavioral control. The attitude toward the behavior refers to an individual’s positive or negative evaluation of performing the behavior. An individual’s perception of social pressure from reference group members to enact the behavior is captured by the subjective norm. Perceived behavioral control includes the perceived ease or difficulty of performing the behavior.

Ajzen (1991) states that, as a general rule, the more favourable the attitude and the subjective norm with respect to a behaviour, and the greater the perceived behavioural control, the stronger should be the individual’s intention to perform the behaviour under consideration. Accordingly, the stronger the intention to engage in a behaviour, the more likely should be its performance. However, a condition of accurate prediction is the principle of compatibility, which demands that attitude and behaviour are measured at the same level of generality or specificity. If this is fulfilled the likelihood will increase that the same set of salient beliefs will be activated and strong correlations between attitudes and behaviour will be observable (Ajzen, 1996). The theory of planned behavior is emphasizing on the importance of not only attitudes and norms in influencing intentions, but also the perceived ability or behavioral control over engaging in the intended behavior (Ajzen and Fishbein, 1980; Ajzen, 1991).

With regard to public environmental goods, WTP is expected to increase with a more favorable attitude toward paying for such goods, with increasing social pressure toward paying, and with an increasing perceived behavioural control regarding paying for such goods. The theory of planned behaviour is confirmed in several valuation studies (Pouta and Rekola, 2001). It has been applied, for example, to explain environmentally oriented behavior (Lynne *et al.*, 1995; Moisander, 1996; Taylor and Todd, 1997; Harland and Staats, 1999; Cheung *et al.*, 1999; Trumbo and O’Keefe, 2001) and nature-related leisure behavior (Hrubes *et al.*, 2001; Ajzen and Driver, 1992).

This study, therefore, integrates economic theory (neo-classical welfare theory), Random Utility Theory and attitude theory (theory of planned behaviour) in models predicting impacts of attitudes toward the invasive eradication fees on both willingness to pay these fees and stated payment amounts.

C. Theory of Trying

The Theory of Trying (Bagozzi and Warshaw, 1990) expands on the originally proposed TPB (Ajzen, 1985) and attempts to explain the process of striving (i.e., trying) to perform a behavior or to achieve a goal i.e., a behavior perceived as problematic to its outcome or success (Bagozzi and Warshaw, 1990).

The Theory of Trying differs from the TRA and TPB in three main ways: (a) it measures three attitudes [attitude toward success, failure and the process] rather than a single uni-dimensional attitude and incorporates two self-efficacy judgments as expectations of success and failure to define aspects of goal pursuit; (b) it suggests that attitude toward success and attitude toward failure will influence intention to act to the extent that expectations of success is high and expectations of success failure is low (Lewin *et al.*, 1944) and (c) it proposes that past behavior defined both in terms of frequency and decency has a direct effect on intention to act and behavior i.e., it is not channelled indirectly through the determinants of intention to act and behavior. Past behavior is argued to serve a theoretical purpose i.e., reflecting habit, “one’s customary ways of behaving” (Ouellette and Wood, 1998) or experience, and hence providing information input] (Triandis, 1977, 1980; Bentler and Speckart, 1979) and a methodologic purpose i.e., if the model contains all determinants, past behavior should not improve the prediction of future behavior) (Ajzen, 1991).

Following these arguments, the neo-classical welfare theoretical perspectives, utility theory and the attitude theory underpin analysis related to perceptions and coping strategies of households.

2.3. Methodological Framework

Studying the environment and ecological impact of IAS cannot be captured using only a single method because environment and ecology are borderer concepts. To deal with such

issue, it needs not only one lens but more is needed to provide fuller and comprehensive picture of the research phenomenon. Therefore, this study uses a mixed method approach as its philosophical stance to evaluate the impacts of IAS in the study area.

Mixed methods research is recognised as a mixing of approaches or methods and includes combining qualitative and quantitative viewpoints, data collection, analysis, and/or inference techniques in a single study (Johnson *et al.*, 2007). It is increasingly being recognised as the third major research approach and has become popular in a number of disciplines (Johnson *et al.*, 2007; Leech and Onwuegbuzie, 2009). Teddlie and Tashakkori (2003) give three areas in which mixed methods are superior to single approach designs:

- a. Mixed methods research can answer research questions that other methodologies cannot;
- b. Mixed methods research provides better (stronger) inferences; and
- c. Mixed methods provide the opportunity for presenting a greater diversity of divergent views.

In mixed methods studies, investigators intentionally integrate or combine quantitative and qualitative data rather than keeping them separate. The basic concept is that integration of quantitative and qualitative data maximizes the strengths and minimizes the weaknesses of each type of data. One of the most difficult challenges is how to integrate different forms of data (Creswell and Clark, 2011).

There are several reasons for using mixed methods in this research. According to Clark (2010) researchers may seek to view problems from multiple perspectives to enhance and enrich the meaning of a singular perspective. They also may want to contextualize information, to take a macro picture of the impact of IAS. Other reasons include to merge quantitative and qualitative data to develop a more complete understanding of a problem; to develop a complementary picture; to compare, validate, or triangulate results; to provide illustrations of context for trends; or to examine processes/experiences along with outcomes.

Based on pragmatic research philosophy and in line with the above or even more reasons that stated above, this research is mixed in its methodological perspective. From its very nature, this study is concerned with the total economic valuation *Prosopis* invasion in

rural Dire Dawa. In the total economic valuation approach most aspects of *Prosopis* impacts were assessed using a mixed method approaches. However, not all the impacts are measured in market-based monetary values; most ecosystem services and biodiversity impacts lack market prices. Even in quantitative terms, the research quantifies impacts in market price based and non-market price based monetary values. Further, non-market price values are categorized in to use and non-use values. This pragmatism entails that this study employs mixed or multiple methodological perspective. The perspective is mixed in terms of assessing impacts in both qualitative and quantitative terms in general.

2.3.1. Methodologies of environmental valuation techniques

2.3.1.1. Monetary valuation techniques

Within the monetary valuation framework, values are derived, if available, from information of individual behavior provided by market transactions relating directly to the ecosystem service. In the absence of such information, price information must be derived from parallel market transactions that are associated indirectly with the good to be valued. If both direct and indirect price information on ecosystem services are absent, hypothetical markets may be created in order to elicit values. These situations correspond to a common categorization of the available techniques used to value ecosystem services: (a) direct market valuation approaches, (b) revealed preference approaches and (c) stated preferences approaches (Chee, 2004).

A. Direct market valuation approaches

Direct market valuation approaches are divided into three main approaches (a) market price-based approaches, (b) cost-based approaches, and (c) approaches based on production functions. The main advantage of using these approaches is that they use data from actual markets, and thus reflect actual preferences or costs to individuals. Moreover, such data – i.e. prices, quantities and costs- exist and thus are relatively easy to obtain.

Market price-based approaches are most often used to obtain the value of provisioning services, since the commodities produced by provisioning services are often sold on, e.g., agricultural markets. In well-functioning markets preferences and marginal cost of production are reflected in a market price, which implies that these can be taken as

accurate information on the value of commodities. The price of a commodity times the marginal product of the ecosystem service is an indicator of the value of the service, consequently, market prices can also be good indicators of the value of the ecosystem service that is being studied.

Cost-based approaches are based on estimations of the costs that would be incurred if ecosystem service benefits needed to be recreated through artificial means (Garrod and Willis, 1999). Different techniques exist, including, (a) the avoided cost method, which relates to the costs that would have been incurred in the absence of ecosystem services, (b) replacement cost method, which estimates the costs incurred by replacing ecosystem services with artificial technologies, and (c) mitigation or restoration cost method, which refers to the cost of mitigating the effects caused by to the loss of ecosystem services or the cost of getting those services restored.

Production function-based approaches (PF) estimate how much a given ecosystem service (e.g., regulating service) contributes to the delivery of another service or commodity which is traded on an existing market. In other words, the PF approach is based on the contribution of ecosystem services to the enhancement of income or productivity (Mäler, 1994; Patanayak and Kramer, 2001). The idea thus is that any resulting “improvements in the resource base or environmental quality” as a result of enhanced ecosystem services, “lower costs and prices and increase the quantities of marketed goods, leading to increases in consumers” and perhaps producers” surpluses” (Freeman, 2003). The PF approach generally consists of the following two-step procedure (Barbier, 1994). The first step is to determine the physical effects of changes in a biological resource or ecosystem service on an economic activity. In the second step, the impact of these changes is valued in terms of the corresponding change in marketed output of the traded activity. A distinction should be made then between the gross value of output and the value of the marginal product of the input.

Hence, the PF approach generally uses scientific knowledge on cause-effect relationships between the ecosystem service(s) being valued and the output level of marketed commodities. It relates to objective measurements of biophysical parameters. As Barbier *et al.* (2009) noted, for many habitats where there is sufficient scientific knowledge of

how these links to specific ecological services that support or protect economic activities, it is possible to employ the production function approach to value these services.

Direct market valuation approaches rely primarily on production or cost data, which are generally easier to obtain than the kinds of data needed to establish demand for ecosystem services (Ellis and Fisher, 1987). However, when applied to ecosystem service valuation, these approaches have important limitations. These are mainly due to ecosystem services not having markets or markets being distorted.

The direct problems that arise are two-fold. If markets do not exist either for the ecosystem service itself or for goods and services that are indirectly related, then the data needed for these approaches are not available. In case where markets do exist but are distorted, for instance because of a subsidy scheme (TEEB, 2009) or because the market is not fully competitive, prices will not be a good reflection of preferences and marginal costs. Consequently, the estimated values of ecosystem services will be biased and will not provide reliable information to base policy decisions on.

B. Revealed preference approaches

Revealed preference techniques are based on the observation of individual choices in existing markets that are related to the market goods and services that is subject of valuation. In this case it is said that economic agents “reveal” their preferences through their choices.

In revealed preferences methods, market imperfections and policy failures can distort the estimated monetary value of ecosystem services. Scientists need good quality data on each transaction, large data sets, and complex statistical analysis. As a result, revealed preference approaches are expensive and time-consuming. Generally, these methods have the appeal of relying on actual/observed behavior but their main drawbacks are the inability to estimate non-use values and the dependence of the estimated values on the technical assumptions made on the relationship between the environmental good and the surrogate market good (Kontoleon and Pascual, 2007).

C. Stated preference approaches

Stated preference approaches simulate a market and demand for ecosystem services by means of surveys on hypothetical (policy-induced) changes in the provision of ecosystem services. Stated preference methods can be used to estimate both use and non-use values of ecosystems and/or when no surrogate market exists from which the value of ecosystems can be deduced.

Stated preference techniques are often the only way to estimate non-use values. Concerning the understanding of the objective of choice, it is often asserted that the interview process “assures” understanding of the object of choice, but the hypothetical nature of the market has raised numerous questions regarding the validity of the estimates (Kontoleon and Pascual, 2007). The major question is whether respondents’ hypothetical answers correspond to their behavior if they were faced with costs in real life.

One of the main problems that have been flagged in the literature on stated preference methods is the divergence between willingness-to-pay (WTP) and willingness-to-accept (WTA) (Hanneman, 1991; Diamond, 1996). From a theoretical perspective, WTP and WTA should be similar in perfectly competitive private markets (Willing, 1976, Diamond 1996). However, several studies have demonstrated that for identical ecosystem services, WTA amounts systematically exceed WTP (Vatn and Bromley, 1994). This discrepancy may have several causes: faulty questionnaire design or interviewing technique; strategic behavior by respondents and psychological effects such as “loss aversion” and the “endowment effect” (Garrod and Willis, 1999).

Another important problem is the “embedding”, “part-whole bias” or “insensitivity to scope” problem (Veisten, 2007). Kahneman (1986) was among the first to claim that respondents in a CV survey were insensitive to scope – he observed from a study that people were willing to pay the same amount to prevent the drop in fish populations in one small area of Ontario as in all Ontario.

There is also a controversy on whether non-use values are commensurable in monetary terms (Martínez-Alier *et al.*, 1998; Carson *et al.*, 2001). The problem here is whether, for instance, the religious or bequest value that may be attributed to a forest can be considered within the same framework as the economic value of logging or recreation in that forest.

Such an extreme range of values may not be equally relevant to all policy problems, but the issue has remained largely unresolved for now.

2.3.1.2. Non monetary environmental valuation technique

Multi-criteria Analysis (MCA)

Multi-criteria analysis (MCA) is a technique that facilitates the use of both qualitative and quantitative measurement scales, which makes it possible to address multidisciplinary problems involving consequences on the environment and/or public health issues (Romero and Rehman, 1987). This process includes the participation of many interested parties in decision making and in problem solving, and is focused on compromise or defining a coalition of views rather than dictation of judgment from a single stakeholder category. Its potential stands is greatest in situations involving multiple value systems and objectives, which cannot be easily quantified (e.g. environmental issues) or translated in monetary terms due to their intangible nature (e.g. social, cultural or psychological issues) (Stahl *et al.*, 2002; Wittmer *et al.*, 2006).

An MCA usually begins by identifying all the potential impacts of each decision, and a set of criteria that all stakeholders find important for choosing among alternatives. The potential options are then ranked using methods that range from simple hierarchical systems to more complex algorithms (Zopounidis and Doumpos, 2002). The ranking of alternatives is then used as a template to guide the final decision and to understand the implications of choosing one option over another, rather than identifying a single ‘best’ option (Kiker *et al.*, 2005).

Multidisciplinary stakeholder involvement is an important aspect of understanding alternatives to a problem and identifying the most desirable solutions. To gain a comprehensive picture of the social, economic, and environmental impacts of a decision requires input from individuals with a wide range of views and knowledge, including decision-makers, scientists and engineers, and the general public. Reliance solely on expert opinion or on the perspective of a single stakeholder, when conducting MCA provides solutions that may satisfy only narrow interests or may have undesirable consequences for another group (Kiker *et al.*, 2005). MCA can be used to explain reasons for conflict between stakeholders (Munda, 1995) and to unravel such things as judgements

on genetically modified crops (Stirling and Mayer, 2001). MCA approaches can be compatible with monetary valuation or value transfer as these can be criteria in the decision matrices. Indeed the outcome of good sensitivity analysis under CBA is in effect a type of MCA (Merrifield, 1997).

The use of open MCA which address conflicts has led to such methods being combined with participatory approaches. Stakeholder or vested interest groups can be brought together in different formats and results analysed to understand why conflicts arise and to aid consensus seeking. Methods such as mediated modelling, scenario analysis, and social-multi-criteria evaluation have been used in this way (Kallis *et al.*, 2006).

A weaknesses of this method is that the weighing of values can be easily biased by the scientists, or if the process is participatory, by power asymmetries among stakeholders. Transparent deliberative processes can reduce such risks, but also involve large amount of time and resources that are not generally available to decision makers (Gómez-Baggethun and de Groot, 2007).

MCA has many advantages which are: it is open and explicit; the choice of objectives and criteria that any decision making group may make are open to analysis and to change if they are felt to be inappropriate; scores and weights, when used, are also explicit and are developed according to established techniques. They can also be cross-referenced to other sources of information on relative values, and amended if necessary; performance measurement can be sub-contracted to experts, so need not necessarily be left in the hands of the decision making body itself; it can provide an important means of communication, within the decision making body and sometimes, later, between that body and the wider community; and scores and weights are used, it provides an audit trail (Kallis *et al.*, 2006). Following these arguments, the present study used stated and revealed preference approaches for total economic valuation of *Prosopis* invasion because impacts of *Prosopis* are both tangible and intangible.

2.3.2. Impact evaluation methods

Impact evaluation of a given intervention program is intended to determine more broadly whether the program had the desired effects on individuals, households, and institutions and whether those effects are attributable to the program intervention. Impact evaluations

can also explore unintended consequences, whether positive or negative, on beneficiaries (Baker, 1960).

To know the effect of a program on a participating individual, one must compare the observed outcome with the outcome that would have resulted had that individual not participated in the program. However, as stated earlier two outcomes cannot be observed for the same individual. In other words, only the factual outcome can be observed. Thus, the fundamental problem in any social program evaluation is the missing data problem (Bryson *et al.*, 2002; Ravallion, 2005).

Estimating the impact of a program requires separating its effect from intervening factors which may be correlated with the outcomes, but not caused by the program. This task of “netting out” the effect of the program from other factors is facilitated if control groups are introduced. “Control groups” consist of a comparator group of individuals or households who did not receive the intervention, but have similar characteristics as those receiving the intervention, called the “treatment groups”. Identifying these groups correctly is a key to identifying what would have occurred in the absence of the intervention (Ezemenari *et al.*, 1999). In theory, evaluators could follow three main methods in establishing control and treatment groups: randomization/pure experimental design; non-experimental design and quasi-experimental design. In practice, in the social sciences, the choice of a particular approach depends, among other things, on data availability, cost, and ethics to experiment. In what follows, are brief descriptions of the main impact on evaluation methods mentioned above.

2.3.2.1. Experimental method

Social experiments are motivated by policy issues about how subjects would react to a type of policy that has never been tried and hence one for which no observed response data exist. The idea of a social experiment is to enlist a group of willing participants, some of whom are randomly assigned to a treatment group and the rest to a control group. The difference between the responses of those in the treatment group, subjected to the policy change, and those in the control group, who are not, is the estimated effect of the policy. The term “experimental” refers to the group receiving treatments, “controls” to the group

not receiving treatment, and “random assignment” to the process of assigning individuals to the two groups (Colin and Pravin, 2005).

Burtless (1995) pointed out the advantages of social experiments with great clarity. The key advantage stems from randomized trials that remove any correlation between the observed and unobserved characteristics of program participants. Hence, the contribution of the treatment to the outcome difference between the treated and control groups can be estimated without confounding bias even if one cannot control for the confounding variables. The presence of correlation between treatment and confounding variables often plagues observational studies and complicates causal inference. By contrast, an experimental study conducted under ideal circumstances can produce a consistent estimate of the average difference in outcomes of the treated and non treated groups without much computational complexity. If, however, an outcome depends on treatment as well as other observable factors, then controlling for the latter will in general improve the precision of the impact estimate.

According to Ezemenari *et al.* (1999), a random assignment of individuals to treatment and non-treatment groups ensures that on average any difference in outcomes of the two groups after the intervention can be attributed to the intervention. The main advantage of a randomized experiment is its ability to avoid problem of selection bias, which arises when participation in the program by individuals is related to their unobservable or unmeasured characteristics (like motivation and confidence), which in turn determine the program outcome. Obviously, randomization must take place before the program begins.

2.3.2.2. Non-experimental method

A non-experimental approach is used in cases where program placement is intentionally located. For programs that are often setup intentionally, it is common to only have access to a cross-sectional survey done after the program is introduced (Jalan and Ravallion, 2003). According to Bryson *et al.* (2002), there are two broad categories of non-experimental approach; before and after estimator and cross-sectional estimator. The essential idea of the before and after estimator of an impact evaluation approach is to compare the outcome of interest variable for a group of individuals after participating in a program with outcome of the same variable for the same group or a broadly equivalent

group before participating in the program and to view the difference between the two outcomes as the estimate of average treatment effect on the treated. Cross-section estimators use non-participants to derive the counterfactual for participants in which case it becomes quasi-experimental method. Well-designed non-experimental studies make good use of measured confounders by creating treatment groups that look as similar as possible on the measured characteristics.

2.3.2.3. Quasi-experimental method

Quasi-experimental design involves matching program participants with a comparable group of individuals who did not participate in the program. This simulates randomization but need not take place prior to the intervention (Kerr *et al.*, 2000). A quasi-experimental method is the only alternative when neither a baseline survey nor randomizations are feasible options (Jalan and Ravallion, 2003).

Quasi-experimental method consists of constructed (matched) control where individuals to whom the intervention is applied are matched with an “equivalent” group from whom the intervention is withheld (Ezemenari *et al.*, 1999). The study used this method as there is no base line data and as the program placement is not random.

The main benefit of quasi experimental designs are that they can draw on existing data sources and are thus often quicker and cheaper to implement, and they can be performed after a project has been implemented, given sufficient existing data.

The principal disadvantages of quasi experimental techniques are that (a) the reliability of the results is often reduced as the methodology is less robust statistically; (b) the methods can be statistically complex and data demanding; and (c) there is a problem of selection bias. This study employed the quasi experimental method as there is no a base line data and based on the firm conviction that the invasion of *Prosopis* is not random.

The central methodological challenge in non-experimental evaluation method is that examining outcome response of an intervention involves distilling the effect of intervention per se from that of the factors that affect individuals (Foster, 2003). The present study used the quasi-experimental methods of impact evaluation after critically weighing the strengths and weakness of alternative methods.

2.4. Analytical Framework

According to Hopkins *et al.* (1996) and Pallent (2001), each and every analytical method has its advantage and limitation. Hence, it is advisable to select the one that can better suit to the specific purpose. Accordingly, appropriate analytical tools used to answer the research question and address the study objectives are reviewed and presented under differing sub-sections. They are:

2.4.1. Valuation techniques of ecosystem services

The valuation approaches for valuing ecosystem services are discussed here as follows:

Market prices: The simplest, most straightforward and commonly-used method for valuing any good or service is to look at its market price: how much it costs to buy, or what it is worth to sell. In a well-operating and competitive market these prices are determined by the relative demand for and supply of the goods or services in question, reflect their true scarcity, and equate to their marginal value.

In theory, market price techniques are applicable to any ecosystem good or service that can be freely bought or sold. They are particularly useful for valuing the resources and products that are harvested directly from ecosystems. Examples of their application to invasive species include looking at direct onsite impacts on marketed goods. The values of direct costs and benefits will be estimated in Ethiopia Birr for products harvested for direct use (both subsistence and trade) as well as for direct losses associated with the *Prosopis* invasion. Benefits will also be estimated from individuals' responses to questions regarding the quantities of various products harvested from *Prosopis* and whether those products will be used domestically, sold or both. Quantities harvested, whether for sale or home use, will also be used to estimate total value derived from those products.

Market prices were used to value the goods yielded by mangrove ecosystems in the Indus River Delta, Pakistan. Fuel wood and fodder use rates by adjacent villagers were quantified, and values were ascribed according to prevailing commodity prices in local markets (Hecht, 1999).

The greatest advantage of this technique is that it is relatively easy to use, as it relies on observing actual market behaviour. Few assumptions, little detailed modelling, and only simple statistical analysis are required to apply it. A major constraint is that market prices cannot, in many cases, be taken as accurate indicators of the value of ecosystem goods and services – in which case an alternative valuation method must be used.

Production function approaches

These approaches, including effect on production, attempt to relate changes in the output of a marketed good or service to a measurable change in the quality or quantity of ecosystem goods and services by establishing a biophysical or dose response relationship between ecosystem quality, the provision of particular services, and related production.

Products often rely on them as basic inputs. For example, downstream hydropower and irrigation depend on upper catchment protection services, fisheries on upstream nursery and breeding habitat, crop production on insect pollination services, and many sources of industrial production utilise natural products as raw materials. In these cases it is possible to assess the value of ecosystem goods and services by looking at their contribution to other sources of production, and to assess the effects of a change in the quality or quantity of ecosystem goods and services on these broader outputs and profits.

Effect on production techniques can thus be used to value ecosystem goods and services that clearly form a part of other, marketed, sources of production – for example watershed protection and water quality services, or natural resources that are used as raw materials. Examples of their application to invasive species include looking at the changes in output that occur when invasive species impact on the provision of particular goods and services which are required for offsite or downstream production.

Effect on production techniques are commonly used, and have applicability to a wide range of ecosystem goods and services. Their weakness relates to the difficulties that are often involved in collecting sufficient data to be able to accurately predict the biophysical or dose-response relationships upon which the technique is based. Such relationships are often unclear, unproven, or hard to demonstrate in quantified terms. Simplifying assumptions are often needed to apply the production function approach.

An additional concern is the large number of possible influences on product markets and prices. For example, in some cases changes in the provision of an ecosystem good or service may lead not just to a change in related production, but also to a change in the price of its inputs or outputs. That product may become scarcer, or more costly to produce. In other cases consumers and producers may switch to other products or technologies in response to ecosystem change or to a scarcity of ecosystem goods and services. Furthermore, general trends and exogenous factors unrelated to ecosystem goods and services may influence the market price of related production and consumption items. They must be isolated and eliminated from analysis. Following Barbier (1998) the potential drawbacks for PFA may be summarised as follows.

Firstly, as already mentioned, the price of the output can be heavily distorted, i.e. it may fail to provide a reliable proxy of the output's 'true' economic value. Besides market failures, prices may be distorted by fiscal policies (taxation or subsidisation). Moreover, public regulatory policies (or the absence of appropriate regulations) may influence the values imputed to the environmental input (ENV) (Barbier, 1998).

Secondly, applications of the PFA may be most straightforward in the case of a natural resource (services) supporting only one economic activity (*single-use resources*) than in the case of *multiple-use resources*.

In fact, when a natural resource supports many different economic activities, "applications of the production function approach may be slightly problematic and assumptions concerning the ecological relationships among these various multiple uses must be carefully constructed to avoid problems of double counting and tradeoffs between the different values" (Barbier, 1998). Finally, "for some valuation problems, choosing whether to incorporate inter-temporal aspects of environment can be very important" (Barbier, 1998).

Surrogate market approaches

These approaches, including travel costs and hedonic pricing, look at the ways in which the value of ecosystem goods and services are reflected indirectly in people's expenditures, or in the prices of other market goods and services.

Travel cost techniques: Ecosystems often hold a high value as recreational resources or leisure destinations. Even when there is no direct charge made to enjoy these benefits, people still spend time and money to visit ecosystems.

TCM is predominantly used in out-door recreation modelling, with fishing, hunting, boating, and forest visit among the most popular applications. The TCM seeks to place a value on non-market environmental goods by using consumption behavior in related markets. Specifically, the costs of consuming the services of the environmental asset are used as a proxy for price. These consumption costs will include travel costs, entry fees, on-site expenditures and outlay on capital equipment necessary for consumption (Hanley and Spash, 1993; Bateman and Turner, 1993).

Travel cost techniques are thus most commonly applied to ecosystems that have a recreational value. TCM application to invasive species include looking at the changes in tourism and recreational earnings which occur when invasive species make a site less or more attractive to visitors. The travel cost method is mainly limited to calculating recreational values, although it has in some cases been applied to the consumptive use of ecosystem goods.

Its main weakness is its dependence on large and detailed data sets, and relatively complex analytical techniques. Travel cost surveys are typically expensive and time consuming to carry out. An additional source of confusion is that several factors make it difficult to isolate the value of a particular ecosystem in relation to travel costs, and these must be taken into account in order to avoid over-estimating ecosystem values. Visitors frequently have several motives or destinations on a single trip, some of which are unrelated to the ecosystem being studied. They also usually enjoy multiple aspects and attributes of a single ecosystem. In some cases travel, not the destination *per se*, may be an end in itself (Dixon *et al.*, 1986; Hufschmidt *et al.*, 1983; Winpenny, 1991).

Hedonic pricing techniques: Hedonic price valuation technique tries to measure the value of an unmarketed environmental service as a measurable component ('attribute' or 'characteristic') of a marketed good (Anderson, 1993).

Even if they do not have a market price themselves, the presence, absence or quality of ecosystem goods and services influences the price that people pay for, or accept for

providing, other goods and services. Hedonic pricing techniques look at the difference in prices that can be ascribed to the existence or level of ecosystem goods and services.

Hedonic pricing techniques are most commonly used to examine differences in property prices and wage rates between two locations which have different environmental qualities or landscape values; the former has the most obvious application to invasive. Examples of their application to invasive species include looking at the changes in property prices which might occur due to changes in the landscape wrought by invasive. Hedonic pricing seeks to find a relationship between the levels of environmental services (such as noise levels or total suspended particular levels), and the prices of the marketed goods (usually houses) (Hanley and Spash, 1993).

Although hedonic pricing techniques can, in theory, be applied to any good or service they are most commonly used within the context of wage and property markets. In practice, the application of hedonic pricing techniques to ecosystem goods and services remain very few. One reason for this, and a weakness in this technique, is the very large data sets and detailed information that must be collected, covering all of the principal features affecting prices. It is often difficult to isolate specific ecosystem effects from other determinants of wages and property prices.

Another potential problem arises from the fact that this technique relies on the underlying assumption that wages and property prices are sensitive to the quality and supply of ecosystem goods and services. In many cases (and especially in developing countries) markets for property and employment are not perfectly competitive, and ecosystem quality is not a defining characteristic of where people buy property or engage in employment (Dixon *et al.*, 1986; Hufschmidt *et al.*, 1983; Winpenny, 1991).

Problems associated with the HP method generally include omitted variable bias, multi-collinearity, choice of functional form, market segmentation, expected versus actual characteristic levels and restrictive assumptions.

Cost-based approaches

These approaches, including replacement costs, mitigative or avertive expenditures and damage costs avoided, look at the market trade-offs or costs avoided of maintaining ecosystems for their goods and services.

Replacement cost technique: It is sometimes possible to replace or replicate a particular ecosystem good or service with alternative products or infrastructure. For example, constructed reservoirs can replace natural lakes, sewage treatment plants can replace wetland wastewater treatment services, and many natural products have artificial alternatives. The cost of replacing an ecosystem good or service with such an alternative or substitute can be taken as an indicator of its value in terms of expenditures saved.

Replacement cost techniques can be used to value ecosystem goods and services that have the potential be at least partially substituted by other products or by technologies. Examples of their application to invasive species include looking at the changes in output that occur when invasive species impact on the provision of particular goods and services which can be replaced by alternative sources.

Replacement cost techniques are particularly useful for valuing ecosystem services, and have the great advantage that they are simple to apply and analyse. They are particularly useful where only limited time or financial resources are available for a valuation study, or where it is not possible to carry out detailed surveys and fieldwork.

The main weakness of this technique is that it is often difficult either to identify all the goods and services provided by an ecosystem or find perfect replacements or substitutes for ecosystem goods and services that would provide an equivalent level of benefits to the same population. In some cases this results in ecosystem under-valuation, as artificial alternatives generate a lower quantity or quality of goods and services. Yet this technique may also lead to the over-valuation of ecosystem benefits, as in some instances the replacement product, infrastructure or technology may be associated with secondary benefits or additional positive impacts. The reality of the replacement cost technique is also sometimes questionable: we may question whether, in the absence of a well-functioning ecosystem, such expenditures would actually be made or considered worthwhile (Dixon *et al.*, 1986; Hufschmidt *et al.*, 1983; Winpenny, 1991).

Mitigative and avertive expenditure techniques: When an economically valuable ecosystem good or service is lost, or there is a decline in its quantity or quality, this almost always has a negative effect. It may become necessary to take steps to mitigate or avert these negative effects so as to avoid economic losses. Coastal marshes and mangroves are important in shoreline stabilisation, erosion control, flood and storm protection on Mahé Island in the Seychelles. The value associated with these functions was calculated by applying a preventive expenditure approach. In the absence of wetlands services it would be necessary to construct groynes and flood barriers to offset or mitigate coastal erosion and damage to infrastructure, the cost of which was used as a proxy for the value of coastal marsh and mangrove services (Emerton, 1997). Under these techniques, the mitigative or avertive expenditures can be taken as indicators of the value of maintaining ecosystem goods and services in terms of costs avoided.

Mitigative and avertive expenditure techniques can thus be used in cases where the effects of the loss of ecosystem goods and services can be clearly offset, averted or mitigated by undertaking particular investments or market actions. Examples of their application to invasive species include looking at the cost of responding to or remediating the ecosystem damage or change that has been caused by invasives.

Mitigative or avertive expenditure techniques are particularly useful for valuing ecosystem services. In common with other cost-based valuation methods, a major strength is their ease of implementation and analysis, and their relatively small data requirements.

As is the case with the replacement cost technique, the mitigative or avertive measures that are employed in response to the loss of ecosystem goods and services do not always provide an equivalent level of benefits. In some cases it is also questionable whether in fact such expenditures would be made or would be seen as being worth making. An additional important factor to bear in mind when applying this technique is that people's perceptions of what would be the effects of ecosystem loss, and what would be required to mitigate or avert these effects, may not always match those of "expert" opinion (Dixon *et al.*, 1986; Hufschmidt *et al.*, 1983; Winpenny, 1991).

Damage cost techniques: Ecosystem services frequently protect other economically valuable assets. The damage costs can be taken to represent the economic value of

ecosystems in terms of expenditures avoided. The Anolis lizard is important in pest control for export crops in the Antilles because it feeds on insects. The market price of agricultural output lost to pests in the absence of services provided by the Anolis lizard was calculated in order to assess its value in terms of damage costs avoided (Narain and Fisher, 1994).

Damage cost techniques can thus be used in cases where the effects of the loss of ecosystem goods and services incur clear economic damages. Application the techniques to invasive species include looking at the cost caused to infrastructure and production when invasive interfere with the goods and services provided by a particular ecosystem,

Damage cost techniques are particularly useful for valuing ecosystem services. There is often confusion between the application of damage costs avoided and production function approaches to valuation. Here it is important to underline that whereas this technique deals with damage avoided such as from pollution and natural hazards (which are typically external effects), change in production techniques usually relate to changes in some input such as water (typically internalised).

A potential weakness is that in most cases estimates of damages avoided remain hypothetical. They are based on predicting what might occur under a situation where ecosystem services decline or are lost. Even when valuation is based on real data from situations where such events and damages have occurred, it is often difficult to relate these damages to changes in ecosystem status, or to be sure that identical impacts would occur if particular ecosystem services declined (Dixon *et al.*, 1986; Hufschmidt *et al.*, 1983; Winpenny, 1991).

Stated preference approaches

Rather than looking at the way in which people reveal their preferences for ecosystem goods and services through market production and consumption, these approaches ask consumers to state their preference directly. The most well-known technique is contingent valuation, while less commonly-used stated preference valuation methods include conjoint analysis and choice experiments.

Conjoint analysis and choice experiments: Other stated preference valuation methods include conjoint analysis and choice experiments. Due to their complexity in terms of data needs and analysis, there exist very few studies on the application to ecosystem services. This CE method was utilized for this study.

Conjoint analysis was originally developed in the fields of marketing and psychology, in order to measure individuals' preferences for different characteristics or attributes of a multi-choice attribute problem. In contrast to contingent valuation, conjoint analysis does not explicitly require individuals to state their willingness to pay for environmental quality. Rather, conjoint asks individuals to consider status quo and alternative states of the world. It describes a specific hypothetical scenario and various environmental goods and services between which they have to make a choice. The method elicits information from the respondent on preferences between various alternatives of environmental goods and services, at different price or cost to the individual (Haab and McConnell, 2003; Louviere *et al.*, 2000).

Choice experiment techniques present a series of alternative resource or ecosystem use options, each of which are defined by various attributes including price. Choice of the preferred option from each set of options indicates the value placed on ecosystem attributes. As is the case for contingent valuation, data collection and analysis for choice experiments is relatively complex. Usually conducted by means of questionnaires and interviews, choice experiments ask respondents to evaluate a series of "sets", each containing different bundles of ecosystem goods and services. Usually, each alternative is defined by a number of attributes. For example, for a specific ecosystem this might include attributes such as species mix, ecosystem status, landscape, size of area, price or cost. These attributes are varied across the different alternatives, and respondents are asked to choose their most preferred alternative. Aggregate choice frequencies are modelled to infer the relative impact of each attribute on choice, and the marginal value of each attribute for a given option is calculated using statistical methods (Haab and McConnell, 2003; Louviere *et al.*, 2000). Choice experiments techniques are often used in combination with other valuation methods, in order to supplement or cross-check their results. This study used CE in valuation of biodiversity and ecosystem services damages induce by *Prosopis* invasion in the study areas.

Contingent valuation (CV) techniques: There are cases in which it is not possible to derive value measures from observing individual choices through a market. Freeman (1993) calls the methods developed to measure environmental values in such cases ‘hypothetical methods’.

Contingent valuation techniques infer the value that people place on ecosystem goods and services by asking them directly what is their willingness to pay (WTP) for them or their willingness to accept compensation (WTA) for their loss, under the hypothetical situation that they could be available for purchase.

CV circumvents the absence of markets for public goods by presenting consumers with hypothetical markets in which they have the opportunity to buy the good in question. Because the elicited willingness to pay (WTP) values are contingent upon the particular hypothetical market described to the respondent, this approach came to be called the contingent valuation method (Mitchell and Carson, 1989). Writing in 1992, Navrud notes, after more than 30 years of CV research the method has passed the experimental prototype stage, but has still not reached the routine application stage. There are no general guidelines for constructing reliable CV studies, although Mitchell and Carson (1989) provide some check points for evaluating CV survey. However, they emphasize that the presence of criteria for a good CV study may create overconfidence in those studies that meet those. Field application should, therefore, always be combined with methodological tests.

Since the CV method at first sight seems very easy to use, it is vulnerable to misuse, which can easily undermine confidence in the method. The construction and framing of a CV survey should therefore be carefully examined before the results from it are used for policy purpose. It has many critics concerning inconsistency with rational choice, implausibility of responses, absence of a meaningful budget constraint, and information provision and acceptance extent of the market (Arrow *et al.*, 1993). CV application to invasive species includes looking at the non-market values that people place on ecosystems that run the risk of invasion and assessing people’s perceptions of option values for particular sites, species or products).

The CV has great flexibility, allowing valuation of a wider variety of non-market goods and services than is possible with any of the indirect techniques (travel cost, hedonic pricing). Lipton *et al.* (1995) say that it is, in fact, the only method currently available for estimating non-use values, in other words it is the only method that has any hope of measuring ‘existence values’, the value that individuals place on simply knowing the natural resource exists in an improved state. For natural resources, contingent valuation studies generally derive values through the elicitation of respondents’ WTP to prevent damage to, or to restore, natural resources.

In CVs, random or stratified samples of individuals selected from the general population are given information about a particular problem, and are presented with a hypothetical occurrence such as a disaster and a policy action that ensures against this disaster. They are then asked how much they would be willing to pay, for instance in extra utility taxes, income taxes, or access fees either to avoid a negative occurrence or bring about a positive one. The actual format may take the form of a direct question (‘how much’), or it may be a bidding procedure (a ranking of alternatives) or a referendum (yes/no) votes. Economists generally prefer the referendum method of obtaining values, since it is one most people are familiar with. The resulting data are then analysed statistically and extrapolated to the population that the sample represents. These studies will be conducted as face-to-face interviews, telephone interviews. The face-to-face is the most expensive survey administration format, but it is considered the best, especially if visual material needs to be presented. Non-response bias is always a concern in all sampling frames, because on average people who do not respond have different values to people who do respond (Lipton *et al.*, 1995).

One of the biggest disadvantages of contingent valuation is the large and costly surveys, complex data sets, and sophisticated statistical analysis and modelling techniques that it requires. Another constraint arises from the fact that they rely on a hypothetical scenario which may not reflect reality or be convincing to respondents (Carson and Mitchell, 1989).

A major strength of contingent valuation techniques is that, because they do not rely on actual markets or observed behaviour, they can in theory be applied to any situation, good

or service. They remain one of the only methods that can be applied to option and existence values, and are widely used to determine the value of ecosystem services. Contingent valuation techniques are often used in combination with other valuation methods, in order to supplement or cross-check their results. Therefore, CV and CE were chosen and used in the present study.

2.4.2. Economic benefits and costs distribution

A. Income distribution

Several different inequality measures have been proposed in the literature. These measures include Theils entropy index T , Theil's second measure L , the coefficient of variation, and the Gini coefficient (Chakravarty, 2001). Which one of these measures should be chosen for decomposition depends on five basic properties. According to Foster (1985), cited in Adams (1996), the chosen measure should have: (1) Pigou-Dalton transfer sensitivity, (2) symmetry, (3) mean independence, (4) population homogeneity, and (5) decomposability.

The two Theil measures, however, are not decomposable when sources of income are overlapping and not disjoint, while the need for non-overlapping groups is not restrictive when inequality is decomposed over different sources (Adams, 1996; Xu, 2004). This restriction rules out using the two Theil measures in this study because many of the survey households receive income from several different sources.

The Gini coefficient is a measure of statistical dispersion most prominently used as a measure of inequality of wealth or product distribution. It is defined as a ratio with values between 0 and 1. A low Gini coefficient indicates more equal incomes, wealth or product distribution, while a high Gini coefficient indicates more unequal distribution. 0 (zero) corresponds to perfect equality and 1 (one) corresponds to perfect inequality. The use of Gini coefficient is most widespread in literature of the income disparity research. Its advantages are: a. it can use a number very conveniently to reflect the overall income differential condition. b. Since there are lots of methods to calculate Gini coefficient, it is easy to use various data. c. Since the Gini coefficient is an international popular index to measure the income disparity that it is easy to make international comparison. d. The Gini coefficient is also convenient for decomposition analysis (Liu, 2003). Gini coefficient has been used in this study to undertake decomposition analysis.

2.4.3. Analysis of the determinants of households' WTP for control and eradication measures

In this study, the dependent variable is dichotomous which is expressed as 0 and 1. According to Wooldridge (2000), in situations when the dependent variable is a discrete dummy variable, the linear estimation is inappropriate for at least three reasons. First, the error term cannot be normally distributed since it takes only two values. Second, the error is heteroscedastic because it can be shown that the variance of the error term is not constant. Third, the estimated probabilities generated via a linear estimation would not necessarily lie between zero and one. The probability value greater than one or less than zero are not acceptable. For example, households' decision to pay for control/eradication of invasive cannot be predicted with over one hundred percent certainty.

According to Gujarati (2005), there are three approaches in developing a probability model for a binary response variable. These are the linear probability model (LPM), the Probit model and the Logit model. The choice between these models depends on the suitability to fit the data. However the LPM has its own limitation. First the heteroscedasticity of the error term (the variance of the error term is not constant). Second, the possibility of getting the probability function result out of 0 and 1, and most importantly the general lower R^2 value is a questionable measure of goodness of fit. Due to these problems the LPM is not an attractive model for dummy response variable.

The Probit and Logit models are commonly used models. The Probit probability model is associated with the cumulative normal probability function. Whereas, the logit model assumes cumulative logistic probability distribution. The advantage of these models over the linear probability model is that the probabilities are bounded between 0 and 1. Moreover, they best fit to the non-linear relationship between the probabilities and the independent variables; that is one which approaches zero at slower and slower rates as an independent variable (X_i) gets smaller and approaches one at slower and slower rates as X_i gets large (Train, 1986).

Usually a choice has to be made between logit and probit models, but the statistical similarities between the two models make such a choice difficult. Gujarati (1988) illustrated that the logistic and probit formulation are quite comparable. It does not matter

much which function is used except in the cases of where the data are concentrated in the tails following points. For this study the logit model is selected for both PSM and choice experiment, and probit model for CV, though both Logit and Probit models may give the same result.

2.4.4. Designing the choice experiment

Discussions were held with experts in the effects of *Prosopis* invasion on ecosystem services and non-market valuation methods in order to identify the most significant attributes and their levels, and to characterize the status quo in terms of our chosen attributes. With the same aim, a focus group was organized allowing informal discussions with community. See Appendix Table 12 for the chosen attributes and levels.

In the CE questionnaire, respondents were asked to choose among three alternatives in each choice set: a status quo scenario where all attribute levels were lower but combined with zero cost and zero labour contribution, and two improvement scenarios where the levels of the 6 attributes varied randomly. Experimental design techniques (Louviere *et al.*, 2000) and SAS experimental and choice design software were used and 24 choice sets were therefore selected using the principle of orthogonal design along with the index of D-efficiency. Subsequently, these choice sets were randomly divided into three blocks, and each respondent was presented with one of the three blocks of eight choices sets.

2.4.5. Perceptions and coping strategies

Perceptions and coping strategies about invasion of *Prosopis* was analyzed using descriptive statistics such as percentage, mean etc.

2.4.6. Impact Evaluation

Double difference or difference-in-differences (DID) methods: This method enables evaluators to compare invaded and non-invaded households before and after the invasion of *Prosopis* by identifying potential participants and collecting data from them. However, only a random sub-sample of these individuals is actually allowed to participate in a certain project. The identified participants who do not actually participate in the project form the counterfactual. This method can reduce the potential selection bias and the impact of other factors exogenous to the invasion on observable characteristics by

analyzing the difference in outcome of invaded households relative to the difference in outcome of non-invaded households. It looks at the difference in indicators for the two groups at the end of the invasion relative to the difference in indicators at the beginning (Jalan and Ravallion, 1999; Baker, 2000). When there are differences between invaded and non-invaded households at the baseline, DID estimator with conditioning variables has the advantage of minimising the standard errors as long as the effects are unrelated to the treatment and are constant over time (Wooldridge, 2002).

Often, we refer to this double difference or this simple comparison-in-means as the difference-in-difference (DID) estimator. The strength of the panel-based-DID estimator comes from its intuitive appeal and simplicity. It can derive an estimate of the impact by comparing the invaded and non-invaded households using the post treatment data (second difference), after we use the pre-treatment data to equate invaded and non-invaded households (first difference). In addition to this, DID estimates are known to be less subject to selection bias because they remove the effect of any unobserved time invariant differences between the invaded and non-invaded households.

However, there are at least two disadvantages that relate to the very simplicity of such a panel based impact assessment. First, constructing panel data sets can be expensive, time consuming, and logistically challenging particularly because we need to collect baseline and follow-up data that straddle the implementation of the intervention. Second, the design assumes that the potential selection bias (i.e., due to administrative targeting or volunteering) is linear and time invariant such that it can be subtracted off in the first differencing (Jalan and Ravallion, 1999).

However, these assumptions might be violated if the time period between two panel data sets is long enough so that the unobservable variables of subjects are altered. In addition, the unobservable variables can be changed as a result the estimate to be biased.

Reflexive comparisons: This is one of the quasi-experimental methods in which a baseline survey of invaded households is conducted prior to the intervention and a follow-up survey is done subsequently to measure the impact through the change in impact indicators before and after the intervention (Baker, 2000). Here, the invaded households are compared to themselves before and after the intervention and serves as both treatment

and comparison group. This method is useful in analyzing of full-coverage interventions such as nationwide policies and programs in which the entire population participates and there is no scope for a control group. However, care should be taken in applying this method as it may not be able to distinguish between the program and other external effects and hence compromising the reliability of results.

Propensity Score Matching: Among quasi-experimental design techniques, matched comparison techniques are generally considered a second-best alternative to experimental design (Baker, 2000).

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 neighbouring 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 *Prosopis* invasion impact provided that (1) a comparable group of agro-pastoral 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.*, 1998). The treatment sample was designed to include an appropriate control group. The control sample is drawn exclusively from the Dire-Dawa Administration who are not invaded by *Prosopis*. Also, the survey includes a large set of variables affecting household welfare and invasion.

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.* (1998) 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 will be presented based on specifications that pass the balancing tests. Related to the balancing property of p-score is the conditional independence assumption (CIA), which states that, the existence of *Prosopis* is random and uncorrelated with household income, once the set of observable characteristics, X , are controlled for. Sensitivity analysis will also undertake to check if the influence of unobserved variables on the selection process is so strong to undermine the matching procedure.

The advantage of propensity models is that they do not necessarily require a baseline or panel survey (especially for the outcome variables), although the observed covariates entering the logit model for the propensity score would have to satisfy the conditional mean independence assumption by reflecting observed characteristics that are not affected by participation. The drawback of propensity methods is that they rely on the degree to which observed characteristics drive from the invasion of the alien species, and do not control for unobservable variables that could lead to bias in the estimates. Thus it is important to test the sensitivity of results with respect to such bias and small changes to the matched or weighted samples. With PSM, it is recommended to adopt the Rosenbaum

(2002) bounds test, which suggests how strongly an unmeasured variable must influence the selection process to undermine implications of matching analysis. In all cases, if the results are sensitive and there are doubts about the CIA, alternative identifying assumptions should be considered.

Like other methods, the PSM also has its own limitations. First, PSM is non-parametric. Hence, any functional form assumptions regarding the average differences in the outcome are not made. Second, PSM method cannot address the bias created by unobservable characteristics that might affect the outcomes (Ravallion, 2005). Third, PSM requires large amounts of data to maximize efficiency (Bernard *et al.*, 2010). Finally, one cannot be entirely sure that he/she has actually included all relevant covariates in the first stage of the matching model and effectively satisfied the conditional independence assumption. Despite these limitations, PSM is the best method to impact evaluators with time constraint and working in the absence of baseline data in that it can be applied with a single cross-section of data. Therefore, PSM impact is employed in the present study to evaluate methods to observe the impact of *Prosopis* invasion on the livelihoods of rural households in the study area.

2.5. Review of Empirical Literature

2.5.1. Valuation studies

After the concept of TEV was introduced in the early 1980s by economists, researchers started to use the TEV concept more frequently. Costanza *et al.* (1997) published in Nature a much debated article on economic valuation of ecosystem services for the whole Earth, which was based on data and information from a broad spectrum of studies by researchers around the world. In the 21st century it has become even more common to conduct TEV exercises in relation to natural resource valuation and management. TEVs have, for instance, been completed for the Leuser National Park in Sumatra (van Beukering *et al.*, 2003), the whole forest sector in Uganda (Bush *et al.*, 2012) and for valuation of forest resources in the whole of the Mediterranean region including 18 countries within the MEDFOREX project framework (Croitoru, 2007). Recently a wetland valuation manual with case studies with an important role for TEVs was published by the Ramsar Convention Secretariat (de Groot *et al.*, 2006).

The TEV analysis approach has also been used in valuation of alien invasive species, for instance, in a study on black wattle in South Africa (de Wit *et al.*, 2001). According to Pimentel *et al.* (2002), the total loss to the world economy as a result of invasive non-native species has been estimated at 5% of annual production. Studies on the economic impact of IAS in a number of countries also demonstrated that in general only direct, market costs are included in studies that estimate the economic impact of IAS due to the lack of the necessary data, despite the extensive literature about the key species (Colautti *et al.*, 2006).

A TEV study in Sudan shows that the arid and semi-arid sandy areas of Sudan bordering the Sahara desert are cases for favouring the *Prosopis* tree. The beneficial impacts of *Prosopis* as a shelterbelt species are in fact completely outweighing the detrimental impacts once the issue is analyzed holistically. This indicates that *Prosopis* is by far the best-performing tree species in desertification mitigation and control (Jörn Laxén, 2007).

Ilukor *et al.* (2014) also applied *TEV* approach to estimate the benefits and costs of *Prosopis* invasion in Afar regional state. The conclusion that they arrived at was the estimated benefits of *Prosopis* invasion in the Afar region are higher than the costs. The total benefits in the Ethiopian Birr amounted to about 4.4 billion (231 million USD), and the costs are estimated to be about 2.2 billion Birr (116 million USD). Results also show that if the current invasion level is not controlled, the net present value in the next 30 years would be negative (37 trillion Birr). The study has captured most aspects of *Prosopis* invasion in the Afar region and concludes that sustainable management and control of *Prosopis* in the Afar region may be a better solution than eradication.

Mesfin *et al.* (2016) have undertaken a study on rural households' Willingness to pay for mitigation of *Prosopis* invasion in three districts of Afar. In their study, the economic value of *Prosopis* invasion was determined through contingent valuation method. Results show that about 84% of the respondents prefer an intervention involving complete eradication of *Prosopis*. The lower and upper bound median willingness to contribute to this intervention were 9.97 and 13.42 USD/household/year in cash. Non-farm income and *Prosopis* invasion levels on pasturelands are among the factors affecting willingness to contribute to the mitigation of *Prosopis* invasion. Incentives to local people and having a proper institutional

setup that involves local culture and institutions are important for mobilizing people on a voluntary basis for mitigation of *Prosopis* invasion.

Ayalneh (2016) tried to elicit households' willingness to pay to gain use and control rights to a natural forest resource at the Forest Priority Area in the Bale Mountains of Ethiopia. In the study, the economic value of the gain use and control rights to a natural forest resource was determined through contingent valuation method by analyzing households' willingness to pay (WTP) to gain use and control rights to a natural forest resource. The estimated mean WTP was found to be 24.41 Birr annually. Households with more members, have better exposure to education and training, perceive the need for forest conservation, are member of forest dwellers' association, and who are wealthier in terms of ownership of more cultivated land and livestock are willing to pay more; whereas those households characterized by earning better annual household income, those who got higher starting bid value, and those who live farther away from the prime forest resource are willing to pay less. This can be used to signal that there is a considerable non-market value attached to use and control rights to the natural forest. In particular, membership in official forest user groups has shown a strong and positive relationship with WTP. This implies community base management using forest user groups is better both for the sustainability of the forest resource and the livelihoods of the people who depend upon it.

2.5.2. Review of empirical literature on impact studies

A study by Ndhlovu (2011) on the impact of *Prosopis* (mesquite) invasion and clearing on ecosystem structure, function and agricultural productivity found that in heavily grazed rangeland *Prosopis* invasion and clearing can significantly 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 *Prosopis* 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. Therefore clearing is one of the management strategies to control the spreads of the IAS and clearing leads to lower alien species richness.

A study by Mulindol and Sang (2004) on the farmers' perceptions and the impact of *Prosopis* on food security in Kenya shows 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. As it expected *Prosopis* species affect food security unless one manages its expansion of invasion.

Esther and Brent (2008) conducted a study on the livelihood effects, costs of control, and local perceptions of the invasive tree, *Prosopis*, on rural residents in the Lake Baringo area of Kenya. Their results show that *Prosopis* 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 utilization may require considerable investment in the development of new commercial enterprises.

A study by Jema and Mohammed (2013) on economic impact of *Prosopis* on agro-pastoral households of Dire Dawa Administration, Ethiopia shows that the invasion by *Prosopis* have a significant and negative effect on annual income from livestock and sale of their products. These losses might be attributed to reduced grazing land and loss of palatable grass species due to *Prosopis* invasion. In addition, the heavy dependence of

livestock on *Prosopis* pod for survival, as it is abundantly found even during drought period might have resulted in *Prosopis* 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).

2.6. Conceptual Framework

Prosopis, a driver of change, have direct and indirect impacts on the provision of ecosystem goods and services to humans, thus influencing their well-being. The relevant effects of *Prosopis* are depicted in Figure 1. Invasive alien species displace native species and occupy natural or human-modified ecosystems, and thereby change the ecosystem services that they provide and which in turn contribute towards human wellbeing. *Prosopis* invasion bring benefits to ecosystem function and to people such as environmental income, carbon sequestration, crop production as well as bringing negative impacts (human and animal health, loss of biodiversity). These effects of *Prosopis* reflected in individuals' utility. The level of utility will lead to the change in the total economic value of ecosystem.

Socio-demographic characteristics of the individual will influence the utility they yield from the consumption of ecosystem goods and services. The socio demographic include the income level, education, age, sex and others. These socio demographic characteristics of an individual will influence the utility she/he yields from the consumption of ecosystem goods and services (Morey *et al.*, 1993) and also affects the levels of *Prosopis* invasion. The levels of utility will lead to the change in WTP for *Prosopis* control and eradication measure. These socio-demographic can also influence the WTP directly.

The utility gain from the consumption of environmental goods and services will influence an individual attitude towards WTP for the control and eradication measures. More specific to this study, attitudes also have been incorporated in models predicting willingness to pay for *Prosopis* invasion control and eradication measures. Attitudes toward payment for control and eradication measures would be directly associated with the intention to pay and indirectly associated with the stated payment amount through the intention to pay. This mediation effect is consistent with aspect of attitude models such as the theories of reasoned action and planned behavior that suggest a hierarchy of cognitions where actual

behavior is influenced by intention to engage in the behavior, and this intention is a function of attitudes and other cognitions about the behavior (Ajzen and Fishbein, 1980).

In a nut shell, *Prosopis* invasion has both benefits and adverse effects on **ecosystem services** in the study area. Individual's WTP in this study was analyzed using two stated preference techniques, namely: CVM and CE and summed up with other market-price based values to come up with TEV of the effects of *Prosopis* on households in the study area. Therefore, results on households' attitude and total economic value are worthy for decision makers to plan and implement feasible *Prosopis* invasion management policy.

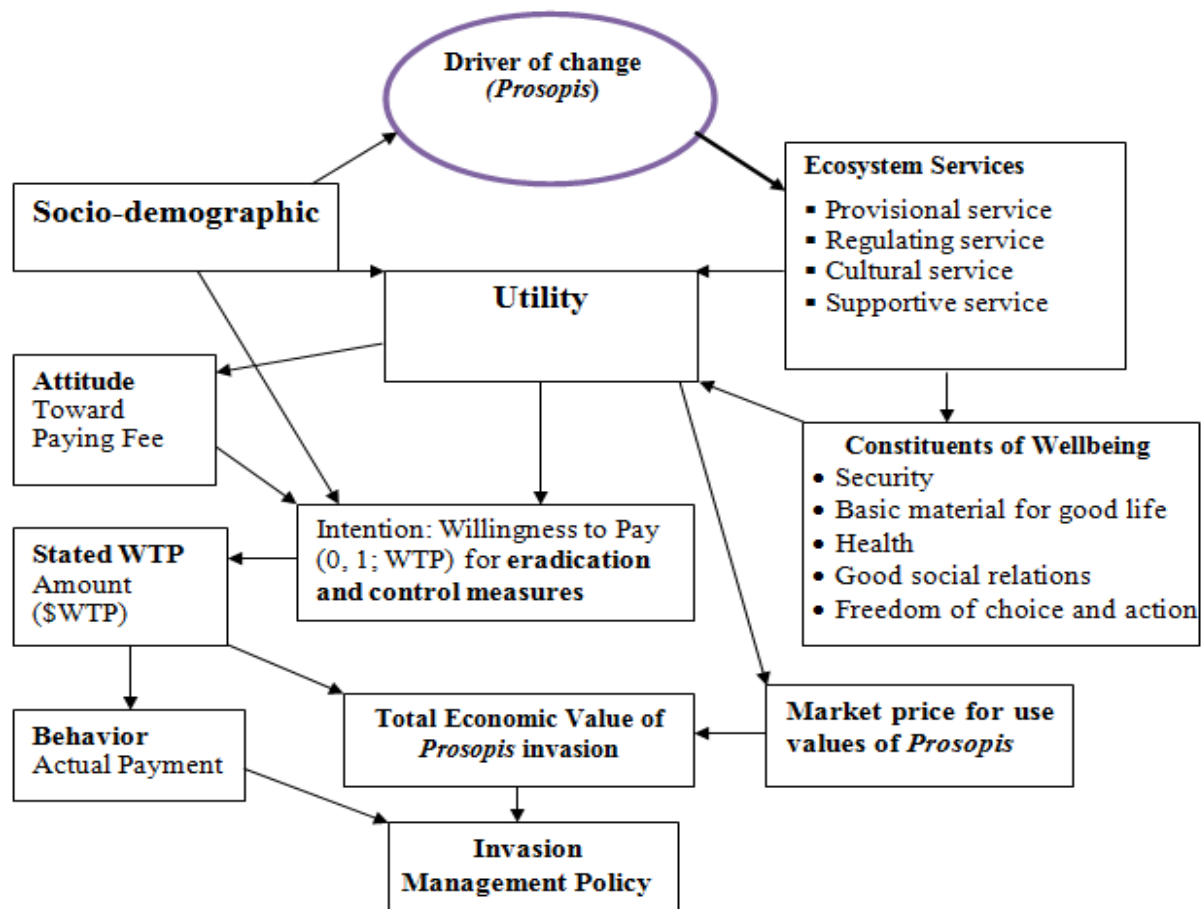


Figure 1. Conceptual framework of the study

Source: Own source

3. METHODOLOGY

Under this part, description of the study area, the sampling procedures, data requirement, descriptive analysis and econometric models and estimation techniques are presented and discussed.

3.1. Location and Description of the Study Area

The study was conducted in Dire Dawa Administration, the second most *Prosopis* infested area in Ethiopia next to the Afar National Regional State. Dire Dawa is located in the eastern part of the country enclosed by the State of Somalia from the West, North and East and the State of Oromia from the South. It is found at a distance of 515 Kilometres from Addis Ababa and 333 km from the international port of Djibouti. Dire Dawa city administration is a large town in Ethiopia with a diverse population. Dire Dawa Administration has 9 urban kebeles and 38 rural kebeles. The population of the Administration was 453,000 persons as estimated for 2016, of which 62.91% are urban dwellers and the remaining 37.09% are rural dwellers (CSA, 2014/15).

Dire Dawa administration is characterized by diverse topographic features with altitudes ranging from 950-960 meters above sea level (m.a.s.l) on the northern and northeast parts to 2260-2450 m.a.s.l on the southern and southwest parts. The physiography of the administration can be classified into: (a) mountain ranges with slopes that exceed 45%, which are mainly located in the southern, southeastern and southwestern parts with shallow soils and mostly covered with scattered woods and shrubs; (b) isolated hills found scattered all over the administration, with slopes ranging between 16 and 30%, with very shallow soils composed mainly of stones and rock outcrops and most of which are either devoid of any vegetation cover or covered with scattered bushy vegetation; (c) valley bottoms and river terraces mainly situated at the foot of mountain ranges, hills, and seasonal river banks with moderately deep soils and with slopes that range from 0 to 3%; mostly covered with river line vegetation dominated by acacia species, and (d) flat plains mostly concentrated in the north-eastern and north-western parts, with slopes ranging between 0 and 3%, deep soils with slight vegetation cover (mostly shrubs) mainly used as grazing and browsing areas (DDAEPA, 2011).

The climatic condition of Dire Dawa seems to be greatly influenced by its topography, which lies between 894 to 2284 meter above sea level, and which is characterized by warm and dry climate with a relatively low level of precipitation. The mean annual temperature of Dire Dawa is about 25.4 °C. The average maximum temperature of Dire Dawa is 31.4 °C, while its average minimum temperature is about 18.2 °C. The administration has two rainy seasons; that is, a short rain season from March to April, and a long rainy season that extends from August to September. The aggregate average annual rainfall that the region gets from these two seasons is about 604 mm. On the other hand, the region is believed to have abundant underground water resources (IDP, 2006).

Dire Dawa administration has two major agro-ecological zones classified based on altitude, moisture, and physiography (DAAEPA, 2011). These agro-ecologies are the low lands locally called *Kolla*, which characterize areas between 500-1500 m.a.s.l and are relatively drier and warmer, and the mid-altitude areas locally known as *Woina Dega*, which represent areas with altitude between 1500-2400 m.a.s.l and are relatively colder and wetter. According to DAAEPA, (2011), desert and semi-desert scrub and shrub land ecosystem bounded by dry ever green mountain forest ecosystem in South and Southwest, and *Acacia commiphora* Wood Land Ecosystem in the Northeast and South part of the administration characterize the ecology of the Administration.

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 26,914 persons which is nearly 16.5% of the rural population in the Administration (BoARD, 2015). 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 agro-pastoral households. Selling of firewood is the most important non-farm income generating activity in the study area.

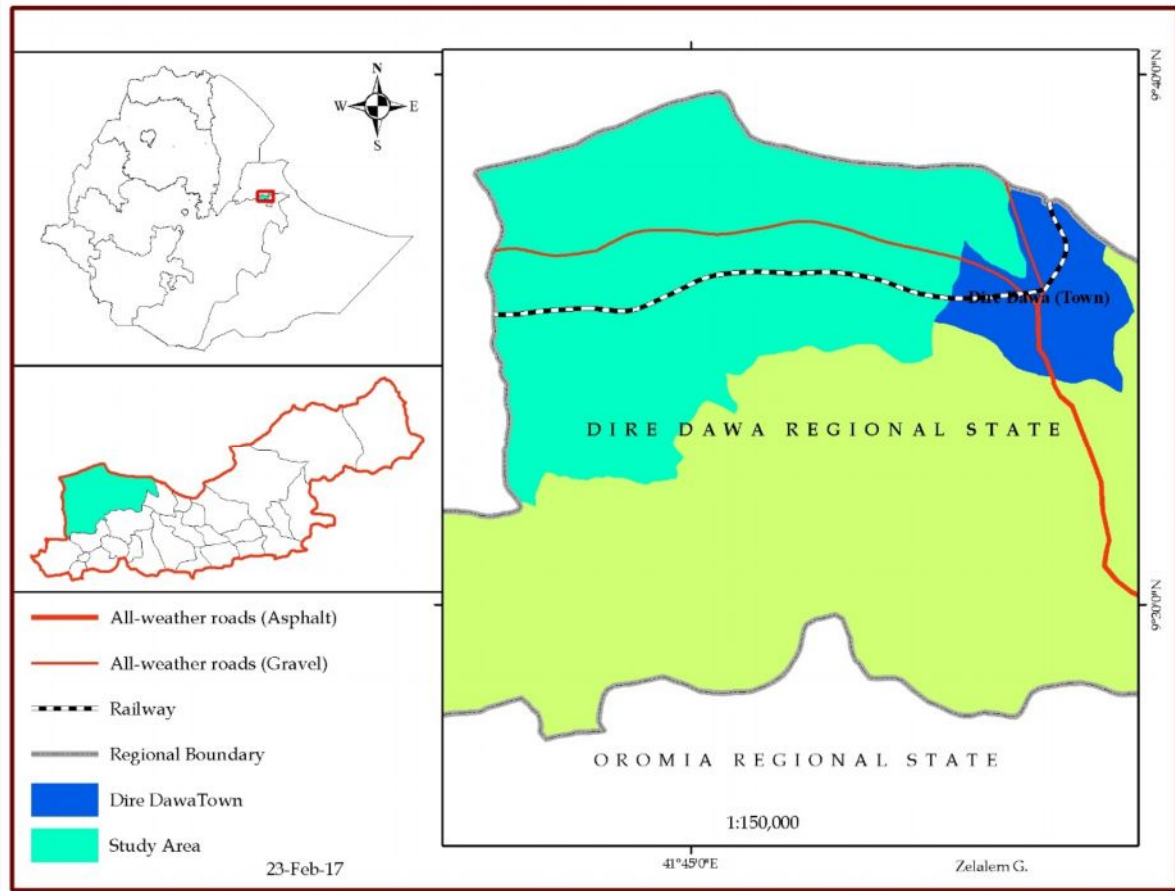


Figure 2. Location map of the study area

Source: ETHIOGIS, 2000.

3.2. Sampling Design

In order to reflect the variety of opinions and concerns regarding the economics of *Prosopis* control/eradication, sample households from both invaded and non-invaded areas were interviewed. The sample was chosen to analyze *Prosopis* impacts on ecosystem services and rural farmers' livelihood. Further, sample households from the two categories can help in reflecting heterogeneity of perception and attitude regarding *Prosopis* impacts. The sample size for the study was determined following Israel (1992).

$$n = \frac{Z^2 pq}{e^2} \quad (1)$$

where n is the desired sample size, Z is the inverse of the standard cumulative distribution that corresponds to the level of confidence with the value of 1.96, e is the desired level of precision, p is the estimated proportion of area invaded by *Prosopis* present in the population and $q = 1-p$.

Assuming large population but the variability is not known in the proportion about the invasion levels, $p = 0.5$ is considered as suggested by Israel (1992) to get the desired minimum sample size of 384 households at 95% confidence level and $\pm 5\%$ precision. Here, 17% additional sample households were added proportionally to both sampled households from invaded and non-invaded Kebeles. Therefore, the total sample size taken for this research was 450 households (Figure 3).

In general, multi-stage sampling technique was applied. The details of the sampling method applied is presented and discussed below. In the first stage, a total of 38 rural Kebeles of the administration were stratified into two strata. Stratum 1 (treatment group) consists 5 rural Kebeles which are severely invaded by *Prosopis* while stratum 2 (control group) consists 33 Kebeles which are non-invaded. In the second stage, following simple random sampling technique was employed to select four invaded kebeles and a purposive sampling method was used to select three adjacent non-invaded *Kebeles* based on their demographic, socioeconomic and geographic similarity with the invaded *Kebeles*.

In the third stage, 12 and 17 villages for invaded and non-invaded kebeles, respectively, were selected using random sampling techniques. Finally, following systematic random sampling technique with probability proportional to sample size in each village, 250 and 200 rural households were sampled and interviewed from stratum 1 and stratum 2 respectively.

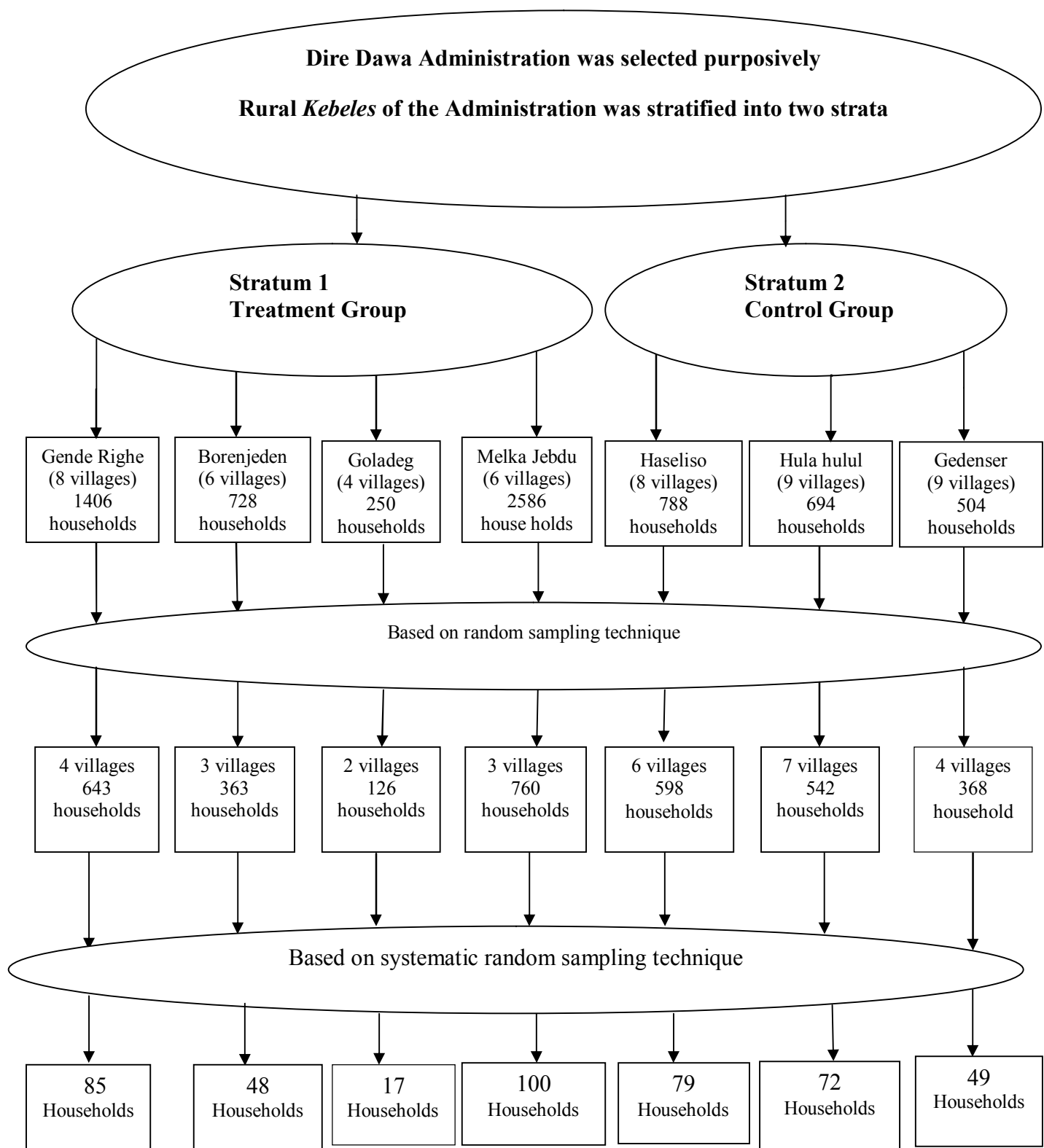


Figure 3. Schematic presentation of households selected for the study

3.3. Data Requirements

Generally, the data required for this study are categorized into two parts. The first one encompasses information regarding the control/eradication of *Prosopis* in the study area. This data include answer to the question who should be responsible for control, livelihood effects, costs of control, and perceptions/attitude on the invasive plant, benefit obtained from it, trade and use of *Prosopis* and households willingness to pay, the general socio-economic characteristics and other relevant information which were gathered from the sample agro-pastoral households using a semi-structured interview schedule. The second type of data are secondary data which were extracted from published and unpublished documents from relevant sources. Research outputs of the Ethiopian Agricultural Research Organization are widely consulted. Relevant internet sources were also widely referred.

3.4. Data Sources and Data Collection Methods

The survey was conducted for more than a month in December 2015. Three focus group discussions were used in each of the sample kebele to have general picture of the kebele regarding the objectives of the study. In each FGD, 8 members (elderly, youth, male and female) of the communities were selected from each kebele and one focus group discussion was conducted in each kebele. All of them were selected after having a thorough discussion with key informants in the kebele particularly with kebele leaders, school teachers and development agents. The discussion was important for re-designing the drafted semi-structured questionnaire, for the determination of the payment bid and triangulation of data and results.

Based on their educational qualification and work experience seven development agents who have been working in the study area over the past many years were selected and trained as enumerators. The data collection process has been continuously supervised by the researcher on a daily basis for incompleteness, omission and incorrectness. The interviewers were trained on how they should presents the questions to the respondents, how to explain the whole scenario and the attributes used in the survey. Next the questionnaire was pre-tested by the enumerators. The pre-test had a significant contribution in allowing modifications of ill-prepared and unclear questions. Secondary data pertinent to

the study were collected from district, zone and national agricultural offices and research centres. Different offices and personal contacts were made to obtain additional information.

3.5. Methods of Data Analysis

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

3.5.1. Descriptive statistics

Descriptive statistics tools like diagrams, charts, ratios, percentages, means, minimum, maximum, variances and standard deviations, frequency, tables and graphs were used to describe the socio-economic, demographic, and institutional characteristics of the sample households. Certain aspects of objectives 2, 3, 6 and 7 were also addressed using descriptive statistical analysis. The third objective that deals with distribution of benefit and cost of *Prosopis* invasion has been addressed using Gini Decomposition Techniques and households' perception were measured using Likert-type rating scale and analyzed using a set of tools for use in descriptive statistics.

A. Gini decomposition technique

One of the objectives of the present study is establishing a relationship between the level of the income obtained or loss incurred from *Prosopis* invasion and households' income distribution under presumption that additional income obtained from *Prosopis* widens income inequality. These were analyzed by decomposing total agro-pastoral household income and uncovering the distribution of each income source and its contribution to the total income inequality after Xu, (2004).

Income can be obtained from different sources, each of which can have its own contribution to the level of inequality. The aggregate inequality can be expressed as the sum of each income factor contribution. Following the decomposition technique used by Fredu *et al.* (2007) and Tassew (2000), decomposition of Gini coefficient is specified as:

$$G = \sum R_k G_k S_k \quad (2)$$

Where S_k is the share of source K of income in total income, i.e.,

$$S_k = \frac{\mu_k}{\mu} \quad (3)$$

G_k is the Gini-coefficient measuring the inequality in the distribution of income component k within the group, and R_k is the Gini-correlation of income source k with total income.

The contribution of income source k to total income inequality is given by:

$$S_k G_k R_k / G \quad (4)$$

While the relative concentration coefficient of income source k in total income inequality is expressed as:

$$g_k = G_k R_k / G \quad (5)$$

Using this decomposition technique, it is possible to identify how much of overall income inequality is due to a particular income source. Assuming that additional increments of an income source are distributed in the same manner as the original units, it is possible to use this decomposition to inquire whether an income source is inequality increasing or inequality decreasing on the basis of whether or not an enlarged share of that income source leads to an increase or decrease in overall income inequality.

B. Descriptive analysis of local perceptions

The perceptions data were measured using Likert-type rating scale and analyzed with descriptive statistics. A five point Likert scale was provided to measure the perceptions of the households about *Prosopis*. In Liket scale, a sample household indicates his or her degree of agreement for a variety of statements related to the perceived changes of a given variable overtime. Total score can then be calculated by summing up the values for all statements to see the significance of each variable. An important assumption of this scaling is that each of the statement measures some aspect of a single variable so as to legitimately apply summation. In addition, the relative importance of sub categories of statements can be measured, by relating its score with the household's total score (Bunce *et al.*, 2009). Thus, in this study a weighted mean scale was used for the interpretation of the Likert scale.

3.5.2. Valuation of ecosystem service and analysis of determinants of WTP

In order to meet objectives 4 and 5 contingent valuation survey data was analyzed using econometric models. The main goal pursued in CV studies is to estimate WTP measures,

determinants of WTP and precision of those estimates. In doing so, the analysis is done using parametric estimation framework.

The parametric analysis of response from discrete choice question is based on Random Utility Model (RUM) (McFadden, 1974; Hanemann, 1984). Under the RUM framework, the indirect utility function for each respondent can be expressed as:

$$U_j = V_j + \varepsilon_j \quad (6)$$

Where U_j is utility of choosing alternative j , V_j is the deterministic component of utility and ε_j is a stochastic element that represents unobservable influences on individual choice.

Utility is assumed to arise from income, the absence (controlled/eradicated) of *Prosopis* invasion and other socio-economic and demographic factors. If the household accepts the offered bid its income is reduced by the bid amount and this holds only under the following condition (Hanemann, 1984):

$$V_{1j}(M_j - B_j; S_j; T_1) + \varepsilon_{1j} \geq V_{0j}(M_j - B_j; S_j; T_0) + \varepsilon_{0j} \quad (7)$$

Where V_{1j} is the indirect utility in a state of controlled or eradicated condition T_1 , and V_{0j} is the indirect utility to the household in the presence of *Prosopis* invasion effects or in the status quo T_0 . Here, $T_1 > T_0$ which shows the fact that the proposed scenario/controlled or eradicated *Prosopis* invasion has a higher non-market benefit than the status quo. M_j is the income of the household; B_j is the bid amount; S_j captures the other socio-economic and demographic factors; and the error terms, ε_{1j} and ε_{0j} are identically and independently distributed with a mean of zero and constant variance σ^2 .

Our dependent variable is dichotomous, and equals 1 if the j^{th} household is willing to pay money to support *Prosopis* invasion control/eradication program and 0, otherwise.

The general form is represented as:

$Y_j^* = X_j \beta' + \varepsilon_j$, where, Y_j^* is the dependent variable, X_j is the vector of independent variables that include M and S of the above specification, β' is the vector of parameter to be

estimated and the random error term is $\varepsilon_j \sim (0, \sigma^2)$. Y_j^* is a continuous latent variable and it is not observable. The observed variable is the answer ‘YES’ or ‘NO’, which can be given by a dummy variable $Y_j=1$ if Yes and $Y_j=0$ otherwise, to the question regarding whether or not the respondent would be willing to pay a given bid amount. The j^{th} household head is expected to say yes if $Y_j^* > 0$ and this will be true if the condition in Equation 7 is satisfied.

$$Y_j = \begin{cases} 1 & \text{if } Y_j^* > 0 \text{ or } V_{1j}(M_j - B_j; S_j; T_1) + \varepsilon_{1j} \geq V_{0j}(M_j - B_j; S_j; T_0) + \varepsilon_{0j} \\ 0 & \text{if otherwise} \end{cases} \quad (8)$$

In the random utility framework, the maximum willingness to pay Y_j is a random variable. While individuals are assumed to know their maximum willingness to pay with certainty, these values are revealed only through observed choices or elicited preferences, and determinants of these values often are unobservable, observable with error or measurable only through proxies. Thus, an observer cannot infer Y_i with certainty. Thus, we can incorporate this uncertainty by specifying a cumulative distribution function $F_\eta(\cdot)$ for the maximum random willingness to pay.

The probability that a household j is willing to pay for eradication or control of *Prosopis* invasion can be expressed as the difference of his/her utility functions with and without *Prosopis* invasion. i.e.

$$\left. \begin{aligned} \Pr_j(\text{yes}) &= \Pr_j(Y_j=1) = \Pr\{V_{1j}(M_j - B_j; S_j; T_1) + \varepsilon_{1j} > V_{0j}(M_j - B_j; S_j; T_0) + \varepsilon_{0j}\} \\ \Pr\{V_{1j}(M_j - B_j; S_j; T_1) - V_{0j}(M_j - B_j; S_j; T_0) > \varepsilon_{0j} - \varepsilon_{1j}\} \\ F_\eta(\Delta V), \text{ Where } \eta &= \varepsilon_{0j} - \varepsilon_{1j}, \Delta V = V_{1j} - V_{0j} \text{ and} \\ F_\eta(\Delta V) &\text{ is the cumulative distribution function (cdf).} \end{aligned} \right\} \quad (9)$$

The above cumulative distribution function in Equation 9 provides an underlying structural model for estimating various econometric models from the discrete choice responses. In order to model the true willingness-to-pay, the double-bounded, dichotomous-choice contingent valuation model is used, which is more information-intensive and asymptotically more efficient than the single bounded method (Hanemann *et al.*, 1991). To estimate WTP, the Bivariate Probit model, Recursive Probit and Random Effect Probit

models were used. The final WTP estimate is reported from the model that best explained our DBDC CV survey. Comparison will be made among models of single bounded dichotomous choice (SBDC) and double bounded dichotomous choice (DBDC), with respect to different criteria.

The improved statistical efficiency of the double-bounded model reported in the literature is also tested after estimating the variants of SB and DB models.

I. Single-Bounded Model

Here, responses to the initial bid (DC1) and follow-up bid (DC2) were analyzed separately, as though they were elicited from two separate independent dichotomous choice experiments. In this case, there is no correlation between the responses thus assuming $\rho = 0$. By estimating a separate single bounded dichotomous choice (SBDC) models for initial bid (*MODEL I*) and follow-up bid (*MODEL II*), attempts were made to verify claims made by environmental economics discipline that DBDC results are better welfare estimates than single bounded ones.

The probability of obtaining a “yes” or “no” response for a given payment amount, (Bid_i) that meant to control/eradicate *Prosopis* invasion can be represented as:

$$\begin{aligned}
 Y_j^* &= \beta' X_j' + \varepsilon_j \\
 &\begin{cases} 1 & \text{if } Y_{j1}^* > Bid_1 \\ 0 & \text{Otherwise} \end{cases} \quad \text{and} \quad Y_{j2}^* = \begin{cases} 1 & \text{if } Y_{j2}^* > Bid_2 \\ 0 & \text{Otherwise} \end{cases} \\
 P(\text{yes}) &= P(Y_j = 1) = \Pr(\beta X_j + \varepsilon_j > Bid_1) \\
 &= \Pr[\varepsilon_j / \sigma > (bid_1 - \beta X_j) / \sigma] \\
 &= 1 - F[(bid_1 - \beta X_j) / \sigma] = 1 - F(Bid; \theta) \\
 &= 1 - F(Z_j)
 \end{aligned} \tag{10}$$

Where, $F(.)$ is the cumulative distribution function (cdf). In the present study, normality in the error term is assumed which results in a Probit Model and the log-likelihood function for $j=1, \dots, N$ observations will be:

$$\log L = \sum_{j=0}^N \{ Y_j \log[(bid_i - \beta X_j) / \sigma] + (1 - Y_j) \log[(bid_i - \beta X_j) / \sigma] \} \tag{11}$$

By adapting Haneman *et al.* (1991) a Probit model can be estimated for both the initial and follow-up responses (*MODEL I and MODEL II*) separately using maximum likelihood estimation.

II. Double-Bounded Model

In the double bounded dichotomous choice model for each person, we have an initial bid and one follow-up bid. Thus, there are four possible outcomes: (1) both answers are “yes”; (2) both answers are “no”; (3) a “yes” followed by a “no”; and (4) a “no” followed by a “yes”.

Let the model be:

$$WTP_{ij} = \beta'X_{ij} + \varepsilon_{ij}, \text{ where } \varepsilon_{ij} \sim N(0, \sigma^2) \text{ and from equation (yes)} = 1 - F(Z_j) \quad (12)$$

For each respondent, we have an initial bid B_j^I and one of the follow-up bids, lower bid (B_j^L) and higher bid (B_j^U), where $B_j^L < B_j^I < B_j^U$. Each respondent will be asked a random initial bid and the follow-up is dependent on the initial bid amount.

Following Hanemann *et al.* (1991), the probabilities associated with the four possible likelihood outcomes of DBDC denoted by $P(yy)$; $P(nn)$; $P(yn)$ and $P(ny)$ for “yes, yes”, “no, no”, “yes, no”, and “no, yes” outcomes, respectively can be presented as:

A. The probabilities for “yes, yes” outcome will be:

$$P_{yy}(\beta_j^I, \beta_j^U) = P(\beta_j^I > \text{Max.WTP and } \beta_j^U < \text{Max.WTP}) = 1 - F(\beta_j^U; \theta) \quad (13)$$

B. The probabilities for “no, no” outcome will be:

$$P_{nn}(\beta_j^I, \beta_j^L) = P(\beta_j^L > \text{Max.WTP and } \beta_j^I > \text{Max.WTP}) = 1 - F(\beta_j^L; \theta) \quad (14)$$

C. The probabilities when a “yes” is followed by “no”, with $B_j^I < B_j^U$ will be:

$$P_{yn}(\beta_j^I, \beta_j^U) = P(\beta_j^I < \text{Max.WTP} \leq \beta_j^U) = F(\beta_j^U; \theta) - F(\beta_j^I; \theta) \quad (15)$$

$$P_{ny}(\beta_j^I, \beta_j^L) = P(\beta_j^L > \text{Max.WTP} \geq \beta_j^I) = F(\beta_j^I; \theta) - F(\beta_j^L; \theta) \quad (16)$$

D. For a “no” answer following a “yes” response, the probabilities can be represented as:

The likelihood function for $j=1, \dots, N$ observation will be:

$$L(\theta) = \sum_{j=0}^N d_i^{yy} \cdot P_{yy}(B_j^I, B_j^U) + d_i^{nn} \cdot P_{nn}(B_j^I, B_j^L) + d_i^{yn} \cdot P_{yn}(B_j^I, B_j^U) + d_i^{ny} \cdot P_{ny}(B_j^I, B_j^L) \quad (17)$$

Where d_i^{yy} , d_i^{nn} , d_i^{yn} and d_i^{ny} are the binary valued indicator variables with their probability represented above. In dealing with data from DBDC we estimate several versions of this model with maximum likelihood procedures.

A. Bivariate probit model

When DBDC survey is used, it is important to consider that the answer to the follow-up bid is endogenous to the initial bid offered randomly. The second bid takes a predetermined value or it is not random and hence a model of joint distribution function is needed.

The *bivariate probit* model introduced by Cameron and Quiggin (1994) has become a general parametric modelling approach for double-bounded CV survey. It is argued that the responses to the two DC questions may not be independent, but rather path dependent i.e. the response to DC2 may be related to the response to DC1. Sequential presentation of WTP questions (DBDC) suggests that responses to these questions might not be independent if unobserved factors influence both responses. To deal with these issues, we use a bivariate probit model to estimate preference parameters and identify correlation in the unobserved factors influencing responses across the two WTP equations. In general, a *Bivariate Probit Model* is specified as:

$$Y_{j1}^* = \beta' X_{j1} + \varepsilon_{j1} \quad (18a)$$

$$Y_{j2}^* = \beta' X_{j2} + \varepsilon_{j2} \quad (18b)$$

In the data Y_{j1} and Y_{j2} are only observable through the two discrete choice responses such that:

$$Y_{j1} = \begin{cases} 1 & \text{if } Y_{j1}^* > \text{Bid}_1 \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad Y_{j2} = \begin{cases} 1 & \text{if } Y_{j2}^* > \text{Bid}_2 \\ 0 & \text{otherwise} \end{cases}$$

$$E[\varepsilon_1] = E[\varepsilon_2] = 0$$

$$\text{Var}[\varepsilon_1] = \text{Var}[\varepsilon_2] = 1$$

$$\text{Cov}[\varepsilon_1, \varepsilon_2] = \rho$$

As the second equation is based on the first question response, the error terms are correlated and hence the two equations can be estimated jointly using the model developed by Cameron and Quiggin (1994), which assumes Bivariate Normal distribution for the two valuations, BVN ($\beta_1 X_1, \beta_2 X_2, \sigma_1^2, \sigma_2^2, \rho$) or BVN ($0, 0.1.1, \rho$). As mentioned earlier the two questions have four possible pairs of response: $(Y_{j1}, Y_{j2}) = (1, 1), (1, 0), (0, 1)$ and $(0, 0)$. Combining the associated probabilities of all possible responses in the likelihood function, Equation 12 can be estimated using the Bivariate Probit or the seemingly unrelated bivariate probit Model (*MODEL III*).

B. Recursive Probit Model

It is believed that response to the second question is likely to suffer from anchoring bias due to the initial bid question. To take account of the possible anchoring effect, a Recursive Probit model needs to be estimated. In modelling the follow up response, WTP estimated from the first equation (bid_1) is included in the second equation, i.e. one dependent variable in a given model should appear as independent variable in the other model. Thus, the recursive system can be derived from (19a and 19b) below where the first equation is the usual reduced form equation:

$$Y_{j1} = \beta_1' X_{j1} + \varepsilon_{j1} \quad (19a)$$

but the second equation is replaced by the structural equation

$$Y_{j2}^* = \beta_{j2}' X_{j2}' + \beta_3' + \widehat{\text{wtp}}_{j1} + \varepsilon_{j2} \quad (19b)$$

Where $\widehat{\text{wtp}}_{j1}$ is the WTP estimated from the first response equation for the j th respondent.

Following Maddala (1983) the system of equations defined by 19 (a and b) can be estimated by a two-stage maximum likelihood procedure. The estimated recursive model was compared with other models by constructing interval estimates around the mean WTP using the Krinsky Robb procedure.

III. Choice experiment

In the survey, we also employed a choice experiment framework as an alternative approach to estimating the *Prosopis* invasion impacts. Choice experiment and contingent valuation approach have a common theoretical basis of random utility theory. According to random

utility approach, the indirect utility function (U_{ij}) for each respondent i 's utility of choosing alternative j , can be decomposed into two components: a deterministic or objective component (V_{ij}), which is typically specified as a linear index of the attributes (i) of the j alternative in the choice set, and a random error component (ε_{ij}), which represents unobservable influences on a choice. It is expressed in Equation 20.

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (20)$$

As it is conditional on the choice of alternative j , it is called a conditional indirect utility function. Selection of an alternative which consists a 'package' of attributes over another implies that the utility of that alternative is greater than the utility of the other (Boxall *et al.*, 1996). The randomness of the utility function suggests that only analysis of the probability of choosing one alternative over another is possible (Hoyos, 2010). Therefore, the probability that a respondent (i) prefers alternative j , over all other alternatives, h , in a complete choice set C , is expressed in Equation 21.

$$P(j/C) = P[(U_{ij} > U_{ih}) \forall j \neq h] = P[(V_{ij} > V_{ih}) > (\varepsilon_{ij} > \varepsilon_{ih})] \quad (21)$$

Equation (23) is the cumulative probability distribution function of a random variable component $\varepsilon_{ih} - \varepsilon_{ij} = \varepsilon_{ihj}^*$ (Vojáček and Pecáková, 2010). As an estimable choice models require a distributional assumption for the random component, is assumed to have Gumbel or type I extreme value probability distribution. With variance of $\lambda^2 \pi^2/6$, this cumulative distribution function is expressed as follows:

$$F(\varepsilon_{ij}) = [\exp(-\exp(-\varepsilon_{ij}))] \quad (22)$$

If these random variables are distributed identically and independently (IID) and follow the Gumbel (type I extreme value) distribution, then their difference follows the logistic distribution (McFadden, 1974; Agresti, 2002), Equation 23, with a zero mean and with the variance of $\pi^2/3$ (a scale parameter λ can be arbitrarily set to 1).

$$F(\varepsilon_{ihj}^*) = [1 + \exp(-\varepsilon_{ihj}^*)] \quad (23)$$

The above distribution of the error term implies that the probability of any particular j being chosen as the most preferred can be expressed in terms of the logistic distribution (McFadden, 1973) stated in Equation 24.

$$P(U_{ij} > U_{ih}, \forall h \neq j) = \frac{\exp(\mu V_{ij})}{\sum_j \exp(\mu V_{ij})} \quad (24)$$

where μ is a scale parameter, inversely proportional to the standard deviation of the error distribution. This parameter cannot be separately identified and is therefore typically assumed to be one.

This model can be estimated by the conventional maximum likelihood procedures, with the respective log-likelihood function stated in Equation 25, where y_{ij} is an indicator variable which takes a value of one if respondent i chose option j and zero otherwise.

$$\log L = \sum_{i=1}^N \sum_{j=1}^J y_{ij} \log \frac{\exp(V_{ij})}{\sum_j \exp(V_{ij})} \quad (25)$$

The conditional Logit model based on IID error terms implies a number of restrictions including on the property of independence of irrelevant alternatives (IIA). There are also limitations in modeling variation in taste among respondents. The IIA property states that the choice probability ratio for any two alternatives in any choice set is constant for an individual, which is considered too restrictive in many practical situations (Ben-Akiva and Lerman, 1985). To relax the IIA assumption, the conditional Logit model can be generalized into a mixed Logit or random parameters Logit (RPL) model (Train, 1998).

In the RPL model, the observed component (β_{ix}) given in Equation 20 is expressed as the sum of the population mean (β) and individual deviation (η). The coefficient vector η , captures a random, unconditional and unobserved type of taste heterogeneity of each random parameter β' (Grosjean and Kontoleon, 2009). In order to capture the source of heterogeneity, we can include socio-economic variables (s) in the utility function. Hence, the indirect utility function is expressed in Equation 26.

$$U_{ij} = \beta'_{xij} + \eta x_{ij} + \gamma S_i \quad (26)$$

The respondents' characteristics do not vary over choices. In this form of estimation, the conditional type of preference heterogeneity can be captured by interacting socio-economic characteristics with given attributes. The socioeconomic variables, S , with coefficient

vector (γ) enter as interaction terms with the alternatives attributes and ASC. These interaction terms examine the impacts of individual-specific characteristics on selected alternatives.

3.5.3. Impact evaluation

Matching may be difficult to implement when the set of conditioning variables Z is large. Rosenbaum and Rubin (1983) prove a result that is useful in reducing the dimension of the conditioning problem in implementing matching methods. They show that for random variables Y and Z and a discrete random variable D

$$E(D|Y, \Pr(D = 1|Z)) = E((E(D|Y, Z)|Y, \Pr(D = 1|Z))),$$

$$\text{So that } E(D|Y, Z) = E(D|Z) = \Pr(D = 1|Z)$$

$$\text{implies } E(D|Y, \Pr(D = 1|Z)) = E(D | \Pr(D = 1|Z))$$

This implies that when Y_0 outcomes are independent of income obtained from *Prosopis* conditional on Z , they are also independent of invasion conditional on the propensity score, $\Pr(D = 1|Z)$. Provided that the conditional invasion probability can be estimated using a parametric method, such as a logit or probit model, or semi-parametrically using a method that converges faster than the nonparametric rate, the dimensionality of the matching problem is reduced by matching on the univariate propensity score. The same author noted that if the propensity score must be estimated non-parametrically, then the curse of dimensionality reappears in the estimation of the propensity score. This potential for reducing the dimensionality of the problem has led much of the recent evaluation literature on matching to focus on propensity score matching methods (Rosenbaum and Rubin, 1983).

The impact of *Prosopis* invasion on the livelihoods of pastoral and agro-pastoral household is the difference in households' mean calorie intake with and without the *Prosopis*. However, invaded households cannot be simultaneously observed in two states. A household can either be invaded or non-invaded. Thus, the fundamental problem of such an impact evaluation is a missing data problem. Hence, this study applied a propensity score matching technique, which is a widely applied impact evaluation instrument in the absence of baseline survey data for impact evaluation.

This study used a PSM technique to address its sixth objective. The PSM technique enables us to extract from the sample of non-invaded households a set of matching households that look like the invaded households in all relevant pre-intervention characteristics. In other words, PSM matches each invaded household with a non-invaded household that has (almost) the same likelihood of invaded household (Rosenbaum and Rubin, 1983).

This study attempted to estimate the average impact of *Prosopis* on particular farmers. As noted above, in this thesis “treatment” implies invaded household and “impact” is meant for the change of food poverty status using calorie intake as an outcome indicator. On the other hand, “control” stands for non-invaded/non-treated households used for comparison.

Dehejia and Wahba (1999) and Heckman *et al.* (1997) point out that this estimation strategy requires several steps: estimation of the propensity score; selection of a matching algorithm; revision of overlap and common support conditions; and assessing matching quality.

Procedures of propensity score estimation

The first step in PSM method is to estimate the propensity scores. As described by Rosenbaum and Rubin (1983), matching can be performed conditioning on $P(X)$ alone rather than on X , where $P(X) = \text{Prob}(D=1|X)$ is the probability of invasion conditional on X . If outcomes without the intervention are independent of invasion given X , then they are also independent of invasion given $P(X)$.

A logit or probit model can be used to estimate propensity scores using a composite of pre-intervention characteristics of the sample households (Rosenbaum and Robin, 1983) and matching is performed using propensity scores of each observation.

According to the matching theory (Rosenbaum and Robin, 1983; Bryson *et al.*, 2002; Jalan and Ravallion, 2003), the logit or probit model via which the propensity score is generated should include predictor variables that influence the selection procedure and the outcome of interest. In this respect, the study was undertaken by including as many explanatory variables as possible to minimize the problem of unobservable characteristics in our evaluation of the impact of *Prosopis* invasion.

Matching estimators

This section explains, in detail, three of the most commonly used matching methods: the nearest available neighbour, caliper matching and kernel matching.

Nearest Neighbour (NN) Matching: It is the most straightforward matching estimator. In NN matching, an individual from a comparison group is chosen as a matching partner for a treated individual that is closest in terms of propensity score (Caliendo and Kopeinig, 2005).

The NN matching can be done with or without replacement options. In the case of the NN matching with replacement, a comparison individual can be matched to more than one treatment individuals, which would result in increased quality of matches and decreased precision of estimates. On the other hand, in the case of NN matching without replacement, a comparison individual can be used only once. Matching without replacement increases bias but it could improve the precision of the estimates. In cases where the treatment and comparison units are very different, finding a satisfactory match by matching without replacement can be very problematic (Dehejia and Wahba, 2002). It means that by matching without replacement, when there are few comparison units similar to the treated units, we may be forced to match treated units to comparison units that are quite different in terms of the estimated propensity score.

Caliper Matching: As noted above, that NN matching faces the risk of bad matches, if the closest neighbour is far away. To overcome this problem researchers use the second alternative matching algorithm called Caliper matching. Caliper matching means that an individual from the comparison group is chosen as a matching partner for a treated individual that lies within a given caliper (propensity score range) and is closest in terms of propensity score (Caliendo and Kopeinig, 2005).

If the dimension of the neighbourhood is set to be very small, it is possible that some treated units are not matched because the neighbourhood does not contain a control unit. On the other hand, the smaller the size of the neighbourhood the better is the quality of the matches (Becker and Ichino, 2002). One problem in caliper matching is that it is difficult to know a priori what choice for the tolerance level is reasonable.

Kernel Matching: Developed by Heckman *et al.* (1997, 1998), kernel matching constructs the counterfactual for each treatment case using all control cases, but weights each control case based on its distance from the treatment case. Because kernel matching uses more cases, it is generally more efficient than other forms of matching; resulting in estimates with smaller expected sampling variance. However, because control cases that are very different from a particular treatment case are used for each treatment case, even though they have a very small weight, there is considerable potential to increase bias.

Although kernel matching estimators appear quite complex, they are the natural extension of the nearest neighbour matching: all control cases are matched to each treatment case, but weighted so that those closest to the treatment case are given the greatest weight (Heckman *et al.*, 1997, 1998).

According to Caliendo and Kopeinig (2005), the drawback of this method is that possibly bad matches are used as the estimator includes comparator observations for all treatment observation. Hence, the proper imposition of the common support condition is of major importance for kernel matching method. A practical objection to its use is that it will often not be obvious how to set the tolerance. However, according to Mendola (2007) kernel matching with 0.25 band width is the most commonly used.

The question remains on how and which method to select. Clearly, there is no single answer to this question. The choice of a given matching estimator depends on the nature of the available dataset (Bryson *et al.*, 2002). In other words, it should be clear that there is no winner for all situations and that the choice of a matching estimator crucially depends on the situation at hand. The choice of a specific method depends on the data in question, and in particular on the degree of overlap between the treatment and comparison groups in terms of the propensity score. When there is substantial overlap in the distribution of the propensity score between the comparison and treatment groups, most of the matching algorithms will yield similar results (Dehejia and Wahba, 2002). To give an example, if there are only a few control observations, it makes no sense to match without replacement. On the other hand, if there are a lot of comparable untreated individuals it might be worth using more than one nearest neighbour to gain more precision in estimates (Caliendo and Kopeinig, 2005).

Region of common support condition

Imposing a common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson *et al.*, 2002). The common support region is the area which contains the minimum and maximum propensity scores of treatment and control group households, respectively. It requires dropping of all observations whose propensity scores is smaller than the minimum and larger than the maximum of treatment and control, respectively (Caliendo and Kopeinig, 2005).

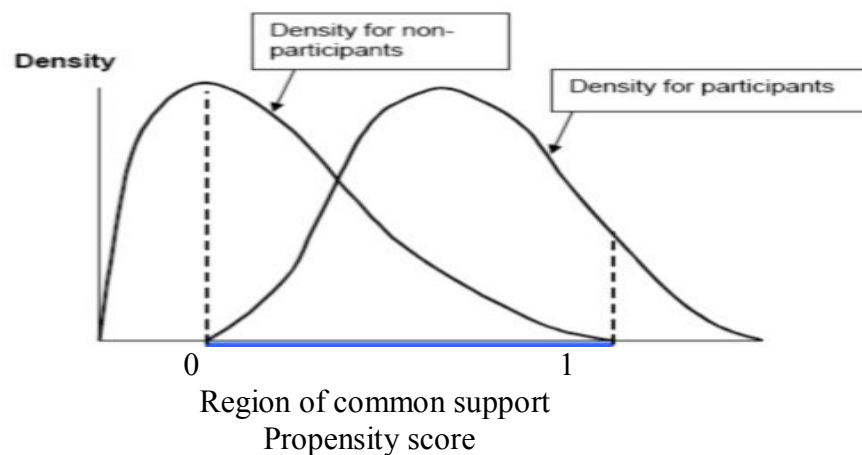


Figure 4. Region of common support condition
Source: Ravallion, 2005

Testing the matching quality

Since we do not condition on all covariates but on the propensity score, it has to be checked if the matching procedure is able to balance the distribution of the relevant variables in both the control and treatment group.

The main purpose of the propensity score matching is not to perfectly predict selection into treatment but to balance all covariates. While differences in covariates are expected before matching, these should be avoided after matching. The primary purpose of the PSM is that it serves as a balancing method for covariates between the two groups. Consequently, the idea behind balancing tests is to check whether the propensity score is adequately balanced. In other words, a balancing test seeks to examine if at each value of the propensity score, a given characteristic has the same distribution for the treated and comparison groups. The

basic idea of all approaches is to compare the situation before and after matching and check if there remain any differences after conditioning on the propensity score (Caliendo and Kopeinig, 2008). Rosenbaum and Rubin (1983) and Dehejia and Wahba (2002), emphasized that the crucial issue is to ensure whether the balancing condition is satisfied or not because it reduces the influence of confounding variables.

Using predicted probabilities of household invasion in the *Prosopis* (i.e. propensity score) match pairs were constructed using alternative methods of matching estimators. Then the impact estimation was the difference between simple mean of outcome variable of interest for those households who are making their living in the *Prosopis* invaded and non-invaded areas participant and non participant households.

The general formula for the mean impact of *Prosopis* invasion on the livelihood of agro-pastoral households is given by

$$\Delta C = \frac{1}{N_T} \sum_{i \in \{D=1\}} \left[y_{1,i} - \sum_j w(i, j) y_{0,j} \right] \quad (27)$$

Where, $0 < w(i, j) \leq 1$ and $\{D=1\}$ is the set of treated individual and j is an element of the set of matched comparison units, N_T is the number in the treated group, i is treated household. Different matching estimators are generated by varying the choice of $W(i, j)$.

Testing the overlap and unconfoundedness assumptions

The first method to detect lack of overlap is to plot distributions of covariates by treatment groups (Imbens and Wooldridge, 2008). A more direct method is to inspect the distribution of the propensity score in both treatment groups, which can reveal lack of overlap in the multivariate covariate distributions.

The unconfoundedness assumption implies that beyond the observed covariates, there are no unobserved characteristics of the individual associated both with the potential outcome and the treatment (Imbens and Wooldridge, 2008). Although the unconfoundedness assumption is not directly testable, this study assesses the sensitivity analysis using the bounding approach that involves calculating upper and lower bounds, using the Wilcoxon signed rank test. This rank tests the null hypothesis of no-treatment effect for different hypothesized values of unobserved selection bias.

Sensitivity analysis

Recently checking the sensitivity of the estimated results becomes an increasingly important topic in the applied evaluation literature (Caliendo and Kopeining, 2008). Matching method is based on the conditional independence or unconfoundedness assumption, which states that evaluator, should observe all variables simultaneously influencing the participation decision and outcome variables. This assumption is intrinsically non-testable because the data are uninformative about the distribution of the untreated outcome for treated units and *vice versa* (Becker and Caliendo, 2007).

As outlined in Equation 33 the estimation of treatment effects with matching estimators is based on the unconfoundedness or selection on observables assumption. However, if there are unobserved variables which affect assignment into treatment and the outcome variable simultaneously, a ‘hidden bias’ might arise (Rosenbaum, 2002).

In other words, if treatment and outcomes are also influenced by unobservable characteristics, then CIA fails and the estimation of ATTs are biased. The size of the bias depends on the strength of the correlation between the unobservable factors, on the one hand, and treatment and outcomes, on the other. It should be clear that matching estimators are not robust against this ‘hidden biases. Different researchers become increasingly aware that it is important to test the robustness of results to departures from the identifying assumption. Since it is not possible to estimate the magnitude of selection bias with non-experimental data, the problem can be addressed by sensitivity analysis. Rosenbaum (2002) proposes using Rosenbaum bounding approach in order to check the sensitivity of the estimated ATT with respect to deviation from the CIA. The basic question to be answered here is whether inference about treatment effects may be altered by unobserved factors. In other words, one wants to determine how strongly an unmeasured variable must influence the selection process in order to undermine the implications of matching analysis.

The bounding approach does not test the unconfoundedness assumption itself, because this would amount to test that there are no (unobserved) variables that influence the selection into treatment. Instead, Rosenbaum bounds provide evidence on the degree to which any significant results hinge on this untestable assumption. If the results turn out to be sensitive,

the evaluator might have to think about the validity of his identifying assumption and consider other estimation strategies. As noted above, it is not possible to estimate the magnitude of selection bias using observational data, instead the sensitivity analysis using the bounding approach that involves calculating upper and lower bounds, using the Wilcoxon signed rank test. This rank tests the null hypothesis of no-treatment effect for different hypothesized values of unobserved selection bias.

3.6. Variable Definitions and Hypotheses

3.6.1. Dependent variables

Willingness to pay: The dependent variable in our WTP analysis is households' willingness to pay to community based conservation practices for the purpose of controlling/eradicating the invasion of *Prosopis*. The variable is dichotomous which assumes a value of 1 whenever the i^{th} household is willing to pay money and answers "yes" to a randomly assigned bid price and 0, otherwise.

Invasion by *Prosopis*: The dependent variable for PSM is a dichotomous variable which takes a value of 1 for households from the invaded areas and 0 for households from non-invaded areas.

***Prosopis* management alternatives:** Different IAS management alternatives were used including the status quo. Except for status quo, all alternatives are supposed to improve *Prosopis* impacts which will, in turn, improve household's utility. These alternatives differ from each other by levels of attributes. This was used as a dependent variable for choice experiment model.

The outcome variables which were used in the PSM estimation are households' income from the sale of milk, income from sale of livestock, income from fire wood and charcoal, annual income from crop production, expenditure on education, food and non-food expenditure, health expenditure and calorie intake per day per AE and non-farm income.

3.6.2. Independent variables included in the models and the working hypotheses

Age of the household head (AGE): It is defined as the period from the respondents birth to the time of the interview and is measured in years. It is assumed that as the age of a household

head increase, his/her ability to eradicate *Prosopis* decreases due to limited working capacity and other related factors (Zeray, 2008). Hence, age of the household head is hypothesized to have positive relationship with the probability that a household to be affected by an invasion of *Prosopis*. Age of the household head negatively affect the probability of participating in the hypothetical market and lower WTP because the older the farmer the less his involvement in controlling or eradicating *Prosopis*. García-Illoriente *et al.* (2008), found that younger people are more aware of IAS than older people and are managing *Prosopis* invasion.

Sex of the household head (SEX): It refers to the sex of the household head taking a value of 1 for male and 0 for female. According to Dubale (2008), in Afar region, female headed households are more likely to make use of *Prosopis* than male headed households. Hence, it is assumed that female household heads can at least take a little advantage of the *Prosopis* invasion because of the experience they have in fuel wood collection and marketing in the study area. In this regard, it is hypothesized that the probability of a household to make a living in an invaded area will be higher for male headed households and lower for female headed ones. Likewise, male headed households have higher probability of participating to manage *Prosopis* in the hypothetical market and willing to pay more than female headed households.

Educational level (EDUC): It refers to the level of the household head education in class years completed. Positive effect on *Prosopis* invasion is assumed as the level of education for a household head rises. This is because educated people can easily understand the multipurpose nature of *Prosopis* than the illiterate ones (Dubale, 2006). In this context, the educational level of the household head is hypothesized to have positive effect on *Prosopis* invasion. Education was associated with lower WTP because these people usually suggest other kinds of solutions (e.g., they prefer to help with their labor and advice, but not with money) (García-Illoriente *et al.*, 2008). In this context, the educational level of the household head is hypothesized to have negative relationship with participation in the hypothetical market and lower WTP for managing *Prosopis* invasion.

Farming experience (FREX): It measures the households farming experience in years. It is assumed that households with long years of farming experience could easily realize the impact of the invasion and hence this variable is hypothesized to have a negative relationship with *Prosopis* invasion. Previous studies have also indicated that farming experience does

negatively influence the *Prosopis* invasion (Jema and Mohammed, 2013). It is also assumed that households with long years of farming experience could easily realize the impact of IAS. Therefore, it is hypothesized that the higher the farm experience is higher probability to choose improved environmental plans or participating in the hypothetical market and higher WTP.

Total cultivated land (TFL): It is a continuous variable expressed in terms of hectares of cultivated land. Households who own large area of cultivated land are expected to cultivate and earn more. Large size of cultivated land is expected to have a negative effect on the possibility of making a living in a *Prosopis* invaded areas and positive effects on the households' willingness to pay for eradication and control measures. In other words it means that, the higher the level of invasion of *Prosopis* on cropland the less likely the household is willing to pay higher bids for the complete eradication and control measures. Invasion into crop fields reduces crop productivity, implies costs for clearing (McConnachie *et al.*, 2012).

Access to irrigation water (AIRW): It is a dummy variable which takes a value of 1 for households having access to irrigation and 0 for those with no access. Since this variable may favor or disfavor the invasion, it is hypothesized that access to irrigation has an indeterminate relationship with all dependent variables. If a household uses the irrigation water for crop production purposes, then the invasion should be controlled. Otherwise, availability of water favor more invasions.

Access to rural credit service (ARCS): It is a dummy variable which takes a value of 1 for households which have access to rural credit service and 0, otherwise. As is the case in the above variable, this variable also may favor or disfavor the invasion. So, it is hypothesized that access to rural credit service has an indeterminate relationship with all dependent variables. If credits are used for crop production, *Prosopis* invasion will be tackled. But, if credits are used for non-farm activities, there is a possibility that an invasion could increase.

Perceived occurrence drought (DRTEF): It is a dummy variable which takes a value of 1 if a household's income from livestock and crop production decreased during the survey year when compared to the normal year and 0 if it remains the same. Here the assumption is that different households have different capacity to cope with the recurrent drought. Hence, it is hypothesized that recurrent drought has an indeterminate relationship with all dependent variables.

Participation in productive safety net program (SFTYNT): It is a dummy variable which takes a value of 1 for households who benefited from the program and 0 if not. Here, the assumption is that households benefiting from this program will favor *Prosopis* as they will not use it as a source of income. In other word it means that participation in the productive safety net program makes the households reluctant to take measures on *Prosopis* invasion. Hence, it is hypothesized that this variable has a positive effect on the possibility of a household to make a living in a *Prosopis* invaded areas and less probability of participating in the hypothetical market and lower WTP.

Non-farm income earning activities (NONFARM): It is a dummy variable which takes a value of 1 for households which are engaged in non-farm income generating activities and 0, otherwise. Households who have non-farm income have more purchasing power so that they seek to obtain a better state of an environment i.e. a state of controlled or eradicated of *Prosopis* invasion and hence are more willing to pay and less likely to be affected by *Prosopis* invasion. Based on this assumption, it is hypothesized that non-farm employment has a negative effect on the possibility of making a living in a *Prosopis* invaded areas and a positive effects is expected to the WTP for control and eradication measures. According to Ilukor (2014), the likelihood to accept higher bids for the mitigation measure increases with household non-farm income. This is due to the consideration of a *Prosopis*-free environment is like a normal good for the households whose demand increases with increasing income from non-farm activities.

Distance from market center (DISMRKT): It is a continuous variable indicating the distance of residential area to the city of Dire Dawa in kilometres. Dubale (2006), stated that households which are nearer to urban areas make better use of *Prosopis*, as it will be easier for them to cut and sell it to urban households, than those situated at a relatively far distance. Hence, it is hypothesized that this variable will have a positive relationship with the probability of a household to reside in an invaded area by *Prosopis* and lower probability of participating in the hypothetical market and lower WTP.

Family size (HOUSESIZE): It is a continuous variable which indicates the number of family members. Larger family size contributes large family labor to use *Prosopis* as a source of income or more labor is available in the house for fuel wood collection. Hence, family size

is expected to negatively affect *Prosopis* invasion. A negative effect is expected between family size and the WTP for the control or eradication program. The WTP for the eradication and control of *Prosopis* invasion is expected to decrease as family size increases. It is because a household with large family size has more labor for fuel wood collection and charcoal production.

Livestock holding (TLU): It is a continuous variable which refers to the total number of livestock a household owns in terms of TLU (Tropical Livestock Unit). Invasion onto grazing areas and associated loss of grazing territories, results in shortage of animal feed, decreasing livestock production and productivity, migration to new areas in search of new grazing areas, conflict among communities about grazing area (Mwangi and Swallow, 2008). Ownership of livestock can be an indicator of wealth for rural society so that a positive effect on WTP and negative effect on the possibility of making a living in a *Prosopis* invaded areas.

Occupation (OCCP): It is a dummy variable which takes a value of 1 for the agro-pastoral households and 0 for the non agro-pastoral households which include (crop-producer, traders, and civil servants). Studies conducted in Afar shows that the likelihood to accept higher bids is lower for the non-pastoral households (Ilukor, 2014). Hence, it is assumed that agro-pastoral households are willing to pay more money than others. Based on this assumption, it is hypothesized that agro-pastoral households' will have higher probability of participating in the hypothetical market and affect the WTP positively.

Utilization of *Prosopis* (HBLUP): It is a dummy variable which takes a value of 1 for the households who benefited from the *Prosopis* and 0, otherwise. Households who are utilizing *Prosopis* have a lesser probability to participate in the hypothetical market. It means that, households benefiting from the local uses of *Prosopis* would be against both the complete eradication option and controlling further expansion through productive use (Tilahun *et al.*, 2015). Management of *Prosopis* through utilization is expected to decrease the probability of households making their living in the *Prosopis* invaded area.

Total income (INCOME): This is the annual income of the household in Birr. Since income reflects the ability to pay, a positive relationship is expected. Higher household income indicates higher WTP so that income is positively associated with WTP for both intervention options. Based on this assumption, it is hypothesized that income of a family is expected to

have higher probability of participating in the hypothetical market and affect the WTP positively. According to Tilahun *et al.* (2015) family income and wealth have a positive effect on the likelihood of saying ‘Yes’ to the valuation question of *Prosopis* invasion management. The relationship between income and probability of finding a household in the *Prosopis* invaded area is indeterminate.

DR (dependency ratio): This is the ratio of dependent household member (age less than 15 and above 65) to the number of economically active family members (age between 15 and 65). A household with more economically inactive labor force compared to the economically active labor force shows a high dependency ratio. Households who have higher dependency ratio consequently have higher opportunity cost of paying for control and eradication measure. In contrast if the composition of the family is dominated by working class, the better will be their purchasing power so that more willingness to pay is expected from the household.

Bid value (bid): The randomly assigned bid price is expected to influence the likelihood of accepting that bid and the maximum willingness to pay. Four bid levels were determined through pilot survey. And it is expected that higher bid values have a negative effect on households willingness to pay for eradication and control measures of *Prosopis* invasion i.e. households are expected to be rational in the face of increasing costs and hence the law of demand holds. The law of demand indicates that the higher the bid price, the less likely households would be willing to pay for either of the interventions against *Prosopis* invasion. The willingness of households to pay either the complete eradication option or to control further expansion of *Prosopis* in their village are significantly and negatively affected by the amount of the bid terms (Tilahun *et al.*, 2015). Based on this assumption, it is hypothesized that bid value will have a negative effect on the households WTP for control and eradication measures of *Prosopis* invasion.

Physical injury incidence (PIOHMTP): It is a dummy variable which takes a value of 1 for household’s whose members had experienced physical injury caused by the thorns of *Prosopis* and 0, otherwise. According to Ilukor (2014), households whose members experienced physical injury caused by the thorn of *Prosopis* were more willing to pay for management measures than households whose members did not experience such an injury. Therefore,

WTP for both management intervention options and incidence of physical injury on household members caused by thorn of *Prosopis* is expected to positively affect WTP. Experiencing an injury incidence is, however, expected to relate negatively with the probability of households living in *Prosopis* invaded areas.

Attitudes toward paying a fee (ATTITUDE): The primary variable of interest is attitudes and intended behaviors associated with a possible annual fee for control/eradication of IAS. Attitudes will be measured by asking respondents to what extent they opposed or supported a mandatory annual use fee. The strength and direction of attitudes toward paying an annual fee were measured using a 5-point scale of 1 “strongly oppose” to 5 “strongly support” an annual fee, with 3 representing “neither”. Respondents who reported that they “support” or “strongly support” an annual fee were considered to hold positive attitudes toward paying fees for control/eradication of invasive alien species, whereas those who reported “oppose” or “strongly oppose” were considered to have negative attitudes toward this fee (Rosenberger, 2012). Finally, it is hypothesized that attitudes toward paying a fee will have a direct association with the WTP.

4. RESULTS AND DISCUSSION

In this chapter, descriptive statistics and econometric model results are presented and discussed.

4.1. Descriptive Statistics Results

As already noted, the present study is based on data collected from a total of 450 sample households, of which 250 households are from the four *Kebeles* which are invaded by *Prosopis* and the rest 200 households are from the three non-invaded rural *Kebeles* of the administration.

4.1.1. Descriptive statistics of sample households' characteristics

As indicated in Table 1, the average age of the 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 6.30 persons or 5.60 in adult equivalent while that of the non-invaded households' was 6.27 persons or 5.41 in adult equivalent. The t-test results for mean differences in age distribution were statistically significant and mean differences of the family sizes between the two groups is insignificant.

Proximity of households to market center/the city/ and main road of Dire Dawa were also assessed and the result showed that the average distance travelled by households from the invaded and non-invaded areas to the city were 3.82 and 13.74 Kms, respectively while the corresponding distances from the main road were 1.84 and 2.48 Kms. The t-test results showed that there is a statistically significant difference at 1% and 10% levels of significance, in proximity of households to market centre and main road, between means of the two groups, respectively (Table 1).

A closer look at an economically active family members in the sampled households (15-65 years old) showed that treatment households (household affected by invasion) had relatively larger active family members, accounting to about 3.41 persons, than the control group of households which is found to be about 2.79 persons. This implies that, on average, the households from the invaded *Kebeles* have relatively more labor force than those households from the non-invaded *Kebeles*. However, the treatment households have a slightly lower average dependency ratio (1.03) than control households (1.06) implying

that every economically active person in the *Prosopis* invaded and non-invaded areas had to support more than one economically inactive person.

It has been learnt from the FGDs that, labor shortage is not observed as a problem in the study area. The main reason is due to small size of farm land owned by individual as well as, the majority of households are engaged largely in livestock production.

Farming experience of the sample households was also assessed and the result showed that, on average, households from *Prosopis* invaded area had 26.11 years of farming experience while their counterparts had an average of 20.14 years of farming experience. The t-test results in Table 1, indicated that there is a statistically significant difference between the two groups in mean years of farming experience at 1% level of significance.

Livestock holding, as a wealth indicator shows the capacity of agro-pastoral households to involve in a high return income sources. As shown in the Table below, livestock holding in TLU was 5.03 for treatment group and 4.61 for control group. This implies that livestock owned by households in invaded areas is higher than that of the non-invaded areas. However, the mean difference is statistically insignificant at conventional levels.

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 the sampled households varied from no farm land (1.7%) to greater than one hectare (30.2%) out of which 20.2% belonged to the treatment (invaded) areas and the rest 10% belonged to the control group (non-invaded). 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 group (non-invaded) and 2.4% from the treatment group held less than 0.5 hectare of farmland. About 10.9% from the control and 11.1% from the treatment group owned 0.5 hectares of cultivated land, while 10.2% of households in the control group and 10.4% of households in the treatment group (invaded) owned one hectare of cropland. Consensus reached at various FGDs show that the small size of plots accompanied with some environmental stresses in the study areas have further aggravated the already existing agricultural practices and of course adversely affected crop production.

Table 1. Scio-economic characteristics of sample households by household type

Independent Variables	Invaded N=(250)		Non-Invaded N = (200)		Total Sample households N=(450)		Means Difference		t-value
	Mean	STD	Mean	STD	Mean	STD	Mean	STD	
Age (years)	42.490	10.208	38.58	11.004	40.545	10.777	3.91	-0.796	-3.694***
Active labor force (number)	3.411	1.802	2.970	1.756	3.192	1.791	0.441	0.047	-2.484**
Distance to road (Kms)	1.840	2.421	2.475	4.027	2.155	3.330	-0.635	-1.606	1.918*
Distance to market (Kms)	3.824	3.872	13.736	5.618	8.756	6.914	-9.912	-1.746	20.614***
Farm expience (years)	26.109	10.902	20.135	8.210	23.137	10.098	5.974	2.692	-6.202***
Family size (number of persons)	6.302	2.496	6.270	2.254	6.286	2.376	0.032	0.242	-0.135NS
Dependency ratio (ratio scale)	1.030	0.072	1.056	0.075	-0.026	-0.003	1.288	1.051	2.678***
Family size in AE	5.578	2.152	5.407	1.894	5.493	2.027	0.171	0.258	-.843NS
Total land holding (ha)	2.621	2.369	2.148	2.211	5.493	2.027	0.474	0.158	-2.073**
Total livestock holding (TLU)	5.033	3.214	4.610	3.271	4.820	3.246	0.423	0.057	1.308NS

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

Table 2. Land holding size of sample households by household type

Land size (ha)	Non-Invaded		Invaded		Total	
	Number	%	Number	%	Number	%
No cultivated land	2	0.4	6	1.3	8	1.7
<0.5	14	3.1	11	2.4	25	5.6
=0.5	49	10.9	50	11.1	99	22
0.5<x<1	44	9.8	45	10.0	89	19.8
=1	46	10.2	47	10.4	93	20.7
>1	45	10.0	91	20.2	136	30.2
Total	200	44.4	250	55.6	450	100.0

Source: Own computation results based on survey data, 2015.

As far as educational status of the household heads is concerned, nearly 80% and 66% of households from *Prosopis* invaded and non-invaded *Kebeles* were illiterate, respectively. Only 19.8% from the invaded and 34% from the non-invaded *Kebeles* attended primary education. The result of chi-square test showed that there is a statistically significant difference in the educational status of household heads at 1% level of significance between the two groups. As the result indicates, majority of households who are confronted 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 (Table 3). The results also indicated that 88% and 12% of households from *Prosopis* invaded areas and 82% and 18% of households from areas non-invaded were male headed and female headed, respectively. The χ^2 -test result for differences in the sex of the household heads between the proportions of the two groups is significant 10% significance level.

In both *Prosopis* invaded and non-invaded areas, it was observed that 64.4% and 50.5% of the households were engaged in food for work, respectively. This implies that more than half of the households are not in a position to feed themselves using from income generated from crop and livestock production. The average number of food secured and insecure households was assessed based on the calorie intake levels of sample households 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 food uncertainty. The result of the chi square test showed that there is a significant difference among the two groups in the proportions of food secured people at 5% level of significance (Table 3). The group discussions have also indicated that the majority of the community were engaged in the productive safety net program as they are food insecure. This serves as a coping mechanism against environment related-problem particularly drought.

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 use 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 shows that the difference between the two groups is statistically significant at 5% (Table 3).

It was also observed that 41.2% of the households 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 Table 3, 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 cooperatives respectively. While only 28.4% from the invaded and 72.50% from the non-invaded *Kebeles* are members of cooperatives. The result of chi-square test showed that there is a significant difference in the proportion of household heads' membership to cooperatives at 1% level of significance between the two groups.

Table 3. Scio-economic characteristics of sample households by household type

Pre-interv. Variables	Description	Invaded (N=250)		Non-invaded (N=200)		Total (N=450)		χ^2
		No	%	No	%	No	%	
Sex of the head (1=male)	Male	220	88	164	82	384	85	2.963*
	Female	30	12	36	18	66	15	
Education level of the head (1= illiterate)	Illiterate	200	80	132	66	332	73	10.311***
	Literate	50	20	68	34	118	27	
Cooperative membership (1=yes)	Yes	71	28.4	145	72.50	216	50.45	25.604***
	No	179	71.6	94	46.50	273	59.05	
Credit access (1=yes)	Yes	103	41.2	68	33.66	171	37.43	2.153NS
	No	147	58.8	132	65.35	279	62.08	
Perceive occurrence Drought (1=yes)	Yes	175	70	190	94.06	365	82.03	43.879***
	No	75	30	10	4.95	85	17.475	
Food security status (1=food secured)	Food secure	126	50.4	81	40.5	207	45.45	4.048**
	Not food secure	124	49.6	119	59.5	243	54.55	
Participation in productive Safety Net program (1=yes)	Yes	161	64.4	102	50.5	263	57.45	7.346***
	No	89	35.6	98	48.51	187	42.06	
Irrigation access (1=yes)	Yes	22	8.8	56	27.72	78	18.26	24.383***
	No	228	91.2	144	71.29	372	81.25	

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

4.1.2. Descriptive results of outcome variables

Table 4 shows that there were significant differences between the two groups of sample households with respect to expenditure on education, milk income, income from livestock sale, income from sale of fuel wood and charcoal production, annual income from crop production, food and non-food expenditure, health expenditure and calorie intake per day per AE. However, there were no significant differences between the two groups of sample households with respect to non-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 465.12 per annum. The average education expenditure for households from *Prosopis* invaded and non-invaded kebeles is Birr 562.644 and Birr 366.62, respectively. The t-test result shows that there is a statistically significant difference among the two groups at 1% probability level in terms of expenditure on education.

The quantity of milk produced by the households was estimated on the basis of the number of milking animals and the amount of milk that the average cow, goat, sheep and camel produced. The descriptive result shows that there is a statistically significant difference between the two groups of households at 5% probability level in mean income from milk sale by households from the *Prosopis* invaded and non-invaded kebeles which are Birr 656.99 and Birr 941.05, respectively. Focus groups aired that, reduced pasture availability (caused by *Prosopis* invasion) and frequent rain shortage are the main problems in the milk production. Pasture availability is of course one of the factors determining cow 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.

Income from livestock sale is the sum of money households obtained from sale of live livestock. The mean annual incomes from livestock sales in *Prosopis* invaded and non-invaded areas were Birr 1719.95 and Birr 2161.13, respectively. The t-test result reveals that there is a statistically significant difference between the two groups at 10% probability level. This result is in line with that of Pasiecznik (1999) which reported that *Prosopis* invasion forms impermeable, dense thickets reducing grazing areas. The same source also stated that the invasion reduces grass cover of grazing lands and consequently affects stocking density.

The mean incomes from fuel wood and charcoal sales in *Prosopis* invaded and non-invaded areas were Birr 1235.46 and Birr 561.20, respectively. The t-test reveals that there is statistically significant difference in income generated from sale of fire wood and charcoal. This may be due to the motive to reduce its impacts through utilization by the local people's preference against other indigenous bush or abundance driven actions. For agro-pastoralists in the study area utilization of *Prosopis* is found to be abundance driven.

Explicit costs such as costs for fertilizer, pesticides, seeds and labor costs, taking a minimum wage of 20 Birr 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 purchase and sales prices. Based on this estimation, the mean annual income generated from crop production in *Prosopis* invaded areas is Birr 3053.03 while it is Birr 2215.01 for non-invaded areas. There is a significant difference in income generated from crop production between invaded and non-invaded areas and the t-value of -3.94 suggests that this variable is significant at 1% probability level. This study is also in line with Jema and Mohammed (2013) who confirmed that *Prosopis* invasion is attributed to have resulted in increased crop yields by 29%. *Prosopis* has positive effects onto 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 *Prosopis* canopy was found to be better than the adjacent open field (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 (Pasiiecznik *et al.*, 2001).

In the Focus Group Discussions, few discussants from the *Prosopis* invaded areas have reported that, even if land clearing has been a tiresome activity, land cleared of *Prosopis* provides better harvest as compared to previously farmed lands and suspected that it could be due to fertility improvement by *Prosopis*.

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 for households from invaded and non-invaded areas is Birr 9879.327 and Birr 6429.45, respectively. The t-test result reveals that there is a statistically significant difference between the means of the two groups at 1% probability level.

Health expenditure is a sum of money spent for medication by the family members and their animals. The mean health expenditure of households residing in the *Prosopis* invaded and non-invaded areas is Birr 243.16 and Birr 153.10, respectively. The t-test result reveals that there is a statistically significant difference between the two groups at 1% probability level.

Results also show that households from the two contrasting areas had a calorie intake of 2704.4 and 1859.7 calories 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 household AE. Finally the computed kilocalorie per AE in each household was compared with the minimum subsistence energy requirement per AE per day, 2100 kcal. Calorie intake of households from the invaded areas appears to be higher than those who are earning their livelihoods in the non-invaded areas (see Table 4). This may be due to *Prosopis* driven livelihood diversification strategy pursued by the affected 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 intake per day per AE of the households from invaded areas were higher than that of non invaded areas, milk income and income from livestock sale are low in the invaded areas compared to the non invaded ones. However, it does not mean that the mean difference is exclusively due to 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 rigorous analysis was conducted using propensity score matching techniques to strengthen the findings.

Table 4. Current income, expenditure and calorie intake of sample households by household type

Variables	Invaded N=(250)		Non Invaded N = (200)		Sample Household N=(450)		Means Difference		t-value
	Mean	STD	Mean	STD	Mean	STD	Mean	STD	
Education expenditure	562.644	485.170	366.620	301.501	465.119	415.608	169.024	183.669	-4.860***
Average annual income from livestock sale	1719.946	2651.149	2161.128	2267.842	1939.439	2474.703	-441.182	383.307	1.792*
Average annual income from milk sale	656.990	1130.953	941.050	1663.434	798.313	1426.359	-284.06	-532.481	2.004**
Average annual income from fuel sale of wood and charcoal	1235.460	2223.456	561.200	1529.271	900.008	1937.154	674.26	694.185	-3.539***
Average annual income from crop sale	3053.03	2350.367	2215.006	1881.040	2636.106	2168.163	838.031	469.326	-3.944***
Non-farm income	6173.871	9412.567	5036.040	14727.954	1137.831	-5315.39	5607.786	12344.15	-0.9240NS
Food and non food expenditure	9879.327	5684.264	6429.45	5636.152	8162.970	5911.239	3449.877	48.112	-6.110***
Health expenditure	243.158	252.378	153.170	295.857	198.388	278.198	89.988	-43.48	-3.282***
Calorie intake per AE	2704.443	1718.556	1859.700	1165.135	2284.173	1527.393	844.743	553.422	-5.763***

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

4.1.3. Farm characteristics and crops grown

In the study area, subsistence mixed farming is the dominant farming system constituting 91.11% of the households in the study area. Sorghum is the major crop produced. It is a number one crop produced by almost all the surveyed households and of course took the lion's share in volume of production mainly because of its better adaptability or resistance to drought.

Table 5. Participation of sample households by the types of farming

Activities	Freq.	Percent
Crop only	28	6.22
Livestock only	12	2.67
Agro-pastoralist	410	91.11
Total	450	100

Source: Own computation results based on survey data, 2015.

4.2. Persepectives of Stakeholders Involved in *Prosopis* Management

4.2.1. Stakeholder's roles and responsibilities

This assessment was carried out based on the information gathered through focus group discussions and key informant interviews made with those who are concerned with the management of *Prosopis*. The stakeholders who are involved in the management of *Prosopis* in the administration are Dire Dawa Administration Council, Dire Dawa Environmental Protection Authority, Hararghe Catholic Secretariat, Haramaya University and Agricultural and Rural Development office. Hence, the assessment has focused on these stakeholders. Results of the assessment are provided below.

Results of the assessment indicates that the administration council has no concern about the stubborn encroachment of *Prosopis*. According to the key informants from the administration council, the area invaded by *Prosopis* is considered to be under urban expansion plan. Thus, *Prosopis* related problem has not been on their agenda.

Dire Dawa Environmental Protection Authority is the only governmental body that is responsible for the management of *Prosopis*. This institution is accountable to the Ministry of Environment and Forest. The Ministry gave statutory mandate to the Environmental Protection Authority (EPA) to coordinate the Climate Resilient Green Economy (CRGE) planning as well as the strategy for 'Reducing Emissions from Deforestation and Degradation. Consequently, the Dire Dawa Environmental Protection Authority takes the responsibility to manage *Prosopis* invasion in the administration. For

instance, for the purpose of managing *Prosopis* invasion, this institution organizes the community and provides equipment for charcoal making.

The other stakeholder involved in such activities is Hararghe Catholic Secretariat. This is a local non-governmental organization which is engaged in developmental and relief activities. Interviewees from this organization have mentioned that the organization has tried to clear *Prosopis* infested land through cooperation with the agro-pastoral community. However, the activity was being carried out without an adequate follow up from the concerned bodies and consequently it was terminated without meeting its objectives.

Haramaya University is one of the Ethiopian Higher Education Institutions which allows PhD and MSc students to do research on *Prosopis*. The research findings can be a valuable resource for the management of *Prosopis* particularly for Dire Dawa Administration. But the findings of the studies related to *Prosopis* were not utilized by the administration.

Agriculture and Rural Development Offices of Dire Dawa has responsibilities and duties assigned to it by the Ministry of Agriculture. Conservation and use of forest and wildlife resources, food security, water use and small-scale irrigation, monitoring events affecting agricultural development and early warning system, promoting agricultural development, and establishing and providing agriculture and rural technology training are among the responsibilities of the office.

Although the Agriculture and Rural Development Office of Dire Dawa is expected to play a leading role, the office is not living to the expectations with respect to the managements of IAS. In other words, the office gives little attention for the managements of IAS. Therefore, the office has to assume its responsibility and play a leading role in checking the expansion of IAS in the study area.

4.2.2. Stakeholder's perception towards environmental problems

Identification of stakeholders' perceptions of stakeholders towards the environmental problems has also been dealt with. Data was collected using questionnaire from Dire Dawa Administration Council, Dire Dawa Environmental Protection Authority, Hararghe Catholic Secretariat, Haramaya University and Dire Dawa agriculture and rural Development offices. The survey result obtained from 45 respondents (which were made to rank the major environmental problems of the administration) shows that increasing

drought incidence and temperature ranked as the top two major environmental problems of the administration followed by an increased biological invasions. Increasing rainfall variation, flood, biodiversity loss, food insecurity and livestock disease are ranked in descending order next to increasing biological invasion. As biological invasion is ranked third, the problem of *Prosopis* invasion can be considered as an epicenter of the issue.

Table 6. Ranked stakeholders' perceptions environmental problems

Environmental problem	Rank
1. Increased temperature	2
2. Increased rainfall variation	4
3. Increased flood	5
4. Biodiversity loss increased	5
5. Livestock disease Increased	6
6. Increased food insecurity	5
7. Biological invasions increase	3
8. Drought incidence increased	1

Source: Own computation results based on survey data, 2015.

In Dire Dawa Administration, so far there is no sound governmental and non-governmental intervention to manage *Prosopis* invasion. There is no an organization who volunteers to play a leading role to control and manage *Prosopis* invasion by integrating or coordinating efforts of different stakeholders. Management and control of *Prosopis* require coordinated and integrated approach where different actors who have a stake in *Prosopis* management should work together to find an optimum solution that might allow to halt *Prosopis* invasion related risks.

4.3. Results of Total Economic Values of *Prosopis* Invasion

This section presents and discusses the analysis results of TEV of *Prosopis* invasion in rural Dire Dawa Administration. The valuation process has been done after conducting a literature review. Above all, the benefits and costs were filtered out, and the remaining ones were gradually separated or grouped under new, more useful analysis headings that indicated the benefits analyzed together in one value entity, so as to avoid overlapping in the monetization process. Some remaining impacts that were identified at the framed research sites were qualitatively assessed and described but left without monetizing.

The TEV analysis results from the study area can be considered almost free from overlapping of benefits and costs, particularly due to the reason that some of the most difficult-to-monetize environmental services were actually not valued but left at a

descriptive level, when it could be seen that these services could be defined as positive impacts.

As discussed in the literature review, it is understood that TEV is sum of the values, which a natural resource will be able to have. This concept was popularized by David Pearce (Perman *et al.*, 1995). As the TEV concept is a sum of values, there are some components of the sum. These components are presented and explained under the following sub-headings.

4.3.1. Benefits of *Prosopis* in the invaded area

As far as the beneficial uses of *Prosopis* are concerned, a largest portion of the households (73.76%) use *Prosopis* as a source of fuel wood and for charcoal production. As a result, *Prosopis* has become a major source of income for rural households in the study area. About 68.32% of the households use *Prosopis* as a source of feed for livestock. This is because pods of *Prosopis* are used as fodder for their animals during drought seasons.

Prosopis grows vigorously in the desert areas with an evergreen leaves and stems under moisture stressed conditions, thereby improving the microclimate. According to the sample households, the natural stands of the plant play significant role in reducing soil erosion (2.48%), reduced wind speed (23.27%), use as a fencing material (15.84%), use for house construction (7.43%) and micro climate regulation (10.40%). The remaining 2.48% of the households use it for soil fertility improvement (Table 7).

Table 7. Benefits of *Prosopis* in the rural Dire Dawa administration

Benefits	Percent	Rank
Source of feed for livestock	68.32	2
Fuel wood and charcoal	73.76	1
Wind break	23.27	3
Fencing material	15.84	4
Micro climate regulation	10.40	5
House construction	7.43	6
Enhance soil fertility	2.48	7
Reducing soil erosion	2.48	7

Source: Own computation results based on survey data, 2015.

4.3.2. Adverse effects of *Prosopis* in the invaded areas

The survey result indicates that the largest proportion (82.7%) of the households attached its adverse effects with a decrease in grazing land and forage availability followed by decline in ground water availability (69.31%), decline in arable land (55.45%), loss of biodiversity (48.51%), damage to the livestock and human beings due to its thorny nature

(42.57%), blocking roads and waterways (47.03%), host to predators (33.67%), and competition for labor (35.64%). This implies that *Prosopis* invasion has significantly affected the grazing land and forage availability and consequently livestock production and productivity.

Table 8. Adverse effects of *Prosopis* in the rural Dire Dawa administration

Disadvantages	Percent	Rank
Loss of grazing land and feed stock for livestock	82.67	1
Invasion of arable land	55.45	2
Damage to the livestock and human beings due to its thorny nature	42.57	3
Blocking roads and waterways	47.03	4
Host to predators	33.66	7
Loss of biodiversity	48.51	5
Reduce ground water	69.31	6
Competition for labor	35.64	8

Source: Own computation results based on survey data, 2015.

4.3.3. Economic values of benefits and costs of *Prosopis* invasion

Environmental income: The main local uses of *Prosopis* reported by the sample households are documented in Table 7. Environmental income were estimated from individuals' responses to a question that sought to find out the quantities of various products harvested from *Prosopis* and whether those products were used for home use, sale or both. Quantities harvested, whether they were for sale or home use or both, were used to estimate the total value derived from those products. Prices were averaged for households in each location who gave Ethiopian Birr values, and these prices are used to calculate the value of both home consumed and marketed products. But for the purpose of estimating *Prosopis* use as a livestock feed, choice experiment was employed (see Appendix Table 2). Accordingly, the total value of the environmental good or income that relates directly to use of *Prosopis* by the rural Dire Dawa households is about 6,476,292 Birr per year. Fuel wood harvesting is a daily activity and the main biomass resource, often 2 to 3 times a week for the entire year. Pods and leaves for livestock fodder are usually harvested in the dry season.

Table 9. Economic value of *Prosopis* products for sample households (in Birr)

Products	Average value	Standard dev.	Total Value
Fencing poles	814.85	1941.62	2,281,584.00
Fuel wood and charcoal	1229.37	2223.46	3,442,236.00
Construction poles	202	626.65	565,600.00
Feed for livestock	-	-	191,295.30
Total			6,480,715.3

Source: Own computation results based on survey data, 2015.

Effects of *Prosopis* on crop income: Based on the evidence obtained from PSM data analysis results, the invasion has brought significant changes on household income generated from crop production or it has been found that, on average, the invasion has increased annual income from crop production by 529.43 Birr per household. The total increase in crop income due to *Prosopis* in rural Dire Dawa administration is approximately 2,631,267 Birr per year (see Table 10).

The estimated positive difference in average annual income from crop production for the invaded households is believed to arise from fertility improvement by *Prosopis* and its contribution to soil and water conservation, which was mentioned by some of the participants in the group discussion held at the invaded *Kebeles*. This result is in line with most of the research works conducted on the contribution of *Prosopis* to soil fertility. The soil properties in highly infested sites are suitable for plant growth or crop production once *Prosopis* has been removed (Ilukor *et al.*, 2014). *Prosopis* invasion has also been linked to increased crop yields per hectare because it has the ability to improve soils by fixing nitrogen, mulching the soil with its leaves and desalinizing the soils (Felker *et al.*, 2001; Kahi and Ngugi, 2009).

Micro-climate regulation (Carbon sequestration): According to Kassahun *et al.* (2005), *Prosopis* in Ethiopia is generally described as short-multistemic (6-8 basal stems) with spreading canopy of twisted branches. The same holds true in Dire Dawa Administration.

According to Kaur *et al.* (2012), *Prosopis* trees have provided protection as well as food for wild animals and ameliorated environmental conditions through carbon sequestration. Felker *et al.* (1990) estimated that *Prosopis* can sequester carbon biomass extending from 0.65 kg to 1300 kg per stem which is equivalent to 2-20 tons per hectare. *Prosopis* has been useful in regulating climate and reducing expansion of desertification (Ilukor *et al.*, 2014).

Studies in Dire Dawa administration shows that *Prosopis* invaded areas have a mean soil organic carbon density (SOCD) of (43.4 ton/ha) next to plantation/forest area (62.6 ton/ha). This result is in line with the findings of other studies (Mulugeta and Fisseha, 2004b; Mulugeta *et al.*, 2005; Solomon *et al.*, 2002) that indicated increment of soil organic carbon in ecosystem as the number of plant species and above ground biomass increases. Increased plant biomass above and below ground as well as higher organic matter content in soils through *Prosopis* invasion can contribute to capturing CO₂ from the atmosphere, which is important for climate change mitigation (Hasen-Yusuf *et al.*, 2013).

Results from choice experiment analysis revealed that the value of micro-climate regulation (carbon sequestered) in the study area is 330,256.50 Birr (see Table 10 and Appendix Table 2).

Effects of *Prosopis* on animal production and health: For valuations of livestock production and productivity, agro-pastoralists were asked to state the number of animals affected in the previous year, number of animals died or slaughtered, and to estimate the loss in weight as well as milk production that they attributed to the invasion of *Prosopis*. These information were collected for each of the five categories of livestock. For products that are traded in the market like milk and meat, the revealed preference method was used. According to OECD (2006), revealed preference methods based on cost of illness and lost output calculations are based on the observation that intangible impacts can, through an often complex pathway of successive physical relationships, ultimately have measurable economic impacts on market quantities.

The results reveal that 15.67%, 6.58%, 1.67% and 5.56% of the cattle, sheep, goats and camel respectively, are either physically injured by *Prosopis* thorns or affected by *Prosopis* pods in each household per year. The amount of milk produced by the households' owning livestock was calculated on the basis of the number of milking animals, lactation periods and the amount of milk that the average cows, sheep, goats and camels produced. The income generated from milk production was calculated using six months of average lactation period for cow, three months for goat and nine months for camel with an average daily yield of 1.9, 0.7 and 3.5 litres per day, respectively. The total value of milk loss in rural Dire Dawa for the sample households, as a result of *Prosopis* invasion is about 2,041,029.90 Birr. In addition, the total weight loss associated with pasture problems created by *Prosopis* per animal is 10, 3, 3, and 9 kilograms for cattle, sheep, goats and camel per year respectively. The total weight loss associated with *Prosopis* is about 3,634,217 Birr. In addition to this, heavy dependency of livestock on *Prosopis* pod for survival, as it can abundantly be found even during drought period resulted in *Prosopis* borne health hazards and adversely contributed to livestock production and productivity. The total animal lost due to diseases that were caused by the excessive feeding *Prosopis* was estimated to be 5,157,567.80 Birr in Rural Dire Dawa administration. In sum, the estimated total loss of the animal production portfolios due to *Prosopis* stands at about 10,832,814.70 Birr.

Table 10. Average and aggregate benefit and loss measures

	Total HH	MWP	Total value
Benefits			
Feed for livestock	4970	37.6	186,872
Crop income	4970	529.43	2,631,267
Micro climate regulation	4970	67.61	336,021.70
Losses			
Biodiversity loss	4970	78.64	390,840.80
Milk loss	4970	410.67	2,041,030
<i>Prosopis</i> related disease (livestock)	4970	1037.74	5,157,567.8

Source: Own computation results based on survey data, 2015.

Table 11. Sample households' affected by *Prosopis* invasion by livestock type

Type of livestock	Total	<i>Prosopis</i> affected	Percent
Cattle	134	21	15.67
Goat	2087	35	1.68
Sheep	395	26	6.58
Camel	36	2	5.56

Source: Own computation results based on survey data, 2015.

Table 12. Total number of livestock affected by *Prosopis* invasion in the whole study area by livestock type

Type of livestock	Total no. of livestock	Percent (<i>Prosopis</i> affected)	Weight loss	Total loss in Birr
Cattle	8824	15.67	10	1659265
Goat	53847	1.68	3	325666.7
Sheep	8609	6.58	3	203930
Camel	24070	5.56	9	1445355
Total				3,634,217

Source: Own computation results based on survey data, 2015.

Effects of *Prosopis* on Human health: The invasion of *Prosopis* affects human health negatively. Based on the information obtained from Melka Jebdu Health Center, the incidence of *Prosopis* invasion associated health risk in the district appears to be 5 - 10 cases per month. According to the information received from a health professional, the cost of medical treatment for a less severely affected individual by *Prosopis* is 10 Birr per person and up to 300-500 Birr for a severe one. In the study area, the thorns of *Prosopis* are inflicting wounds on legs, hands and eyes causing blindness, lameness and even amputation of legs and hands due to infection of wounds. Agro-pastoralists have complained during the FGDs and personal communication that, the thorns of *Prosopis*

inflict severe inflammation that does not heal easily unless intensive medical treatments is received.

Results reveal that about 22% of the households had their member(s) physically injured by *Prosopis* thorn in a given year. On average two of the household members (out of the average of 6.77) get physically injured by *Prosopis*. Physical injury had forced an average loss of 22.28 labour days per households per year. In such a scenario, the average cost of treating a person injured by *Prosopis* is 356 Birr. The total loss per household per year due to human health becomes 801.6 Birr which totals to about 3,983,952 Birr per year in the *Prosopis* invaded areas of rural Dire Dawa. Based on the above survey results, one could conclude that *Prosopis* had a clear aggravating effect on the already fragile health conditions of rural households.

Effects of *Prosopis* on biodiversity loss: The invasion of invasive alien species is causing environmental crises and huge losses on biodiversity (Manchester and Bullock, 2000; D’Antonio and Kark, 2002). According to the Global Invasive Species Database, *Prosopis* is one of such species. D’Antonio and Kark (2002), described such plants are mostly characterized by high ecological adaptability and vigorous growth even in harsh climate to cover huge acreages. The introduction of such plant species are often meant for reclaiming eroded lands in a given area, but subsequently the plant invades other land use systems, like arable lands and grazing lands of the area. Studies in Ethiopia reveal that *Prosopis* invasion has been devastating; rangeland areas have been degraded, and forage grass productivity has declined drastically as a result (Wakie *et al.*, 2014; Angassa and Oba, 2008). They affect people’s livelihoods by threatening their means of stay like grazing areas and farmlands; either by reducing its productivity or completely denying access (Admasu 2008; Amdihun *et al.*, 2010). This further worsens the living conditions of resource poor rural people of developing countries. With the loss of indigenous grasses and other plant species, the main fodder resource for grazers such as cattle, and the number and productivity of animals has reduced substantially (Hamedu, 2014).

According to Jema and Mohammed (2013), forage/fodder cover of grazing areas has reduced in the past ten to fifteen years in *Prosopis* invaded areas of Dire Dawa administration. The authors further argue that, recurrent drought and *Prosopis* invasion are the most important factors for decline in forage /fodder availability.

Focus group discussion results stressed that the invasion threatened some grass species which are the major source of feed for their cattle. Accordingly, nearly thirty different

grass species were perceived to be threatened by *Prosopis* in the invaded *Kebeles*. Grass species known by their vernacular/local names such as *Serdu*, *Balbalessa Hadhawa*, *Hollagabis*, *Metasedi*, *Buran*, *Daremo*, *Cawis macaan*, *Nafriy*, *Kundi*, *Agar*, *Gumer*, *Deberduli*, *Cashcade*, *Andekis*, *Shakume*, *Maddhbur*, *Dunfure* and *wechere* are reported to the most affected grass types due to *Prosopis* invasion in the study area.

As clearly shown in Tabel 8, loss of grazing land and forage availability (82.67%), decline in ground water potential (69.31%), decline in invasion of arable land (55.45%) and loss of biodiversity (48.51%) are the top four ranked negative effects of *Prosopis* in the study area. This implies that *Prosopis* invasion does significantly affect the grazing land and forage availability and consequently livestock production which is in agreement with the findings of Shiferaw *et al.* (2004), who reported that *Prosopis* invasion is threatening livelihood of pastoralists and agro-pastoralists due to loss of pasture and indigenous trees and destruction of croplands. Similar problems were also reported elsewhere (Al-Humaid and Warrag, 1998; Gavali *et al.*, 2003; Nakamo *et al.*, 2003; Esther and Brent, 2005; Zeray, 2008).

In addition, one of the main threats of *Prosopis* in rural Dire Dawa administration is loss of biodiversity, mainly pasture production and other plant species. The method used for valuing biodiversity was the choice experiment approach. The values of pasture lost's is used as a proxy value for biodiversity loss. Thus, the value of pasture (biodiversity) maintenance in *Prosopis* invaded area of Dire Dawa administration is estimated to be 387,262.40 Birr (see Appendix Table 2).

From the calculation undertaken for each TEV component, it turns out to be that the positive and the negative TEV components of *Prosopis* invasion in rural Dire Dawa administration are estimated to be about 9,442,238.30 and 15,204,029.10 Birr respectively. This result makes clear that the current costs of *Prosopis* invasion are higher than the benefits.

4.4. Income Characteristics of the Sample Households

Data on the income of the households, in the study area, came from a cross sectional survey of households. For the purpose of this study, total income of each household did come from four sources, namely, (1) non-farm income without taking into consideration of *Prosopis* income: which includes wage earnings from non-farm labor; public and private sector employment; nonfarm self employment income: income gained from nonfarm

enterprises and activities; (2) Income from *Prosopis* (charcoal, fuel wood) (3) Crop income: Includes income from all crop production, including imputed values from home production and crop by-products; (4) Livestock includes returns from traded livestock (cattle, goats, sheep, camel, poultry) and livestock products (milk, eggs, hides) plus imputed values of home-consumed livestock and livestock products. Unearned income includes transfer payments (like pensions, internal and international remittances, and religious donations).

Profit analysis of livestock and crop in subsistence agriculture and peasant societies is a difficult task because of problems related to valuation of resources (Elise, 1993). In subsistence agricultural system where the integration of capital market is nonexistent or imperfect, to avoid an uncertainty of pricing, imputed land rent can be excluded in calculating costs (Adams, 1996).

The value of family labor on a farm can be priced by the opportunity cost of the prevailing wage in the given area though it is also a problem in peasant societies where labor market is imperfect and inexistent (Elise, 1993). However, in developing countries, market wage rates differ dramatically for men, women and children. Even if it were possible to assign market wage rates for different types of laborers, these full wage costs would have to be adjusted according to whether or not a particular household member was actually employed outside of the home. Such adjusted wage rates adjusted for length and status of outside employment are very difficult to accurately calculate (Adams, 1996). Hence, because of this fact, labor is not included in the calculation of costs for livestock production but included in crop production. Free range backyard type of livestock rearing also makes cost consideration of feeding for livestock difficult and uncertain. So to be more practical, feeding cost is considered only for purchased feeds.

Following this approach, the average crop income of the typical rural households in the study area, after costs of labor (including the family labor) priced by the opportunity cost of the prevailing wage at the period of study i.e. 20 Birr per man day and input costs (fertilizer, seed and other incurred costs) deducted is reported to be around Birr 4423.82 per year.

The income earned from the sales of livestock and livestock products within the range of 12 months before the survey is calculated after deducting purchased feeds, veterinary and other costs of production and marketing. Accordingly, an annual average profit of 2376.94

Birr has emerged after the computations. The average aggregated annual income per household becomes 6800.75 Birr.

Table 13 shows contributions of different income sources to total income of sample households. The analysis provides background information on the amount and sources of income earned by an average agro pastoral household, which would later form the basis of the income inequality analysis.

Results indicate that all households derive income from farming which accounts for 51.04% of the total income on average. The other portion (48.96%) was derived from different non-farm activities. Non-farm income without *Prosopis* and crop farming were the most important sources of income for the agro-pastoral households, providing about 37.1% and 33.2% of total income, respectively. More than 73.38% of the sample households derived income from livestock enterprises, but income from this source was only 17.84% of the total income. This suggests that the livestock activities are of small-scale, mostly free range backyard type.

Table 13. Distribution of the sample households' income from different sources

Source of income	Mean income	Share in total Income (%)
Total on farm income	6800.75	51.04
Livestock income	2376.94	17.84
Crop income	4423.82	33.20
Total non-farm income	6173.87	46.33
Income from <i>Prosopis</i>	1235.46	9.27
Non-farm income less <i>Prosopis</i>	4938.41	37.06
Other source of income	350.99	2.63

Source: Own computation results based on survey data, 2015.

4.5. Gini Decomposition and Measurement of Income Inequality in the Study Area

As mentioned earlier, the Gini decomposition method was used to estimate income inequality among the sample households. Table 14 and Figures 5 to 8 present the Gini decomposition of income inequality by income sources.

The overall total income inequality of 0.39 in the sample is the same as Gini coefficient value reported by Alemayehu and Addis (2014) for Dire Dawa administration. Among the disaggregated income sources, non-farm income without *Prosopis* is the most correlated with total household income with a correlation coefficient of 0.887. This is followed by other income source of 0.612, income driven from *Prosopis* 0.532 and livestock income

0.501. Compared to on-farm income, income from varied *Prosopis* sources is found to be distributed unequally with Gini coefficient of 0.775 which is greater than the former by 0.243. However, the situation is different when the source of income is more disaggregated. Income from *Prosopis* sources is among the most unequally distributed income with Gini coefficient of 0.775 followed by non-farm income without *Prosopis* and livestock income with a Gini coefficient of 0.759 and 0.658, respectively. Apart from other income, the most unequally distributed income sources are income from *Prosopis* and non-farm income without *Prosopis* with Gini coefficients of 0.775 and 0.759, respectively.

Decomposing the overall income inequality into on-farm and non-farm income, the result showed that on-farm income as a whole accounts for 22.5%, while non-farm income accounts for 73.5% of total inequality. This is inconsistent with the finding of Fredu (2007), who reported that farm income contributes more than non-farm income to inequality in some parts of Ethiopia. Table 14 shows relative concentration coefficients of 0.441 for on-farm and 1.588 for non-farm. This implies that while non-farm income is inequality-increasing, farm income is inequality-decreasing in the context of rural Dire Dawa administration. This result is consistent with the finding of Woldehana (2002). Further disaggregation of the income sources reveal that, *Prosopis* income source and income from non-farm without *Prosopis* are inequality aggravating activities while income from crop production and income from livestock production contribution towards reduction of income inequality.

The source elasticity suggest that a 1% increase in on-farm income would decrease the overall Gini coefficient by 0.285%, while a 1% increase in non-farm income would lead to an increase in the overall Gini coefficient by 0.272%.

Table 14. Gini decomposition of inequality by income sources

Source	S_k Income share	G_k (Gini Coefficient)	R_k (Correlation coefficient)	% share in total inequality ($S_k G_k R_k / G$)	Relative conc. of income source $G_k R_k / G$	Source elasticity of total inequality ($(S_k G_k R_k / G) - S_k$)
Total on-farm income	0.510	0.310	0.556	0.225	0.441	-0.285
Livestock income	0.178	0.658	0.501	0.150	0.843	-0.028
Crop income	0.332	0.257	0.344	0.075	0.226	-0.257
Total non-farm income	0.463	0.696	0.892	0.735	1.588	0.272
Income from <i>Prosopis</i>	0.093	0.775	0.532	0.098	1.054	0.005
Non-farm income less <i>Prosopis</i>	0.371	0.759	0.887	0.637	1.722	0.267
Other sources of income	0.026	0.974	0.612	0.040	1.525	0.014
Total income		0.391				

Source: Own computation results based on survey data, 2015.

The combined Gini index for the total sample is about 0.39. Moreover, the Gini coefficient computed in this study is higher than the 0.34 value reported by the Ministry of Finance and Economic Development for the rural areas of the country for the year 1999/2000 (MoFED, 2002). This suggests that the income distribution in the study area was fairly uneven, as some households had been able to increase their income through utilizing of *Prosopis*. Laxen (2007) through the research conducted in the Sudan also found the substantial impact of the environmental income on absolute total income but imbalanced redistributed among the households.

4.6. Contingent Valuation Results

In order to model willingness to pay for eradication and control of *Prosopis* invasion, a double bounded contingent valuation method was used. Before conducting the actual survey, a pilot survey was made to design the bid vectors. Consequently, for the final survey three bid levels (Table 15) were determined for the willingness to pay for eradication as well as control of *Prosopis* invasion based on pilot survey data using open-ended willingness to pay questions on a sample of 30 households from the same study area. A method developed by Boyle *et al.* (1988) had been applied to determine the initial bids. For each initial bid level, about 83 households were randomly assigned for the main survey and the follow-up bid was determined depending on the response for the initial question. Finally, respondents were asked to state their maximum willingness to pay for eradication and control of *Prosopis* invasion using open-ended question so that any inconsistencies are dealt with.

Table 15. Bid design for willingness to pay (WTP) in Birr/household/year and number of randomly assigned sample households

Bid	Bid (Initial, Upper, Lower)		Sample size
	Complete Eradication	Controlling Expansion	
	WTP	WTP	
A	[150, 300, 75]	[25, 50, 13]	83
B	[300, 600, 150]	[50, 100, 25]	83
C	[500, 1000, 250]	[83, 166, 42]	84

Source: Own computation results based on survey data, 2015.

4.6.1. Adjustment to uncertainty and protest responses

To use data for further statistical analysis, we calibrated it by dropping protest responses and adjusted WTP responses with certainty and consistency using respondents' answers to debriefing questions. Initially a total of 250 households were considered in this survey but

only 241 respondents from eradication and 227 from control intervention are found to be valid. Protest responses are those that are indicative of the undue influence of the contextual elements of the CV (e.g., payment vehicle, information constraints, etc) (Jorgensen *et al.*, 1999). According to Labao *et al.* (2008) as cited in Mesfin *et al.* (2011) reasons other than financial constraint and the commodity having no value to the respondent are considered as protest responses. In the WTP bidding, out of 250 respondents, 17 (6.8%) from eradication and 31 (12.4%) from control answered no/no. Of no/no respondents, 8 (47.06%) from eradication and 8 (25.81%) from control groups reported that it is not their responsibility. Rather they point to government and they do not want to pay. These reasons could be classified as protest responses and adjustment was made. Initially, a total of 250 survey questionnaire were administered and after adjustment to protest responses, 9 (3.6%) from the eradication measure and 23 (9.2%) from the control measure answers are excluded; therefore, only 241 respondents from eradication and 227 from control were retained for statistical analysis.

Due to a one-time nature of a hypothetical market valuation practices, individual preferences may be highly uncertain. Thus as mentioned earlier, the data need to be calibrated for certainty. Such adjustment helps to mitigate a bias in CV studies, named hypothetical bias. Respondents who replied yes/yes, yes/no and no/yes to initial and follow-up bids were allowed to express the degree of uncertainty of their valuation responses. A ten point scale was used with 1 as 'Very uncertain' and 10 as 'Very certain'. All yes/yes, yes/no and no/yes responses were classified as no/no responses if the respondent chooses certainty scores 1 to 10. The result of such adjustment classified 4 responses as no/no responses for eradication and 3 responses as no/no responses for control. In addition, the data was also tested for any inconsistencies in response to the DBDC questions using a debriefing of final open-ended question of their maximum willingness to pay. When the final open-ended value was lower than the accepted bid in the follow-up question, we asked the reason for such inconsistencies. The situation was dealt by recoding the inconsistent responses as a "No" response for the follow-up bid (Carlsson *et al.*, 2004). In our case, we have found responses to the final open ended question to be inconsistent with the approved follow-up bid and hence converted (recoded) the 'yes' responses into 'no'.

The summary of responses to the DBDC willingness to pay question adjusted for certainty, consistency and protest responses are given in Table 16.

Table 16. Bid vectors and responses to the DBDC questions

	Yes-Yes		Yes-No		No-Yes		No-No		Total	
WTP(Eradication)										
	Number	%	Number	%	Number	%	Number	%	Number	%
150(300/75)	33	13.69	34	14.11	22	9.13	1	0.41	90	37.34
300(600/150)	30	12.45	34	14.11	20	8.30	3	1.24	87	36.10
500(1000/250)	20	8.30	26	10.79	14	5.81	4	1.66	64	26.56
Total	83	34.44	94	39.01	56	23.24	8	3.31	241	100.00
WTP(Control)										
	Number	%	Number	%	Number	%	Number	%	Number	%
25(50/13)	43	18.94	35	15.42	27	11.89	2	0.88	108	47.58
50(100/25)	23	10.13	27	11.89	16	7.05	3	1.32	70	30.84
83(166/42)	12	5.29	23	10.13	12	5.29	3	1.32	50	22.03
Total	78	34.36	86	37.89	55	24.23	8	3.52	227	100.00

N.B: Initially a randomly assigned bid price was asked and following the response to the initial bid, one of the two bids in bracket of the first column was asked as a follow up bid price.

Source: Own computation results based on survey data, 2015.

As shown in Table 16, 34.44% and 34.46% of the sample households provide two positive responses and 3.32% and 3.52% gave two negative responses, whereas about 38.01% and 37.89%, fell in the “yes no” response categories and 23.24% and 24.23%, fell in the “no yes” response categories of eradication and control measures, respectively. Table 16 further shows significant variation in WTP of households within each initial bid category. For instance, within the left censored, i.e., ‘no no’ response category, about 12.5% and 25% of the households rejected the follow-up bid with minimum payment amount designed in the survey i.e. Birr 75 per year and Birr 13 per year for eradication and control measures, respectively. This implies that these households are not willing to pay even Birr 75 per year for eradication and Birr 13 per year for control measure. On the other hand, among the right censored observations, i.e., in response category ‘yes yes’, 24.10% and 15.38% of the households stated that they are willing to pay Birr 1000/year and Birr 166/year for eradication and control measures of *Prosopis* invasion respectively, which implies their WTP is equal to or more than Birr 1000 per year for eradication measure and Birr 166 per year for control measure. Moreover, Table 17 presents the proportion of yes responses in both initial and follow-up bids.

Table 17. Bid vectors and acceptance in double-bounded CVM by eradication measure

“No” bid follow up	Proportion accepted	initial bid	Proportion accepted	“Yes” bid follow up	Proportion accepted
75	0.24	150	0.74	250	0.36
150	0.23	300	0.73	600	0.34
300	0.21	500	0.72	1000	0.32

Source: Own computation results based on survey data, 2015.

Table 18. Bid vectors and acceptance in double-bounded CVM by control measure

“No” bid follow up	Proportion accepted	initial bid	Proportion accepted	“Yes” bid follow up	Proportion accepted
13	0.25	25	0.73	50	0.40
25	0.23	50	0.73	100	0.34
50	0.23	83	0.70	166	0.23

Source: Own computation results based on survey data, 2015.

Looking at the proportion of yes responses in all bid values it is noted that this share declines as the bid price rises, which is in line with the well established economic theory.

4.6.2. Reasons for WTP and not WTP

To distinguish the components or rationale for positive WTP, those who responded “yes” both or either of the two WTP questions were asked to state their motives to do so. Moreover, respondents who are not willing to pay were also asked to indicate their reasons. Table 19 presents the values or motives for the willingness to pay and the reason for not willing to pay.

Table 19. Reasons for WTP and non-WTP

No.	Reasons for being willing to pay	Eradication		Control	
		No.	%	No.	%
1	I would like to bring it back to the pervious condition were <i>Prosopis</i> is not there to benefit the current and the future generations	168	71.49	67	28.51
2	It is my duty as a resident of this area	130	55.32	104	44.26
3	I want to avoid the effects because I am being hurt	96	44.65	119	55.35
4	I would like to contribute because I am concerned about the people who are being affected by the invasion of <i>Prosopis</i>	54	49.54	56	51.38
No.	Reasons for non willingness to pay	Eradication		Control	
		No.	%	No.	%
1	I cannot afford to pay	10	32.26	21	67.74
2	I think it should be the government’s responsibility	7	41.18	10	58.82

Source: Own computation results based on survey data, 2015.

From those who are not willing to pay, the protest votes are distinguished, looking at the reason for their decision and were removed from the data set. Of the total 250 valid

responses 241 respondents from eradication and 227 respondents from control are willing to pay and say ‘Yes’ to both or either of the two bids, while the rest 17 and 31 are a valid ‘No’ responses for eradication and control measures, respectively.

4.6.3. Households’ Attitude towards WTP and management options

Examination of respondent’s attitude towards WTP for the eradication or control measures of *Prosopis* invasion, as either a challenge to their area, livestock and their farm revealed that *Prosopis* is a problem to them. Result in Table 20 shows that most of the respondents (82.4%) and (70.8%) support and strongly support the essence of paying for the eradication and control measures.

Table 20. Sample households’ attitudes towards willingness to pay to eradicate and control *Prosopis* invasion

Attitude	Eradication		Control	
	No.	%	No.	%
Strongly oppose	5	2	20	8
Oppose	12	4.8	11	4.4
Neutral	27	10.8	42	16.8
Support	126	50.4	116	46.4
Strongly support	80	32	61	24.4
Total	250	100	250	100

Source: Own computation results based on survey data, 2015.

In the case of choice of the management options, the majority of the households (84.80%) were in favour of complete eradication of *Prosopis* from their villages whereas only 15.20% were in favour of controlling further expansion of the plant through utilization.

With regard to households’ perception towards the rules of contingent interventions, 94% reported that the requirement of minimum number of volunteers’ participation would increase their interest to contribute for the intervention of eradication and control measures of *Prosopis* invasion in their villages (see Appendix Table 11). With regard to the payment mechanism for eradication and control measures, 20.4% prefer to contribute in terms of cash, 19.2% of the households prefer to make their contributions in terms of labour, 47.6% are indifferent between paying in cash and contributing in labour, whereas the remaining 12.8% do not want to contribute at all (Table 21).

Table 21. Preferred types of payments by the households for eradication and control measures

Types of payment	No.	%
Cash	51	20.4
Labour	48	19.2
Either cash or labour	119	47.6
Refusal	32	12.8
Total	250	100

Source: Own computation results based on survey data, 2015.

4.7. Econometric Analysis

The econometric models used here are based on economic theory and specifications developed in the previous chapter. In order to model the true willingness to pay from DBDC CV survey, both the single bounded and double bounded models were estimated.

Before deciding the optimum model, the explanatory variables were checked for the existence of multicollinearity and heteroscedasticity. The precision for estimating the coefficients of variables is reduced by the existence of multicollinearity between variables i.e. if the independent variables are highly correlated it is difficult to distinguish the effects of one single independent variable on the dependent variable (Maddala, 1992). The VIF values of the variables in the model as shown in Appendix Table 4 are less than 10 showing that there is no problem of multicollinearity.

In most econometric data, particularly in cross-sectional data, it is more likely to encounter heteroscedasticity problem. To correct a heteroscedasticity problem, robust standard errors were estimated for the Probit, Bivariate Probit model and Random Effect Probit model.

4.7.1. Single-bounded models

Here, responses to the initial bid (wtp1) and follow-up bid (wtp2) were analyzed separately, as though they were elicited from two separate independent dichotomous choice experiments. In this case, there is no correlation between the responses thus assuming $\rho=0$. A separate single bounded (SBDC) probit model was estimated for both the initial bid (*MODEL I and MODEL III*) and follow-up bid (*MODEL II and MODEL IV*) responses to identify factors affecting households' WTP for eradication and control measures of *Prosopis* invasion. Summary of conventional probit model estimates for the initial and follow-up bid responses are reported in Appendix Tables 12 and 13.

4.7.2. Double bounded models

To model responses from the DBDC CV survey, variants of both single bounded and double bounded models were estimated including: The Seemingly Unrelated Bivariate Probit and Recursive Bivariate Probit models.

I. Bivariate Probit

The bivariate probit model introduced by Cameron and Quiggin (1994) has become a general parametric modeling approach for double-bounded CV survey. The argument here is that sequential presentation of WTP questions (DBDC) suggests that responses to these questions might not be independent if unobserved factors influence both responses. Formally the model is specified as:

$$\begin{aligned} y_1 &= \beta_1' x_1 + \varepsilon_1, \quad y_1 = 1 \text{ if } WTP_1 \geq B^I, \quad 0 \text{ otherwise.} \\ y_2 &= \beta_2' x_2 + \varepsilon_2, \quad y_2 = 1 \text{ if } WTP_2 \geq B^F, \quad 0 \text{ otherwise.} \\ \text{Var}[\varepsilon_1] &= \sigma_1, \quad \text{Var}[\varepsilon_2] = \sigma_2, \end{aligned}$$

To deal with these issues, a seemingly unrelated bivariate probit (SUBVP) model has been used and preference parameters and correlation coefficient of the unobserved factors influencing responses across the two WTP equations have been estimated. The results of BVP model with covariates included shows that the Wald test of goodness of fit under the null hypothesis that all parameters are zero can be rejected. The model is jointly significant at 1% level of confidence [Wald χ^2 (34) = 166.02; Prob > χ^2 = 0.000] for eradication; [Wald χ^2 (34) = 654.19 Prob > χ^2 = 0.000] for control measure or at least one of the variable included in the model is different from zero. The correlation coefficient implies, error terms of the two responses are positively correlated and significant (rho = 0.518) for eradication and (rho = 1) for control measure. The Wald test of rho = 0 [Wald test of rho = 0: χ^2 (1) = 5.235 and Pr. χ^2 > = 0.022] for eradication and Wald test of rho = 0 [χ^2 (1) = 546.328 and Pr. χ^2 > = 0.000] for control measure suggests that the two disturbances are significantly correlated.

The welfare estimates constructed using the Krinsky-Robb procedure reveals that the SUBVP model gives a better mean WTP of 224.3 Birr and WTP of 107.49 Birr estimates than the SBDC Probit model, as it has a tighter confidence interval (a range of 46.34 Birr) and (range of 46.34 Birr) for WTP for eradication and control measure, respectively.

II. Recursive Bivariate Probit

In case of the above seemingly unrelated bivariate probit model, the parameter estimates of the first equation enters in the computation of mean willingness to pay in general. This is because the follow-up question response is likely to suffer from anchoring bias due to the initial question. To take account of the possible anchoring effect, a Recursive Bivariate Probit (RBP) model is estimated. In modeling the follow up response equation, the estimated WTP from the first response equation is included i.e. $y_1 = \beta_1' x_1 + \varepsilon_1$ but the second equation is replaced by the structural equation:

$$y_2 = \beta_2' x_2 + \beta_3' \text{WTP}_{1j} + \varepsilon_2$$

Summary of RBP Model estimation are reported in Appendix Table 14. The point estimate of welfare (mean WTP) from the SUBVP model has a tighter CI relative to the Recursive Bivariate Probit model. Thus, the claim of improved efficiency of Seemingly Unrelated Bivariate Probit over the Recursive Bivariate Probit is justified for both measures, that is, eradication and control through utilization.

Table 22. Results of seemingly unrelated models for WTP eradication and control measures

WTP for Eradication measure				WTP for Control measure		
Model V Seemingly unrelated bivariate probit				Model VII Seemingly unrelated bivariate probit		
WTP1	Coef.	Robust Std. Err.	dy/dx	Coef.	Robust Std. Err.	dy/dx
Bid1	-0.014***	0.002	-0.002	-.0171***	0.003	-0.002
Annual family income	0.001***	0.001	2.0-e4	0.153***	0.044	0.034
Age	-0.033*	0.019	-0.005	-1.213	1.594	-0.148
Sex	1.319**	0.528	0.094	0.095	0.816	0.012
Educational level	-0.751	0.591	-0.143	0.289	0.641	0.032
Benefit from <i>Prosopis</i>	0.046	0.051	0.006	0.002	0.045	2.0e -4
Occupation	0.170	0.151	0.024	0.125	0.221	0.015
Family size	-0.125	0.076	-0.017	0.828	0.655	0.101
Physical injury	0.339***	0.171	0.047	0.181***	0.045	0.038
Size of cultivated land	0.010	0.053	0.001	0.509	0.530	0.062
Livestock holding	-0.032	0.043	-0.005	0.030	0.193	0.004
Participation in non-farm	0.042	0.377	0.006	0.238	0.503	0.030
Access to rural credit	0.037	0.326	0.005	0.433	0.531	0.053
Strongly oppose	-2.885***	0.871	-0.099	-7.522***	0.731	-0.125
Oppose	-4.934***	1.044	-0.125	0.324	0.582	0.033
Support	1.005*	0.547	0.077	0.316	0.958	0.041
Strongly support	1.03**	0.409	0.148	0.916	1.069	0.092
Constant	5.235***	1.649		-1.069	6.343	
WTP2						
Bid2	-.008***	0.001	-2.0e- 4	-0.001	0.004	-1.0e-4
Annual family income	0.001*	0.000	0.006	0.340	0.557	0.071
Age	0.014	0.014	0.644	-0.795	1.213	-0.166
Sex	3.480**	0.855	.0080	0.062	0.688	0.013
Educational level	-0.200	0.322	0.005	0.090	0.614	0.019
Benefit from <i>Prosopis</i>	0.013	0.038	0.031	0.054	0.045	0.011
Occupation	0.079	0.129	0.041	.859***	0.243	0.179
Family size	-0.103	0.064	-0.010	-1.669*	0.904	-.3484
Physical injury	0.025	0.182	0.040	0.388	0.298	0.081
Size of cultivated land	0.100*	0.055	0.003	0.491	0.374	0.103
Livestock holding	-0.007	0.036	-0.190	0.387*	0.231	0.081
Participation in non-farm	-0.486	0.350	-0.153	2.161***	0.656	0.423
Access to rural credit	-0.385	0.369	-0.040	0.652	0.497	0.139
Strongly oppose	-0.100	0.659	-0.073	-6.011***	0.909	-0.204
Oppose	-0.184	0.907	-0.230	0.106	0.790	0.023
Support	0.613	0.504	0.486	0.622	0.815	0.135
Strongly support	1.307***	0.396	0.003	1.378	0.815	0.227
WTP1						
Constant	6.133***	1.544		2.845	6.733	
/athrho	0.574**	0.251		14.636***	0.626	
Rho	0.5185	0.184		1	4.85e-13	
Number of obs = 241				Number of obs = 227		
Wald chi2(34) = 166.02 Prob > χ^2 = 0.000				Wald chi2(34) = 654.19 Prob > χ^2 = 0.000		
Log pseudolikelihood = -59.310				Log pseudolikelihood = -41.892		
Wald test of rho χ^2 (1)=5.235 Prob>				Wald test of rho=0: χ^2 (1) = 546.328 Prob > χ^2 =		
χ^2 =0.022				0.000		

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

4.7.3. Single bounded and double bounded models: a welfare and efficiency comparison

To estimate the economic benefits of eradicating *Prosopis*, we have compared results of the SBDC and DBDC models. A probit model from the first response equation is selected as a SBDC model for the reasons mention earlier. For a direct comparison with the SB result, the SUBVP and RBP models are selected as DBDC models.

Models I, II, V, VI, and VII provide evidence that respondents are rational when faced with increasing cost as the coefficient of bid amount is negative and statistically significant. The income coefficient is positive and statistically significant for models I, II, V and VI.

The comparison can be made from the perspective of efficiency in estimating welfare. The precision estimates of welfare measures computed from Krinsky-Robb procedure can serve as main criteria for judging efficiency of the models.

The precision of estimates from DBDC can be compared directly by constructing confidence interval around the mean using Krinsky-Robb procedures. The SB probit and REP models are both nested in the seemingly unrelated bivariate probit model, so that a direct comparison is possible by means of Krinsky-Robb procedure. The point and interval estimates of SBDC (MODEL I) and, SUBVP and RBP (MODEL III) are reported in Table 28.

We see that the point estimates of mean WTP from the SBDC model hasn't as such bid difference to that of SUBVP model for eradication and control measures, but have wider confidence interval. Comparing the achieved level of significance and the interval estimates of DB models, we found that the SUBVP models are more efficient than the RP and RE models. Results provided in Tables 27 and 28 show that the SUBVP models are more efficient than the RBP model for both mitigation measures.

The comparison criteria revealed that in all cases, estimates from the DBDC models are more efficient than the SB ones. Hence, the claim for improved efficiency of DB CV survey over single bounded is confirmed in this study. From Tables 27 and 28 it is clear that SUBVP model is relatively efficient. The result of Bateman *et al.* (2001) confirms this finding. The double-bounded dichotomous choice CV model is asymptotically more efficient than the single-bounded model.

Table 23. Comparisons of alternative estimates of mean WTP for eradication measure

Models	Mean WTP	Confidence Interval 95%		Asl	Range (UB-LB)	CI/ Mean
		Krinsky Robb				
		LB	UB			
SBDC	223.73	192.22	238.66	0.0000	46.44	0.207
Bivariate Probit (SUBVP)	224.30	189.69	236.03	0.0012	46.34	0.206
Recursive Bivariate Probit (RBP)	218.85	186.11	232.54	0.0000	46.43	0.212

Source: Own computation results based on survey data, 2015.

Table 24. Comparisons of alternative estimates of mean WTP for control measure

Models	Mean WTP	Confidence Interval 95%		Asl	Range (UB-LB)	CI/ Mean
<div>Krinsky Robb</div>						
		LB	UB			
SBDC	107.73	82.22	128.66	0.0000	46.44	0.43
Bivariate Probit (SUBVP)	107.49	79.69	126.03	0.0000	46.34	0.43
Recursive Bivariate Probit (RBP)	99.85	76.11	122.54	0.0000	46.43	0.46

Source: Own computation results based on survey data, 2015.

4.7.4. Welfare determinants

In addition to estimating the mean willingness as indicator of welfare, the determinants of willingness to pay were also identified from the selected value function. The SUBVP model as specified in previous section has been employed to identify the determinants of household's willingness to pay for eradication and control of *Prosopis* invasion.

In order to control a potential bias in CV study due to non-normality and outliers, the robust estimator was advocated (Mitchel and Carson, 1989; Haneman *et al.*, 1991). Table 24 model V and Table 25 model VII reports the robust SUBVP model along with the marginal effects of explanatory variable on the probability of household willingness to accept a bid.

Results revealed that among the variables expected to influence households' WTP, only bid level, income of households, age of the household head, sex of the household head, physical injury incidence, size of land holding, strongly oppose, oppose, support and strongly support payment responses had significant effect on the WTP for eradication measure.

Among the variables that were expected to influence households' WTP for *Prosopis* control measure were bid level, occupation, family size, total livestock holding, participation on non-farm income generation activities, strongly oppose and strongly support payment attitudes of the interviewees.

As expected for both measures, the coefficient of bid is negative and significant at 1% level of significance. This indicates that the higher the bid price for the proposed *Prosopis* eradication and control measure program, the less likely the household would be willing to pay, which makes sense and support the claim that rural households' are rational decision makers.

The other variable consistent with a *priori* expectations is annual income of the household. It is significant at 1% and has the expected positive sign. This result confirms with economic theory, which states that an individual/household demand for a particular commodity depends on his/her income and that income and quantity demanded are positively related, except in the case of inferior goods. The result shows that those high income earning households are willing to pay more for eradication and control measures of *Prosopis* than low income group households. Specifically, holding other things constant a 1% increase in total annual income increases the probability of accepting bid1 and bid2 by 0.02% and 0.63% for the eradication measure, respectively and bid1 by 3.40% for the control measure of *Prosopis* invasion.

Sex is positively related to the probability of households' WTP for the eradication of *Prosopis* for improved biodiversity and ecological conditions. It is significant at less than 5% and 1% in the 1st and 2nd bids, respectively. The result revealed that those male headed households were found to be more willing to pay than female headed households. This can be explained by the fact that female headed households are more likely to make use of *Prosopis* than male headed households. Hence, it is also assumed that female household heads can at least take a little advantage of the *Prosopis* invasion because of the experience they have in fuel wood collection and marketing.

The variable age has negative sign as expected and it is significant at 10% for the first bid price. This signifies that older people are less willing to pay a higher price than the younger, keeping all other factors constant. When the age of the household head increases by one percent, the amount of price that households are willing to pay for eradication of *Prosopis* decreases by 0.46%. Thus the age of the decision makers is one of the major determinants of the maximum amount of price they are willing to pay. The negative and significant correlation between age and WTP might be perhaps because of two reasons. Younger people are more aware of IAS concerns than older people. On the other hand, older household heads might face constraint of money to pay for eradication of *Prosopis* i.e. young household heads are more financially stable than the elder.

The result of the model showed that physical injury incidence has positive sign and significant at 5% level of significance to WTP for the eradication of *Prosopis* that aims towards having improved biodiversity and ecological conditions. The estimated marginal effect showed that all other factors kept constant, as households whose members had experience on *Prosopis* thorn injury increase infinitesimally, the probability of willingness to pay increases by 4.71%. This implies that households whose members had more experience of thorn injury caused by *Prosopis* would be more willing to accept higher bids than inexperienced households with such injury. This result is consistent with the findings of Mesfin *et al.* (2016) based on data gathered from Afar region of Ethiopia.

The total cultivable land holding of the household has expectedly a positive sign for the second bid implying the odds in favor of willingness to pay the bid price by a household increase as the plot size increases. The variable is significant at 10% significance level. Keeping all other things constant, the probability of the households' willingness to pay the bid price will increase by 0.29% as the plot size increases by one ha.

The variable negative attitude has a *prior* expected sign and it has a significant effect towards paying a fee (strongly oppose, oppose) as it is forced to decrease the probability of being willing to pay (WTP) for the first bid. Whereas, the stronger negative attitudes are related to lower probabilities of willingness to pay, but they did not surface out statistically significance for the second bid. Also a positive attitude toward a fee (support, strongly support) increases the probability of being willing to pay for the first bid and the strongest positive attitude (strongly support) is found significantly increase willingness to pay for the second bid. These findings show that attitude toward a specific behaviour of paying a fee is directly associated with the intention to pay a fee (WTP). With the same explanation for control measure affected by strongly opposed and strongly supported attitudinal factors. OLS results provided in Appendix Table 4 show that attitudes towards paying a fee are indirectly related to stated payment amount (\$WTP).

As expected an occupation variable is forced to affect the WTP for control of *Prosopis* invasion positively. This means that the likelihood to accept more cash is higher for the agro-pastoral households than non-agro pastoral households (which include traders and civil servants).

The dummy variable non-farm activity has a positively significant effect at 1% level suggesting that households involved in non-farm activity are more willing to pay for the control of *Prosopis* invasion. This indicates that a *Prosopis* control environment is like a

normal good for the households whose demand increase with increasing income. This is because a non-farm income is an income that households obtain from non-farm activities in the form of cash that helps households to overcome their liquidity constraints.

Livestock are the main livelihood source for pastoral and agro-pastoral community. Results show that livestock holding affects positively and significantly households' willingness to pay for the control measure options. As discussed before, livestock owned by a household is taken as a proxy for wealth. It follows that a wealthy household is expected to be more likely concerned about the natural resources in general not only for their economic values but also for their social and cultural values. On top of this, the concern for the transferability of the resources for the future generation may increase with wealth. Hence, people with more livestock are more likely to be concerned about the risk posed by *Prosopis* on the environment, and hence their willingness to pay for control of *Prosopis* invasion increased accordingly. The same result is reported by Mesfin *et al.* (2016) based on their research conducted in the Afar region of Ethiopia.

As expected for control measures, the coefficient of a family size variable is negative and significant at 10% level of significance. This indicates that a larger family size contributes a low amount of resource needed for the proposed control of *Prosopis* invasion. This negative relationship between family size and the WTP for control measure program is seemingly due to the fact that consumption expenditure is high for such families. Yet, a large sized family can afford supply of more labor for fuel wood collection and charcoal production so that benefits obtained from *Prosopis* is maximized. Thus, family size is one of the determinants of households' willingness to pay for the control of *Prosopis* invasion.

4.8. The Aggregate Benefit

The main objective of this research was to estimate the mean willingness to pay thereby the aggregate benefits of eradication of *Prosopis* from the DB CV survey. The SUBVP model is found to be the appropriate model for welfare estimation. Accordingly estimation of mean WTP as a measure of economic benefit showed that the community based *Prosopis* eradication and control program offers a welfare gain of 224.3 Birr/annum/household and 107.49 Birr/annum/household, respectively. This WTP value estimated from the SUBVP model using Krinsky Robb procedure is significant at 1% probability level for both eradication and control measure, with a tighter confidence interval ranging from 189.69 to 236.03 Birr for eradication and from 79.69 to 126.03 Birr for control measure.

In aggregating the benefits, the mean value was used as an average value of individual WTP. This is because the good being valued is not a pure public good; there are private gains from eradication of *Prosopis* invasion. Issues that need to be considered in aggregation like population choice bias, sampling frame bias, non-response bias and selection bias (Mitchel and Carson, 1989) were properly addressed in this study.

As mentioned in the preceding pages, face to face interviews surveys on randomly selected households were used. Protest responses are excluded from analysis and expected protest zeros were accounted in aggregation of benefits.

The total number of households in the study area is 4970 and after accounting for both mitigation measure i.e. eradication and control, the total expected protest zero counts of 4840 and 4870 households were retained for benefit aggregation, respectively. Using the mean annual WTP of 224.30 Birr and 107.49 Birr per household, the total annual WTP of the households in the study area is estimated to be about 1,085,612 Birr and 523,476.3 Birr for eradication and control measure, respectively. Then based on the aggregation result, one can safely conclude that the total economic benefits to be derived by the households from eradication and control of *Prosopis* invasion, is approximately 1,085,612 Birr per year and 523,476.3 Birr per year, respectively.

Table 25. Estimation of total aggregate benefits to be derived from eradication and controlling *Prosopis* invasion

Measures	Total HH	Expected HHs to have protest zeros	Expected HHs to have valid responses	Mean WTP in Birr	Total benefit
Eradication	4970	130	4840	224.3	1,085,612
Control	4970	100	4870	107.49	523,476.3

Source: Own computation results based on survey data, 2015.

4.9. Reliability and Validity of CV Estimates

Contingent valuation (CV) method is one of the most popular survey-based non market valuation techniques and it estimates the economic value of a resource by constructing a hypothetical market and asking respondents to directly state their WTP to obtain a commodity. Due to the hypothetical nature of the study, the method is prone to numerous different biases. As a result, testing reliability and validity of survey responses is an important component of CV study.

I. Reliability

Reliability refers to how stable and reproducible the measure is. Reliability of a CV survey can be explained in terms of consistency in responses (Kealy *et al.*, 1990). The test of such reliability is based on the magnitude of explanatory power of model used in the study and if a higher proportion of variation in the stated WTP from the open ended question is explained by the variation in theoretically expected variables, we can say our CV result is reliable. According to Mitchell and Carson (1989), the simplest way of testing reliability of WTP values is to obtain a respectable R^2 value ($R^2 > 0.15$) from regressing the hypothesized covariates against the stated willingness to pay. The results from linear regression of the maximum stated willingness to pay on variables that were expected to influence WTP is reported in the Appendix. The R^2 value of 0.9194 and 0.9734 implies our CV result achieves above the threshold value of $R^2 = 0.15$. Moreover, the F-test rejects the hypothesis that all variables are jointly zero, so that our CV result is reliable at least from the simplest criteria of coefficient of determination, R^2 .

Reliability is also defined as, the extent to which the variance of a response or estimate is a result of random sources of noise (Mitchell and Carson, 1989) and hence the standard error of the mean WTP estimate can measure reliability and the confidence intervals can describe the reliability of calculated estimates as a measure of the true value. In our case, the mean WTP estimated from the relatively efficient model for eradication and control mitigation measure is 224.30 Birr and 107.49 Birr with a lower bound and upper bound of 189.69 to 236.03 Birr and 79.69 to 126.03 Birr, with more than 1% achieved level of significance, respectively.

II. Validity

Validity refers to the degree to which the CV evaluation correctly indicates the true value of the asset under investigation (Bateman and Turner, 1992). The validity of the study has been tested following the approaches of validating CV estimates described by Mitchell and Carson (1989).

Content validity: Refers to the extent to which the survey design and content is suited to the task. Content validity assesses whether or not the CV questionnaire asks the ‘right questions in an appropriate manner’s and whether the WTP measure is ‘what respondents would actually pay for a public good if a market for it existed (Turner, 1993).

Accordingly, to address/reduce such problem we have conducted a pilot survey *prior* to the actual survey and the entire survey script was pre-tested. It is also vital to reiterate the fact that the present study had encountered low protest zeros. Hence, it is believed that the design and content of this survey is valid in view of the above pertinent points.

Construct validity: It is related with the extent to which economic theory explains empirical behavior/choice. More specifically, construct validity refers to how well the signs and value of the explanatory variables fits in to the theoretical explanation on which the model is based. All the SB and DB probit regression analyses revealed that the probability of a ‘Yes’ response to the willingness to pay vary with a number of covariates in a reasonable manner and this offers some support for the construct validity of our contingent valuation application. As Turner (1993) noted, two types of construct validity exist: a) theoretical and b) convergent validity.

a) Theoretical validity: Refers to testing the extent to which WTP values are consistent with economic theory (such as transitivity, stability, etc.) of preferences. Following Mitchell and Carson (1989) a linear regression of stated willingness to pay amount on variables expected to be theoretical determinants of willingness to pay was run, in order to assess the theoretical validity of our estimates. The multiple linear regression result (see Appendix Table 4) demonstrate evidence of theoretical validity as the coefficients of the explanatory variables have theoretically expected sign and statistically significant. In case of discrete choice data, the probability of a yes response decreases with an increase in bid price if the respondent behaves rationally. Hence, a test of theoretical validity is if $\partial \text{Pr}(\text{wtp})/\partial \text{bid} < 0$. In the present study, for all models this result holds, confirming the theoretical validity of the CV exercises.

Moreover, Forsythe (2001) and Whittington *et al.* (1992) argue that if people overbid without giving enough thought to their economic status, the correlation between income and WTP would be very small or non-existent. In this study, the correlation coefficient between income and WTP shows that the variables are significantly correlated.

b) Convergent validity: Refers to the degree of correspondence between different values for the same good estimated using different methods. Considering convergent validity, the study restricted to use estimates only from CV.

Criterion validity: Criterion validity is the definitive test of validity. A comparison of the CVM estimates with the true value of eradication and control measure of *Prosopis* invasion would test for criterion validity. Mitchell and Carson (1993) noted that if a created market exists for the public good being valued, it is possible to compare the resulting prices with values obtained from the CV analysis. But its implication is difficult since it requires huge finance. So, the said comparison is not considered in the analysis conducted in this study.

4.10. Propensity Score Matching (PSM) Estimation Results

This section describes the whole process of measuring the economic impact of *Prosopis* invasion using propensity score matching method. It explains the estimation of propensity scores, matching methods, common support region, balancing test and sensitivity analysis.

4.10.1. Propensity scores

This section describes the steps followed to measure the impact of *Prosopis* invasion on the agro-pastoral households in Dire Dawa administration. More precisely, it presents the estimation of propensity scores, matching methods, common support region and balancing test. It also explains the treatment effect of *Prosopis* invasion across the households who are making their living in the invaded areas.

Results of a propensity score are obtained as the probability scores of individuals from the fitted simple logistic regression model. The model is estimated with STATA 13 software package using the propensity scores matching algorithm developed by Leuven and Sianesi (2003). In the estimation process, data collected from the two groups, namely: households from the *Prosopis* invaded and non-invaded areas were pooled such that the dependent variable takes a value 1 if a household belongs to an area invaded by *Prosopis* and 0, otherwise.

Table 26. Results of the logistic regression model

Variables	Coef.	Std. Err.
Age	0.044**	0.020
Sex	0.393	0.682
Educational level	0.068	0.457
Distance from road	0.099*	0.054
Distance to the market	-0.373***	0.044
Family size	-0.218**	0.104
Dependency ratio	-0.351*	0.209
Cultivated land holding	-0.121	0.126
Livestock holding	-1.041***	0.320
Access to irrigation water	-1.132**	0.515
Access to rural credit	0.197	0.479
Participation in Safety net	0.804	0.495
Perceive occurrence of drought	1.054	0.702
Marital status	0.929	1.681
_cons	2.278	2.106
Number of obs	450	
LR chi2(14)	214.08	
Prob > chi2	0.0000	
Pseudo R2	0.59.5542	
Log likelihood	-86.097086	
Count R2:	0.881	

Note: *** and ** means significant at the 1% and 5% probability levels, respectively

Source: Own computation results based on survey data, 2015.

Figure 9 shows the distribution of households with respect to estimated propensity scores. The figure illustrates the imbalanced distribution between treatment and control households and shows the cases excluded from the analysis to avoid bad matches.

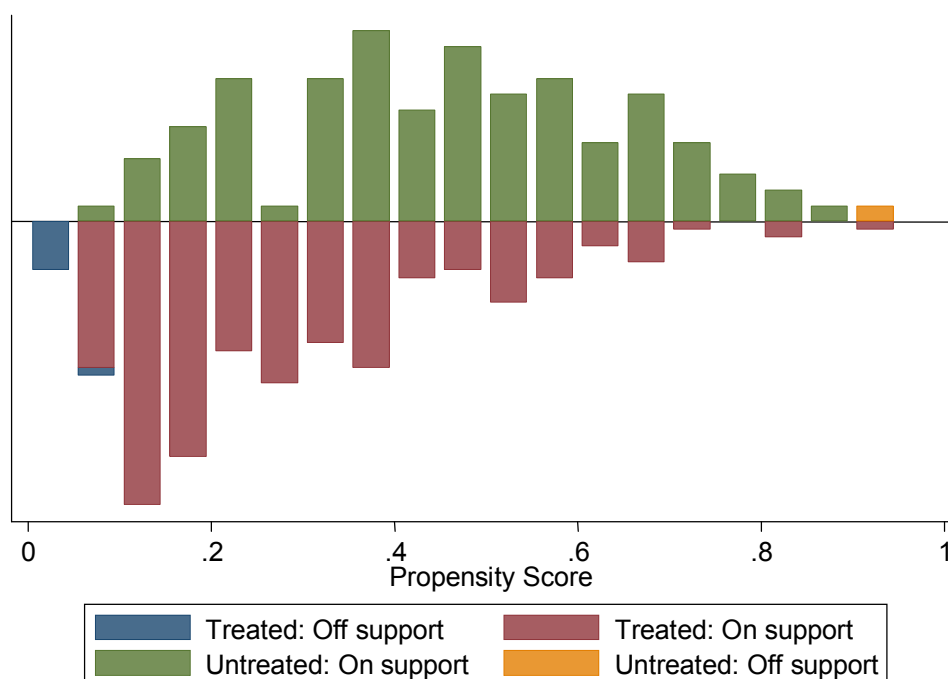


Figure 5. Propensity score distribution and common support area

Source: Own computation results based on survey data, 2015.

4.10.2. Matching households from *Prosopis* invaded and non-invded areas

As noted earlier, before implementing the matching task, three main steps must be followed and these are presented as follows: First, predicted values of propensity scores should be estimated for all treated and control households. Second, a common support condition should be imposed on the propensity score distributions of households with and without the *Prosopis* invasion. Finally, observations whose predicted propensity scores fall outside the range of the common support region should be discarded.

The estimated propensity scores vary between 921 (mean = 0.461) for households from *Prosopis* invaded area or treatment groups and between 0.014 and 0.904 (mean = 0.275) for those who are from non-invaded (control) areas. The common support region would then lie between 0.059 and 0.904. This means, based on the rule of matching exercise households whose estimated propensity scores less than 0.059 or greater than 0.904 were not considered for the matching exercise. As a result of this restriction, 12 households (10 treated and 2 controlled) were discarded from the analysis (see Table 31).

Table 27. Distribution of sample households by estimated propensity scores and household type

Group	Obs	Mean	Std.	Minimum	Maximum
Total households	450	0.338	0.205	0.014	0.921
Treatment households	250	0.461	0.194	0.059	0.921
Control households	200	0.275	0.180	0.014	0.904

Source: Own computation results based on survey data, 2015.

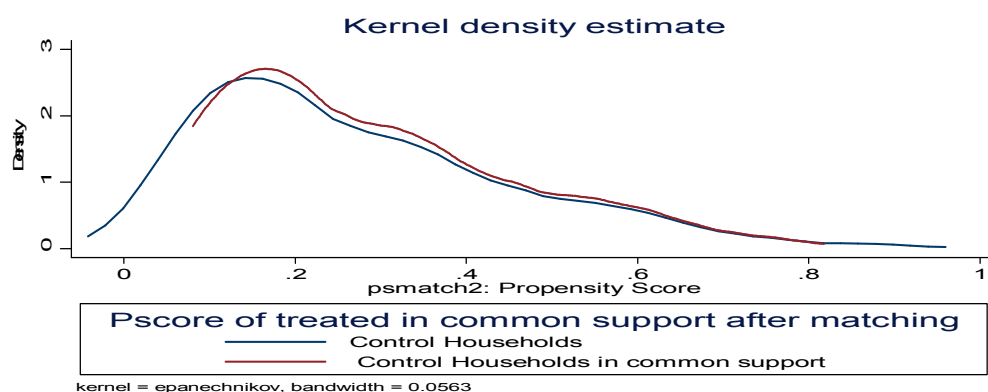


Figure 6. Kernel density of propensity scores of households from non-invaded area

Source: Own computation results based on survey data, 2015.

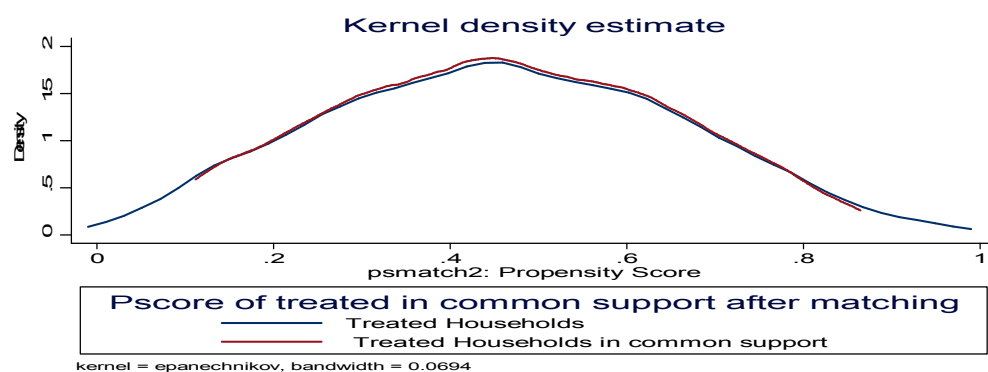


Figure 7. Kernel density of propensity scores of households from invaded areas

Source: Own computation results based on survey data, 2015.

4.10.3. Choice of matching algorithm

In order to get the best matching estimators for matching the treatment and control households in the common support region, the Nearest Neighbor, Caliper and Kernel matching estimators were tested. Finally, the matching estimators make use of different criteria such as equal means test referred to as the balancing test (Dehejia and Wahba, 2002), pseudo- R^2 and matched sample size. In selecting a given matching estimator, a

matching estimator which balances all explanatory variables (i.e., results in non-significant mean differences between the two groups), bears a low Pseudo R^2 value and also results in large matched sample size is preferable. Consequently, a Kernel matching with band width of 0.1 was found to be the best estimator for the data.

Table 28. Comparison of the three matching estimates by performance criteria

Matching Estimator	Performance Criteria			
	Balancing test*	Pseudo R^2	Matched sample size	Mean SB
NN				
1 neighbor	12	0.077	438	11.8
2 neighbor	12	0.043	438	9.4
3 neighbor	13	0.040	438	8.6
4 neighbor	13	0.028	438	7.7
Caliper				
0.01	13	0.031	378	7.4
0.25	13	0.026	438	8.3
0.5	13	0.109	438	16.6
KM				
With no band width	14	0.014	438	5.0
Band width of 0.1	14	0.013	438	4.3
Band width of 0.25	14	0.016	438	6.6
Band width of 0.5	13	0.069	438	13

Note: * Number of explanatory variables with no statistically significant mean differences between the matched groups of *Prosopis invaded* households and non-invaded households.

Source: Own computation results based on survey data, 2015.

Table 33 depicts the estimated results of matching quality tests. Based on the selected best estimator (Kernel matching with 0.1 band width), the balancing test of covariates, before and after matching households from *Prosopis invaded* and non-invaded areas shows that there is no a statistically significant mean difference between the two groups in terms of education level of the household head, distance to the market, livestock holding and access to irrigation.

Table 29. Results of the balancing tests of covariates using the kernel matching estimator

Variable	Sample	Mean		%bias	%reduct /bias/	t-test	
		Treated	Control			t	p>t
Pscore	U	0.560	0.224	140.1		12.25	0.000
	M	0.500	0.490	4.1	97.1	0.27	0.789
Age	U	42.363	38.580	36.3		2.93	0.004
	M	42.208	41.952	2.5	93.2	0.15	0.878
Sex	U	0.863	0.820	11.7		0.94	0.346
	M	0.861	0.886	-4.6	43.2	-0.52	0.606
Educational level	U	0.245	0.340	-20.9		-1.69	0.092
	M	0.248	0.248	-0.2	99.1	-0.01	0.989
Distance from road	U	1.943	2.475	-14.6		-1.16	0.248
	M	1.952	1.957	-0.1	99.1	-0.01	0.992
Distance to the market	U	3.444	13.736	-68.1		-5.62	0.000
	M	3.468	13.653	-3.0	95.6	-0.20	0.839
Family size	U	6.255	6.270	-0.7		-0.05	0.956
	M	6.248	6.345	-4.3	-547.4	-0.30	0.762
Dependency ratio	U	1.249	1.428	-16.9		-1.39	0.165
	M	1.248	1.250	-0.2	99.0	-0.01	0.990
Cultivated land holding	U	1.961	2.148	-10.6		-0.80	0.426
	M	1.971	1.886	4.8	54.3	0.44	0.663
Livestock holding	U	6.668	3.498	61.5		5.72	0.000
	M	5.080	4.145	3.7	94.0	1.59	0.114
Access to irrigation water	U	0.167	0.280	-27.4		-2.19	0.030
	M	0.168	0.145	5.0	81.6	0.46	0.645
Access to rural credit	U	0.431	0.34	18.8		1.56	0.121
	M	0.426	0.342	4.9	73.94	1.22	0.224
Participation in Safety net	U	0.500	0.51	-2.0		-0.16	0.870
	M	0.505	0.505	0.1	97.4	0.00	0.997
Perceive occurrence of drought	U	0.922	0.950	-11.6		-0.99	0.325
	M	0.921	0.904	7.0	39.3	0.43	0.667
Marital status	U	0.989	0.990	0.2		0.02	0.987
	M	0.990	0.990	-0.1	68.0	-0.00	0.996

Source: Own computation results based on survey data, 2015.

The low pseudo-R2 and the insignificant likelihood ratio tests support the hypothesis that both groups have the same distribution in covariates X after matching (Table 34). These results clearly show that the matching procedure is able to balance the characteristics in the treated and the matched comparison groups.

Table 34. Chi-square test for the joint significance of variables

Sample	Pseudo R ²	LR chi ²	p>chi ²
Unmatched	0.154	59.55	0.000
Matched	0.013	3.59	0.999

Source: Own computation results based on survey data, 2015.

4.10.4. Treatment effect on the treated

The effect of *Prosopis* invasion on households' income, consumption and expenditure was meticulously analysed. The estimated results show supportive evidence of statistically significant impact of *Prosopis* invasion on household's expenditure on education, milk income, average annual income from crop production, non-farm income, food and non-food expenditure and food poverty measured in calorie intake per AE. Pre-intervention differences (demographic and socioeconomic characteristics) among the households earning their livelihoods from *Prosopis* invaded and non-invaded areas are controlled.

The finding of this study reveals that mean difference in education expenditure, milk income, calorie intake per AE and average annual income obtained from fuel wood collection and charcoal making between the two groups of sample households is significant at 1% probability level. For food and non-food expenditure, the two groups of sample households showed significant mean difference at 5% probability level. Results also show that average annual income from milk, average annual incomes from crop production and non-farm income are significant at 10% probability levels. In other words, on average, *Prosopis* invasion has boosted households' education expenditure, average annual income from crop production, non-farm income, food and non-food expenditure, physical food consumption and income from fuel wood and charcoal in *Prosopis* invaded areas by 213.05 Birr, 529.40 Birr, 3831.30 Birr, 2607.10 Birr, 562.21 calories and 2133.40 Birr, respectively, over the households residing the invaded areas. On the other hand, *Prosopis* invasion has reduced milk income by 410.67 Birr compared to households belonging to the non-invaded rural settings.

Table 305: Average treatment effect on the treated (ATT)

Variables	Treated	Controls	Difference	t-value
Education expenditure	572.65	359.59	213.05	3.63***
Food and non-food expenditure	9894.33	7287.23	2607.10	2.95*
Health expenditure	260.35	215.81	44.54	0.48NS
Calorie intake per AE	2336.70	1774.50	562.21	3.13***
Annual income from livestock sell	1676.30	1796.25	-119.95	-0.33NS
Annual income from milk	677.24	1087.91	-410.67	-1.68*
Annual income from crop	4436.47	3907.04	529.43	1.70*
Non-farm income	6030.37	2199.08	3831.30	1.78*
Annual income from fuel wood and charcoal sale	2257.85	124.45	2133.40	4.57***

Note: * and *** means significant at 1% and 10% probability levels respectively

Source: Own computation results based on survey data, 2015.

4.10.5. Sensitivity analysis

In this section, the issue of 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 the identification of conditional independence assumption was satisfactory or affected by the dummy confounder or the estimated 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 the null hypothesis of no-treatment effect for different hypothesized values of unobserved selection bias. Table 35 reveals the sensitivity result of outcome ATT values to the dummy confounder.

Regarding milk income, non-farm income, income from crop production and income from sales of *Prosopis* products (wood and charcoal), 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 influence the selection process in order to undermine the implications of matching analysis.

Table 316. Sensitivity analysis of the estimated ATT

Outcome variables	Percentage change
Education expenditure	4.63
Annual income from milk production	13.74
Annual income from crop production	4.68
Non-farm income	12.47
Food and non food expenditure	8.23
Annual income from fuel wood and charcoal	2.19
Calorie intake per AE	5.45

Source: Own computation results based on survey data, 2015.

4.11. Household Perceptions and Coping Strategies

4.11.1. Households' perceptions about *Prosopis*

Literature confirm that household perception is difficult to measure since respondent are not willing to express their actual feeling rather they express their contextual feeling. Researchers used Likert scaling that presumes the existence of an underlying (or latent or natural) continuous variable whose value characterizes the respondents' attitudes and opinions. Despite weakness of Likert scale indications, Chimka *et al.* (2000) used likert scaling to find the department exhibiting the most favorable attitude regarding the given statement. From the five choices which are commonly assigned numbers in some order 0, 1, 2, 3, 4 or 1, 2, 3, 4, 5., one may calculate sample means and declare the department with the greatest mean as exhibiting the most favorable attitude. Likewise five options were considered in this study to rate the species as very bad, bad, neutral, good and very good. In turn, these were used as present perception of the households regarding *Prosopis*.

With regard to the present agro pastoral households perception about the species, out of 250 sample households from the invaded area (Table 36) 83 (33.2%) and 121 (48.4%) of them considered the species as very bad and bad, respectively and the rest 11 (4.4%), 11 (4.4%) and 24 (9.6%) households considered the species as neutral, good and very good, respectively. The average value of the Likert scale that is 4, in the table below indicates that agro-pastoral households residing in the invaded areas perceived *Prosopis* as an undesirable species.

Table 37. Perceptions of sample households about *Prosopis*

Perception	Freq.	Percent	Likert Index
Very good	11	4.4	0.044
Good	24	9.6	0.192
Neutral	11	4.4	0.132
Bad	121	48.4	1.936
Very bad	83	33.2	1.66
Total	250	100	3.964

Source: Own computation results based on survey data, 2015.

4.11.2. Coping mechanisms against *Prosopis* invasion

This section presents the coping strategies used by the rural communities to mitigate the impacts of *Prosopis* invasion.

From the survey it was observed that the local community pursue different coping strategies against the invasion. Among the coping strategies, using *Prosopis* either as a source of income or domestic consumption takes the lion's share (61.2%) followed by diversification of livelihoods or engaging in different income earning opportunities generating activities (24.8%), eradication (12.8%) and migration (1.2%).

Controlling through utilization

Agro-pastorals who live in the invaded areas have been trying to cope with the impacts of *Prosopis* invasion by engaging themselves into selling firewood and/or charcoal from the plant. It was estimated that about 61.2% of the surveyed households earn income from selling firewood and/or charcoal. This implies that agro-pastorals are using the bush as source of income. Existing literature on *Prosopis* show that the shrub offers significant opportunities for rural households such as income and livelihoods diversification as well as ecological benefits (Berhanu and Tesfaye, 2006).

Diversification as a coping mechanism against the invasion

On the other hand, Barrett *et al.* (2001) suggest several reasons why households choose to diversify, and these can be classified as “push” and “pull” factors. Diversification due to “pull” factors is a response by households to exploit economic opportunities that are created by local economic and population growth, proximity to urban markets and improvements in infrastructure. In contrast, “push” factors are those that force households to diversify as a coping strategy. Diversification by poor households in developing

countries is usually a response to “push” factors. Thus, livelihood diversification, distress-push diversification seems a coping strategy in response to the prevailing invasion risk in the study area.

Results presented in Table 37 show that livelihood diversification is one of the coping strategies practiced against the invasion by households from the invaded area (24.8%). The additional subsidiary income generating activities practiced by these households were petty trading, poultry production and involvement in casual labor.

Eradication of *Prosopis* as a coping mechanism against the invasion

As presented in Table 37, 12.8% of households in the invaded area have tried to control the invasion of *Prosopis* by cutting down the bush either in group or an individually bases. However, practical experiences from many parts of the world have shown that complete eradication of established *Prosopis* is virtually impossible. The plant has great ability to re-sprout with quick coppice growth and ability to cover a lot of area in a short period of time have discouraged the local people to continue their ‘controlling’ activity. According to Felker (2004), eradication of *Prosopis* is possible if the species is identified at early stage of colonization but once *Prosopis* is firmly established it is difficult to eradicate. Therefore, there is a need to find ways of better utilizing and managing *Prosopis*, with an eye towards controlling its spread. Successful interventions would require extensive collaboration among government, non-government and private sector groups.

Migration as a coping mechanism against the invasion

Migration is one of the coping mechanisms practiced by the sample households. Accordingly, 1.2% of the sample households in the invaded area indicated that migration is one of their coping strategy to fight the impacts *Prosopis* invasion. Several animal species have migrated to other areas since they were not able to move around freely because of the dense thickets of *Prosopis* (ARPARDB, 2008). Most of the climatic problems the pastoralists have been facing are seasonal and can be managed through seasonal interventions like migration to other places in search of rangeland resources, intra-clan patronage and looking for temporary aid from GOs and NGOs. However, the problem associated with *Prosopis* invasion is different. It can not be controlled by seasonal interventions and needs a lasting solution.

Table 38. Coping mechanisms of the affected households against *Prosopis* invasion

Coping mechanism	Freq.	Percent
Livelihood diversification	62	24.8
Migration	3	1.2
Eradication of <i>Prosopis</i>	32	12.8
Controlling through utilization	153	61.2
Total	250	100

Source: Own computation results based on survey data, 2015.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

In this study, cross sectional data from *Prosopis* invaded and non-invaded *kebeles* of rural

Dire Dawa administration were used to estimate the economic values, economic impacts of *Prosopis* invasion and their coping mechanisms against the invasion. To address this issue, data were collected and analyzed using descriptive and econometric tools. The econometric tools applied for this study were valuation methods and propensity score matching technique.

Results show that, *Prosopis* invasion has both negative and positive effects for the communities in the invaded areas although the current cost is higher. Notwithstanding, the most astronomically immense households prefer complete eradication over control, it would result in loss of ecological benefits such as carbon sequestration, environmental income and crop production. Therefore, albeit households prefer complete eradication of the invasive plant than the option of controlling the plant through productive use, it is not an appropriate solution.

In the study area, only the community who lived in the invaded areas are worried about the invasion of *Prosopis* and other stakeholders give less focus for the expansion of the species.

The results from Gini coefficient analysis show that income obtained from *Prosopis* and non-farm income activities were inequality-increasing activity in the rural areas of Dire Dawa administration. Thus, policy makers aiming to alleviate income inequality should continue to explore options for promoting the agro pastoral sector suitable for the poor. Moreover, policy interventions related to non agricultural activities could serve as an instrument to reduce income inequality. Youth targeted rural entrepreneurship and skill development coupled with expansion of women entrepreneurship promotion should be the focus of policy makers in the study area.

Applying a double bounded contingent valuation method, the study found that WTP for eradication measure is influenced most by bid level, income of the households, age of the households head, gender, physical injury incidence, size of cultivated land holding, a negative attitude toward paying a fee (strongly oppose, oppose), positive attitude towards paying a fee (support and strongly support) and WTP for control measure influenced by bid level, occupation, family size, total livestock unit, participation on non-farm income, a negative attitude toward paying a fee (strongly oppose) and positive attitude toward paying a fee (strongly support). This shows that attitudes were among the most important factors of willingness to pay. The result also indicates that eradication and control of *Prosopis*

invasion offers 224.30 and 107.49 Birr respectively. This means that the cash contributions that the households are willing to make for the complete eradication option are higher than the contributions for the controlling of further expansion of the invasive plant.

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.

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 195 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 households who live in *Prosopis* invaded areas, over the non-invaded areas on education expenditure by 213.053 Birr (37.23%), average annual income from crop production by 529.43 Birr (11.93%), non-farm income by 3831.295 Birr (63.53%), food and non food expenditure by 2607.103 Birr (26.35%) and physical food consumption by 805.421 calories per AE (30.12%). On the other hand, *Prosopis* invasion has reduced milk income of *Prosopis* invaded household by 410.667 Birr (60.64%) over the non-invaded households.

Among the coping strategies used by *Prosopis* invaded households, controlling through utilization (using *Prosopis* either as a source of income or domestic consumption) took the lion's share (61.2%) followed by diversification of livelihood or engaging in different non-farm income generating activities (24.8%), eradication (12.8%) and migration (1.2%). The average annual income generated from fuel wood/charcoal sale obtained from *Prosopis* is estimated to be Birr 2120.41 which constitute about 26% of the total average annual income of *Prosopis* invaded households.

From the discussion that has been made so far and experiences from around the world, it is possible to conclude that *Prosopis* by itself is not a problem or threat as such. The problem

lies on the presence or absence of appropriate and sustainable management practices of this controversial plant species.

The policy implication of this study points towards designing a comprehensive adaptation and mitigation plan of invasive alien species (IAS) in general and *Prosopis* invasion in particular that enable proper utilization and management practices at both national and regional levels. In addition to this, the study may contribute to poverty alleviation efforts and the growth and transformation plan undertaken by the Ethiopian Government today in general and assuring household food security in particular, provided that the following recommendations are given due attention by all concerned stakeholders in the Administration.

5.2. Recommendations

Based on the empirical findings reported in this research, the following recommendations are forwarded:

Agro-pastoralists suffer a lot from the effect of *Prosopis* invasion and majority of the residents prefer to participate managing the invasion so that active involvement of the local community on voluntary basis is important in the design and success of *Prosopis* invasion control and eradication programs. Given this, awareness creation among the local community about the pros and cons of *Prosopis* effects on households' welfare plays a great role for the success of community based *Prosopis* invasion management programs before trying to mobilize the community in control/eradication of *Prosopis* invasion.

The strong positive relationship between the income of the households and their willingness to pay for eradication measure of *Prosopis* invasion indicates that the payment to the proposed program should be based on the income level of the households. Furthermore, designing income-generating programs that address both the poor and the rich households can help to eradicate *Prosopis*.

The result shows that older household heads have relatively little interest to pay for the eradication measure of *Prosopis* invasion whereas male headed household heads have greater interest to pay. Hence, the payment mechanism for eradication measure of *Prosopis* invasion should take into account the differences in age and sex of the household heads.

Similarly, the payment mechanism for control measure has to consider the differences in number of livestock holdings, level of non-farm income, family size and size of land holdings. Because households with more livestock number, more non-farm income and more cultivated land holding have higher preference for the control measure whereas households with larger family size showed little preference to pay for this measure.

Results on attitude toward payment profile in the study area indicated the relevance of integrating economic and psychological value to the willingness to pay for the *Prosopis* management. This understanding of the community attitude can be an input for the policy makers. This underscores the need for policies aimed at increasing willingness to pay behaviors and compliance with payment policies, therefore, may want to consider targeting individuals with negative attitudes and conveying educational messages informing these rural people about the rationale and need for fees and related policies.

Apparently, any intervention that aims to tackle the challenges of *Prosopis* invasion need to consider more effective community based management approaches to drastically reduce adverse impacts and enhance the apparent benefits. Moreover, active involvement of the local community is important in the design and success of *Prosopis* invasion community based management programs.

In the meantime, the ‘control through utilization’ method should be widely employed in the affected areas because it will maintain the biodiversity of the range lands. This needs to be done along with creation of awareness among the community about the potential merits of the tree, establishing community groups controlling and ensuring the proper removal of the tree for different purposes, giving hands-on skills on processing the tree and its parts for different purposes, organization of producers’ and marketing cooperatives, advocacy and promotion work on potential products from processing of *Prosopis* and creation of market linkage.

Above all, before the introduction of management intervention, a management on how to utilize the land that is cleared from *Prosopis* and the cleared biomass of *Prosopis* is important as an incentive for the communities.

6. REFERENCES

- Abeygunawardena, P., Bindu, N.L., Bromley, D.W. and Barba, R.C.V. 1999. Asian Development Bank series 1999. Environment and Economics in Project Preparation. Ten Asian Cases. 394p.
- Adams, R. 1996a. Livestock income and Inequality in rural Pakistan. *Journal of Development Studies*, 31:110-133.
- Adams, R. 1996b. Nonfarm income and inequality in rural Pakistan: A decomposition analysis. *Journal of Development Studies*, 31: 110-133.
- Admasu, D. 2008. Invasive plants and food security: The case of *Prosopis juliflora* in the Afar region of Ethiopia, 1–13. FARM-Africa, IUCN.

- Agresti, A. 2002. *Categorical Data Analysis, 2nd Edition*. Wiley.
- Ahmed, M.H. 2004. *Principles of Environmental Economics: Economics, Ecology and Public Policy*. Routledge publication, New York, USA and Canada.
- Ajzen, I. 1985. From intentions to actions: A theory of planned behavior. In Kuhl, J. and Beckmann, J. (eds.), *Action control: From cognition to behavior*. New York: Springer-Verlag.
- Ajzen, I. 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50: 179–211.
- Ajzen, I. 1996. The directive influence of attitudes on behavior. pp. 385-403. In: Gollwitzer, P. and Bargh, J.A. (eds.), *Psychology of action*. New York, NY: Guilford.
- Ajzen, I. and Driver, B.L. 1992. Contingent value measurement: on the nature and meaning of willingness to pay. *Journal of Consumer Psychology*, 1: 297–316.
- Ajzen, I. and Fishbein, M. 1973. Attitudinal normative variables as predictors of specific behaviors. *Journal of Personality Social Psychology*, 27: 41–57.
- Ajzen, I. and Fishbein, M. 1980. *Understanding Attitudes and Predicting Social Behavior*. Prentice-Hall, Englewood Cliffs, NJ.
- Ajzen, I. and Madden, T.J. 1986. Prediction of goal-directed behavior: Attitudes, intentions perceived behavioral control. *Journal of Experimental Social Psychology*, 22:453–474.
- Ajzen, I., Brown, T.C. and Rosenthal, L.H. 1996. Information bias in contingent valuation: Effects of personal relevance, quality of information, and motivational orientation. *Journal of Environmental Economics and Management*, 30: 43-57.
- Alberini, A., Kanninen, B.J. and Carson, R.T. 1997. Modeling response incentives in dichotomous choice contingent valuation data. *Land Economics*, 73: 309-324.
- Alcamo, J., Leemans, R. and Kreileman, G.J.J. 1998. Global Change Scenarios of the 21st Century. *Results from the IMAGE 2.1 Model*. Pergamon and Elsevier Science, London.
- Alemayehu Geda and Addis Yimer. 2014. Growth, poverty and inequality in Ethiopia, 2000-2013: *A Macroeconomic Appraisal*. A chapter in Book to be published by Forum for Social Studies, FSS.
- Al-Hmaid, A.I. and Warrag, M.O.A. 1998. Allelopathic effects of mesquite (*Prosopis juliflora*) foliage on seed germination and seedling growth of Bermuda grass (*Cynodondactylon*). *Journal of Arid Environments*, 38: 237-243.
- Amdihun, A., Tadesse, G., Peden, D. and Getahun, Y. 2010. Invasive plant *Prosopis juliflora* expansion on farm and Grazing land in Ethiopia: a threat to pastoral grazing land. International Livestock Research Institute, Addis Ababa, Ethiopia. <http://www.>

docstoc.com/docs/23533265/*Prosopis-Juliflora*-distribution-in-Awash-River-Basin-Ethiopia. Accessed March 2016

- Ameha Tilahun. 2006. Impact of *Prosopis Juliflora* (Sw.DC.) invasion on plant biodiversity and soil properties in the Middle Awash valley, Ethiopia. Unpublished MSc. Thesis, Hawassa University, Hawassa.
- Anderson, E. 1993. *Value in Ethics Economics*. Cambridge, MA: Harvard University Press.
- Andersson, S. 2005. Spread of the introduced tree species *Prosopis juliflora* (Sw.) DC in the Lake Baringo area, Kenya. Institutionen for Skoglif Vegetation sekologi, SLU (Swedish Agricultural University), UMEA, Sweden.
- Angassa, A. and Oba, G. 2008. Herder perception on impacts of range enclosure, crop farming, fire ban and bush encroachment on the Rangelands of Borana, southern Ethiopia. pp 201–215
- Armitage, C.J. and Conner, M. 1999. The theory of planned behaviour: assessment of predictive validity and perceived control. *British Journal of Social Psychology*, 38: 35-54.
- ARPARDB (Afar Regional State Pastoral and Agro-Pastoral Rural Development Bureau). 2008. Annual Report, unpublished Regional Profile, Semera, Ethiopia.
- Arrow, K., Solow, R., Portney, P.R., Leamer, E.E., Radner, R. and Schuman, H. 1993. Report of the NOAA panel on contingent valuation, <http://www.darrp.noaa.gov/library/pdf/cvblue.pdf>.
- ATA (Agricultural Transformation Agency) progress report. 2015. Ethiopian Agricultural transformation Agency. Addis Ababa.
- Ayalneh Bogale. 2011. Valuing natural forest resources: an application of contingent valuation method on Adaba-Dodola forest priority area, Bale Mountains, Ethiopia. *Journal of Sustainable Forestry*, 30(6): 518-542, DOI: 10.1080/10549811.2011.567353.
- Bagozzi, R.P. and Warshaw, P.R. 1990. Trying to consume. *Journal of Consumer Research*, 17: 127–140.
- Baker, J.L. 1960. Evaluating the impact of development projects on poverty. World Bank, Washington, D.C.p1.
- Baker, J.L. 2000. Evaluating the impact of development projects on poverty: A handbook for Practitioners. Washington D.C. World Bank.
- Balmford, A., Rodrigues, A., Walpole, M., Brink, P., Kettunen, M., Braat, L. and de Groot, R. 2008. The economics of ecosystems biodiversity: Scoping the science. European Commission. Cambridge, UK.

- Barbier, E.B. 1994. Valuing tropical wetland benefits: Economic methodologies and applications. *Geographical Journal*, 59: 22-32.
- Barbier, E.B. 1998. The economic value of tropical ecosystems 2 - tropical forests. London, Gatekeeper Series 98-01, London Environmental Economics Centre.
- Barbier, E.B., Baumgärtner, S., Chopra, K., Costello, C., Duraiappah, A., Hassan, R., Kinzig, A., Lehman, M., Pascual, U., Polasky, S. and Perrings, C. 2009. The valuation of ecosystem services. pp. 248–262. In: Naeem S., Bunker, D., Hector, A., Loreau, M. and Perrings C. (eds.), *Biodiversity, Ecosystem Functioning, and Human Wellbeing: An Ecological and Economic Perspective*. Oxford University Press, Oxford, UK,
- Barrett, C.B., Barbier, E.B. and Reardon, T. 2001. Agroindustrialization, globalization, and international development: the environmental implications. *Environment and Development Economics*, 6: 419–433.
- Bateman, I.J. and Turner, R.K. 1992. Evaluation of the environment: the contingent valuation method. *CSERGE Working Paper GEC 92-18*, University of East Anglia and University College London.
- Bateman, I.J. and Turner, R.K. 1993. Valuation of Environment, Methods and Techniques: The Contingent Valuation Method. In Kerry Turner R. (ed.), *Sustainable Environmental Economics and Management*. Belhaven Press, London.
- Becker, S.O. and Caliendo, M. 2007. Sensitivity analysis for average treatment effect. *Stata Journal*, 7(1): 71–83.
- Becker, S.O. and Ichino, A. 2002. Estimation of average treatment effects based on propensity scores. *The Stata Journal*, 2(4): 1-19.
- Ben-Akivam, M. and Lerman, S. 1985. *Discrete Choice Analysis: Theory and Application to Travel Demand*. MIT Press, Cambridge.
- Bentler, P.M. and Speckart, G. 1979. Models of attitude-behavior relations. *Psychological Review*, 86: 452–464.
- Berhanu Abiyot and Tesfaye Getachew. 2006. The *Prosopis* dilemma, impacts on dryland biodiversity and some controlling methods. *Journal of Drylands*, 1(2): 158–164.
- Bernard, T., Spileman, D.J., Alemayehu, S. and Eleni, G. 2010. Cooperatives for staple crop marketing: evidence from Ethiopia. International Food Policy Research Institute (IFPRI) research monograph; 164.
- BoARD (Bureau of Agriculture and Rural Development). 2009. Annual report. Dire Dawa.
- BoARD (Bureau of Agriculture and Rural Development). 2015. Annual report. Dire Dawa.

- Boxall, P.W. Adamowicz, M., Williams, J., Swait and Louviere, J. 1996. A comparison of stated preference approaches to the measurement of environmental values. *Ecological Economics*, 18: 243-253.
- Boyle, K.J., MacDonald, H.F., Cheng, H. and McCollum, D.W. 1998. Bid design and ye saying in singlebounded dichotomous-choice questions. *Land Economics*, 74(1): 49-64.
- Brand, F. 2009. Critical natural capital revisited: ecological resilience sustainable development. *Landscape Ecology*, 68: 605–612.
- Brander, L., Gómez, B.E., Martín, L.B. and Verma, M. 2002. The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations.
- Brander, L.M., Ghermandi, A., Kuik, O., Markandya, A., Nunes, P.A.L.D., Schaafsma, M., and Wagtendonk, A. 2010. Scaling up ecosystem services values: methodology, applicability, and a case study. Report to the European Environment Agency.
- Bryson, A., Dorsett, R. and Purdon, S. 2002. The use of propensity score matching in the evaluation of labour market policies. *Working Paper No. 4, Department for Work and Pensions*. Londen School of Economics.
- Bunce, M., Rosendo, S. and Brown, K. 2009. Perceptions of climate change, multiple stressors and livelihoods on marginal African coasts. *Environment, Development and Sustainability*, 12: 407-440.
- Burtless, G. 1995. The Case for randomized field trials in economic and policy research. *Journal of Economic Perspectives*, 9: 63–84.
- Bush, G., Hanley, N., Moro, M. and Rondeau, D. 2012. Measuring the local costs of conservation: A provision point mechanism for eliciting willingness to accept compensation. *Land Economics*, 89(3): 490-515
- Caliendo, M. and Kopeinig, S. 2005. Some practical guidance for the implementation of Propensity Score Matching, *Discussion Paper No. 1588*, University of Cologne: cologne.
- Caliendo, M. and Kopeinig, S. 2008. Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys*, 22(1): 1-212.
- Cameron, T.A. and Quiggin, J. 1994. Estimation using contingent valuation data from a dichotomous choice with follow-up questionnaire. *Journal of Environmental Economics and Management*, 27(3): 218-34.
- Carlsson, F., Köhlin, G. and Alemu, M. 2004. Contingent valuation of community plantations in Ethiopia: a look into value elicitation formats and intra-household preference variations. *Working Papers in Economics no. 151*. Gothenburg University, Sweden.

- Carson, R. and Mitchell, R. 1989. Using Surveys to Value Public Goods: The contingent valuation method. Resources for the future, Washington DC.
- Carson, R.T. and Mitchell, R.C. 1993. The issue of scope in contingent valuation studies. *American Journal of Agricultural Economics*, 75(5): 1263-1267.
- Carson, R.T., Flores, N.E. and Meade, N.F. 2001. Contingent valuation: controversies and evidence. *Environmental and Resource Economics*, 19: 173–210.
- CBD (Convention of Biological Diversity) Ad Hoc Technical Expert Group on Biodiversity and Climate Change. 2003. Convention on Biological Diversity. Draft report for experts and governments review. Version 17 February 2003. pp. 146.
- CBD (Convention of Biological Diversity). 2010. <http://www.cbd.int/invasive>. Accessed 15 Feb 2015.
- Chakraborty, A. 2001. The concept and measurement of group inequality. Discussion papers 315 Centre for Development Studies, Thiruvananthapuram.
- Chee, Y.E. 2004. An ecological perspective on the valuation of ecosystem services. *Biological conservation*, 120: 459–565.
- Chenje, M., and Mohamed-Katerere, J.C. 2006. Invasive Alien Species. pp. 331-349. In: Mohamed-Katerere, J.C., Mayar, S. and Editorial, H. (eds.), *Africa Environment Outlook 2. Our Environment, Our Wealth*. Nairobi, Kenya: United Nations Environment Programme.
- Chertow, M. 2001. The IPAT equation and its variants: Changing views of technology and environmental impact. *Journal of Industrial Ecology*, 4: 13–29.
- Cheung, S.F., Chan, D.K.S. and Wong, Z.S.Y. 1999. Reexamining the theory of planned behavior in understanding wastepaper recycling. *Environment and Behavior*, 31: 587-612.
- Chimka, J.R., Harvey, W. and Mary, B.S. 2000. Ordered logit modeling of Likert Scale indications for outcomes assessment, Department of Industrial Engineering. University of Pittsburgh, Pittsburgh, PA 15261, USA.
- Choge, S.K. and Muthike, G.M. 2014. Control of invsive *Prosopis juliflora* species through management and utilization. Guidelines for foresters, agricultural officers and extension agents: Kefri and Asareca (in press).
- Clark Plano, V.L. 2010. The adoption and practice of mixed methods: U.S. trends in federally funded health-related research. *Qualitative Inquiry*, 6(6): 428-440.
- Colautti R, Bailey S, van Overdijk C, Amundsen K, MacIsaac H. 2006. Characterised and projected costs of non-indigenous species in Canada. *Biological Invasions*, 8: 45-59

- Colin, A. and Pravin, K. 2005. *Micro-econometrics method and applications*, 1st Edition. Cambridge University Press, New York. p49.
- Common, M.S. 1995. *Ecological Economics: An Introduction to the Study of Sustainability*. Cambridge University Press, Cambridge.
- Cook, D. and Proctor, W. 2007. Assessing the threat of exotic plant pests. *Ecological Economics*, 63: 594-604.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature*, 387: 253-260.
- Creswell, J.W. and Plano Clark, V.L. 2011. *Designing and conducting mixed methods research*. 2nd Edition. Thousand Oaks, CA: Sage.
- Croitoru, L. 2007. How much are Mediterranean forests worth? *Forest Policy and Economics*, 9: 536 – 545.
- CSA (Central Statistical Agency). 2014/15. Population and Housing Census in Ethiopia. Addis Ababa.
- D'Antonio, C.M. and Kark, S. 2002. Impacts and extent of biotic invasions in terrestrial ecosystems. *Trends in Ecology and Evolution*, 17: 202–204.
- DDAEP (Dire Dawa Administration Environmental Protection Agency). 2011. Dire Dawa Administration Program of Adaptation to Climate Change, Dire Dawa, Ethiopia.
- de Groot, R., Stulp, M., Finlayson, M. and Davidson N. 2006. Valuing wetlands. guidance for valuing the benefits derived from wetland ecosystem services. Ramsar Technical Report No. 3. CBD Technical Series No. 27. 52 p.
- de Wit, M.P., Crookes, D.J. and van Wilgen, B.W. 2001. Conflicts of interest in environmental management: estimating the costs and benefits of a tree invasion. *Biological Invasions*, 3: 167-178.
- Dehejia, R. and Wahba, S. 1999. Causal effects in non-experimental studies: reevaluating the evaluation of training programs. *Journal of American Statistical Association*, 84: 1053-1062.
- Dehejia, R.H. and Wahba, S. 2002. Propensity score matching methods for non-experimental causal studies: *The Review of Economics and Statistics*, 84(1): 151–161.
- Deutsch, L., Folke, C. and Skånberg, K. 2003. The critical natural capital of ecosystem performance as insurance for human well-being. *Ecological Economics*, 44: 205–217.

- Diamond, P. 1996. Testing the internal consistency of contingent valuation surveys. *Journal of Environmental Economics and Management*, 30(3): 265–281.
- Dietz, T., Rosa, E.A. and York, R. 2012. Environmentally efficient well-being: Is there a Kuznets Curve? *Journal of Applied Geography*, 32: 21-28.
- Dietz, Thomas, and Eugene Rosa A. 1994. The effects of population, affluence and technology on CO₂ emissions. Manuscript. Fairfax, Virginia: George Mason University.
- Dixon, J. and Pagiola, S. 1998. Economic analysis and environmental assessment. *Environmental Assessment Sourcebook Update No. 23*. Environmental Department, the World Bank. April 1998. 14 pages.
- Dixon, J.A. and Hufschmidt, M.M. 1986. *Economic Valuation Techniques for the Environment: A Case Study Workbook*. John Hopkins University Press, Baltimore and London.
- Dubale Admassu. 2006. Invasive plant and food security: the case of *Prosopis juliflora* invasion in Afar National Regional State, Ethiopia. Farm Africa for IUCN. 13p.
- Dubale Admasu. 2008. Invasive plants and food security: the case of *Prosopis juliflora* in the Afar region of Ethiopia. FARM-Africa for IUCN.
- Eagly, A.H. and Chaiken, S. 1993. *The Psychology of Attitudes*. Harcourt Brace Jovanovich College Publishers: Orlando.
- EARO, HDRA (Ethiopian Agricultural Research Organization and Henry Doubleday Research Association). 2005. Controlling the Spread of *Prosopis* in Ethiopia by its Utilisation. Ethiopian Agricultural Research Organization (EARO) and Henry Doubleday Research Association (HDRA), Addis Ababa.
- EHNRI (Ethiopia Health and Nutrition research Institute). 2000. Food Consumption Table for use in Ethiopia, part III. Addis Ababa, Ethiopia.
- Ellis, F. 1993. *Peasant Economics: Farm Households and Agrarian Development*. Cambridge University press New York.USA.
- Ellis, G.M. and Fisher, A.C. 1987. Valuing environment as input. *Journal of Environmental Management*, 25: 149–156.
- Emerton, L. 1997. Economic assessment of seychelles biodiversity. Conservation and National Parks Section, Division of Environment, Ministry of Foreign Affairs, Planning and Environment, Republic of Seychelles, Mahé.
- Emerton, L., and Howard, G. 2008. A toolkit for the economic analysis of invasive species. Nairobi: Global Invasive Species Programme.

- Esther, M. and Brent, S. 2008. *Prosopis* invasion and rural livelihoods in the Lake Baringo area of Kenya. *Conservation Society*, 6(2): 130-140
- Esther, M., and Brent, S. 2005. Invasion of *Prosopis juliflora* and local livelihoods: Case study from the lake Baringo area of Kenya, *ICRAF Working Paper no.3* (pp. 66). Nairobi: World Agroforestry Center.
- Executive Presidential Order. 1999. Executive Order 13112 of February 3, 1999: Invasive Species. *Federal Register*, 64(25): 6183-6186.
- Ezemenari, K., Rudqvist, A. and Subbarao, K. 1999. Impact evaluation: A note on concepts and methods, poverty reduction and Economic Management Network, World Bank: Washington DC.
- Felker, P. 2004. Mission report: TCP *Prosopis* control and utilization in Kenya. 19 September – 2 October 2004. 48p;
- Felker, P., Grados, N., Cruz, G. and Prokopiuk, D. 2001. Economic assessment of production of flour from *Prosopis alba* and *P. pallida* pods for human food applications. *Journal of Arid Environments*, 53: 517–523.
- Felker, P., Meyer, J.M. and Gronski, S.J. 1990. Application of self-thinning in Mesquite (*Prosopis glandulosa* var. *glandulosa*) to range management and lumber production. *Forest Ecology and Management*, 31: 225-232;
- Fishbein, M., Ajzen, I. 1975. *Belief, attitude, intention, and behavior: An introduction to theory and research*. Addison-Wesley, Reading, MA.
- Forsythe, S.S. 2001. An economic evaluation of HIV/AIDS services in Kenya: A practical policy application of contingent valuation. Unpublished PhD Thesis, University of Liverpool.
- Foster, E., 2003. Propensity score matching. An illustrative analysis of dose response. Lippincott Williams and Wilkins, Inc. *Journal of Medical Care*, 41(10): 1183-1192.
- Fredu, N., Marysse, S., Tollensc, E. and Mathijsc, E. 2007. Diversification, income inequality and social capital in Northern Ethiopia. Gordon.
- Freeman III, A.M. 1993. Non-use values in natural resource damage assessments. In: Kopp, R.J. and Smith, V.K. (eds.). *Valuing Natural Assets, the Economics of Natural Resource Damage Assessment*. Washington, D.C.: Resources for the Future.
- Freeman, A.M. 1986. On assessing the state of the arts of the contingent valuation method of valuing environmental changes. In Cummings, R.G., Brookshire, D.S. and Schulze, W.D. (eds.), *Valuing Environmental Goods*. Rowman and Allanfield, Totowa, N.J.
- Freeman, A.M. 2003. *The Measurement of Environmental and Resource Values: Theory and Methods*. 2nd Edition. Washington: Resources for the Future.

- García-Llorente, M., Martín-López, B., González, J.A., Alcorlo, P. and Montes, C. 2008. Social perceptions of the impacts and benefits of invasive alien species: implications for management. *Biological Conservation*, 141: 2969–2983.
- Garrod, G.D. and K.G. Willis. 1999. *Economic Valuation of the Environment: Methods and Case Studies*. Cheltenham: Edward Elgar.
- Gavali, D.J., Lakhmapurkar, J.J. and Wangikar, U.K. 2003. The impact of *Prosopis juliflora* invasion on biodiversity and livelihood on the Banni grassland of Karachi, Gujarat. Gujarat Ecology Society.
- Georgescu-Roegen, N. 1993. The entropy law and the economic problem, in Daly, H. E. And Townsend, K. N. (eds), *Valuing the Earth: Economics, Ecology, Ethics*. Cambridge, Mass.: MIT Press.
- Gómez-Baggethun and de Groot. 2007. The history of ecologic service in economic theory and practice: From early notions to market and payment schemes. *Ecological Economics*, 69: 1209-1218
- Gren, I.M., Folke, C., Turner, R.K. and Batman, I.J. 1994. Primary secondary values of wetlecosystems. *Environmental Resource Economics*, 4(4): 55–74.
- Grosjean, P. and Kontoleon, A. 2009. How sustainable are sustainable development programs? The case of the sloping land conversion program in China. *World Development*, 37(1): 268-285.
- Gujarati, D.N. 1988. *Basic Econometrics. Second Edition*. McGraw-Hill Inc, New York.
- Gujirati, D. 2005. *Basic Econometrics, 4th Edition*. New York McGraw Hill international edition, economics series, New York.
- Haab, T.C. 1997. Analyzing multiple question contingent valuation surveys: A reconsideration of the bivariate probit. Department of Economics, East Carolina University, Greenville, NC 27858,
- Haab, T.C. and McConnell, K.E. 2003. *Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation*. Edward Elgar Publishers, Cheltenham.
- Hamedu, Herrie. 2014. Socioeconomic and ecological impacts of *Prosopis juliflora* invasion in Gewane and Buremudaytu Woredas of the Afar region. Pp 118–124. In: *Regional conference on managing Prosopis juliflora for better (agro-) pastoral livelihoods in the Horn of Africa*. Addis Ababa, Ethiopia: Desalegn Hotel.
- Hanemann, W.M. 1984. Welfare evaluations in a contingent valuation experiments with discrete responses. *American Journal of Agricultural Economics*, 66: 332-341.

- Hanemann, W.M., Loomis, J. and Kanninen, B. 1991. Statistical efficiency of double bounded dichotomous choice contingent valuation. *American Journal of Agricultural Economics*, 73: 1255-1263.
- Hanley, N. and Spash, C.L. 1993. *Cost-Benefit Analysis and the Environment*. Cheltenham, UK. Northampton, MA.
- Hanneman, M. 1991. Willingness to Pay and Willingness to Accept: How Much Can They Differ. *American Economic Review*, 81: 635–647.
- Harland, P. and Staats, H. 1999. Explaining proenvironmental intention and behavior by personal norms and the theory of planned behavior. *Journal of Applied Social Psychology*, 29: 2505-2529.
- Hasen-Yusuf, M., Treydte, A.C., Abule, E. and Sauerborn, J. 2013. Predicting aboveground biomass of woody encroacher species in semi-arid rangelands, Ethiopia. *Journal of Arid Environments*, 96: 64–72.
- Heal, Geoffrey. 2001. *Valuing the Future: Economic Theory and Sustainability*. Columbia University Press, 1998.
- Hecht, J.E. 1999. *The Economic Value of the Environment: Cases from South Asia*. IUCN the World Conservation Union, Nepal Country Office, Kathmandu.
- Heckman, J.J. 1981. The incidental parameters problem and the problem of initial conditions in estimating a discrete. Time-discrete data stochastic process. In Manski, C. and McFadden, D. (eds.), *Structural Analysis of Discrete Data with Econometric Applications*, MIT Press.
- Heckman, J.J., Hidehiko Ichimura, Jeffery, Smith, A. and Petra Todd. 1998. Characterizing selection bias using experimental data. *Econometrica*, 66(1): 1017-98.
- Heckman, J.J., Ichimura, H. and Todd, P.E. 1997. Matching as an economic evaluation estimator: Evidence from evaluating a job training program. *Review of Economic Studies*, 64(1): 605-54.
- Heckman, J.J., Ichimura, H., Smith, J. and Todd, P.E. 1998. Characterizing selection bias using experimental data. *Economics*, 66(5): 1017-1098.
- Hicks, J.R. 1943. The four consumer surpluses. *Review of Economic Studies*, 11: 31-41.
- Holling, C.S. 1973. Resilience stability of ecological systems. *Annual Review of Ecology Systematic*, 4: 1–23.
- Hopkins, D., West, M. and Ainscow, M. 1996. *Improving the Quality of Education for All*. London, David Fulton Publishers.

- Hoyos, D. 2010. The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, 69: 1595–1603.
- Hrubes, D., Ajzen, I. and Daigle, J. 2001. Predicting hunting intentions and behavior: An application of the theory of planned behavior. *Leisure Sciences*, 23: 165-178.
- Hufschmidt, M.M., James, D.E., Mesiter, A.D., Bower, B.T. and Dixon J.A. 1983. *Environment, Natural Systems, and Development: An Economic Valuation Guide*. Johns Hopkins University Press, Baltimore and London
- Hunde, A. and Thulin, M. 1989. *Mimosoideae*. pp 71-98. In: Hedberg, I. and Edwards, S. (eds), *Flora of Ethiopia: Pittosporaceae to Araliaceae*. Addis Ababa University, Addis Ababa and Uppsala University, Sweden,
- IDP (Integrated Development Plan). 2006. Annual Report. Dire Dawa, 2006/7 2010/2011.
- Ilukor, J., Rettberg, S., Treydte, A. and Birner, R. 2014. Impact assessment of *Prosopis juliflora* invasion in the Afar Region, Ethiopia - Synthesis and recommendations from an interdisciplinary perspective. *Conference Paper*. May 2014.
- Imbens, G.W., and Wooldridge, J. M. 2008. Recent developments in the econometrics of program evaluation. *Journal of Economic Literature*, 47(1): 5–86.
- Israel, G.D. 1992. Sampling the evidence of extension program impact. Program evaluation and organizational development, IFAS, University of Florida. PEOD-5.
- Jalan, J. and Ravallion, M. 2003. Estimating the benefit incidence of an antipoverty program by propensity-score matching. *Journal of Business and Economics Statistics*, 21(1): 19-30.
- Jalan, J., and Ravallion, M. 1999. Income gains to the poor from workfare: Estimates for Argentina's Trabajar Program. Indian Statistical Institute and World Bank. Policy Research Working Paper 2149. Washington, DC.
- James, L.D. and Lee, R.R. 1971. *Economics of Water Resources Planning*. New York: McGraw-Hill Book Company. McGraw-Hill series in water resources and environmental engineering.
- Jema Haji and Abdu Mohammed. 2013. Economic impact of *Prosopis* on agropastoral households of Dire Dawa Administration, Ethiopia. *African Journal of Agricultural Research*, 8(9): 768-779.
- Johansson, P.O. 1987. *The Economic Theory and Measurement of Environmental Benefits*. Cambridge University Press.
- Johnson, R.B., Onwuegbuzie, A.J. and Turner, L.A. 2007. Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, 1: 112-133.

- Jorgensen, B.S., Syme, G., Bishop, B. and Nancarrow, B. 1999. Protest responses in contingent valuation. *Environmental and Resource Economics*, 14(1): 131-150.
- Jörn Laxén. 2007. Is *prosopis* a curse or a blessing? An ecological-economic analysis of an invasive alien tree species in Sudan, University of Helsinki Viikki, Tropical Resources Institute VITRI.
- Just, R.E., Hueth, D.L. and Schmitz, A. 1982. *Applied Welfare Economics and Public Policy*. Prentice Hall, Englewood Cliffs, N.J.
- Kahi, C.H., Ngugi, R.K., Mureithi, S.M. and Ng'ethe, J.C. 2009. The canopy effects of *Prosopis juliflora* (dc.) and *Acacia tortilis* (hayne) trees on herbaceous plants species and soil physico-chemical properties in Njemps flats, Kenya. *Tropical and Subtropical Agroecosystems*, 1: 117–122.
- Kahneman, D. 1986. The review panel assessment: comment. In: Cummings, R.G., Brookshire, D.S. and Schulze, W.D. (eds.), *Valuing Public Goods: The Contingent Valuation Method*. Rowman and Allanheld, Totowa, NJ
- Kallis, G., Videira, N., Antunes, P., Guimarães Pereira, Â., Spash, C.L., Coccossis, H., Corral Quintana, S., del Moral, L., Hatzilacou, D., Lobo, G., Mexa, A., Paneque, P., Pedregal, B., Santos, R. 2006. Participatory methods for water resource planning. Environment and Planning. *Government and Policy*, 24 (2): 215–234.
- Kassahun, Z., Yohannes, L. and Olani, N. 2005. *Prosopis juliflora*: potentials and problems. *Arem*, 6: 1-9.
- Kaur, A., Kaur, P., Singh, N., Singh Virdib, A., Singh, P. and Chand Ranac, J. 2012. Grains, starch and protein characteristics of rice bean (*Vigna umbellata*) grown in Indian Himalaya regions. *Food Research Institute*, 54 (1): 102–110
- Kealy, M.J., Montgomery, M. and Dovidio, J.F. 1990. Reliability and predictive validity of contingent values: Does the nature of the good matter? *Journal of Environmental Economics and Management*. 19: 244-263.
- Kennedy, J.J., Fox, B.L. and Osen, T.D. 1995. Changing social values and images of public rangeland management. *Rangelands*, 17: 127–132.
- Kerr, J., Pangare, G., Pangare, V.L. and George, P.J. 2000. An evaluation of dry land watershed management projects in India: Environment and production technology division, International Food Policy Research Institute: Washington, D.C.
- Kiker, G.A., Bridges, T.A., Verghese, A., Seager, T.P. and Linkov, I. 2005. Application of multicriteria decision analysis in environmental decision making. Integrated Environmental Assessment and Decision Making.
- Kontoleon, A. and Pascual, U. 2007. Incorporating Biodiversity into Integrated Assessments of Trade Policy in the Agricultural Sector. Volume II: *Reference*

- Manual*. Chapter 7. Economics and Trade Branch, United Nations Environment Programme. Geneva. Available at: <http://www.unep.ch/etb/pdf/UNEP%20T+B%20Manual.Vol%20II.Draft%20June07.pdf>.
- Labao, R., Francisco, H., Harder, D. and Santos, F.I. 2008. Do colored photographs affect willingness to pay responses for endangered species conservation? *Environmental Resource Economics*, 40: 251-264.
- Laxen, J. 2007. Is *Prosopis* a curse or a blessing? An ecological-economic analysis of an invasive alien tree species in Sudan Helsinki. PhD Thesis, University of Helsinki, Viikki Tropical Resources Institute (VITRI).
- Leech, N.L. and Onwuegbuzie, A.J. 2009. A typology of mixed methods research designs. *Quality and Quantity*, 43: 265-275.
- Leuven, E. and Sianesi, B. 2003. PSMATCH2. Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing.
- Lewin, K., Dembo, T., Festinger, L. and Sears, P.S. 1944. Level of aspiration. pp. 333–378. In: Hunt, J.M. (Ed.), *Personality the Behavior Disorder*. New York: Ronald Press.
- Liba, P. and Gretchen, C.D. 2009. The impact of Invasive Species on ecosystem services and human well-being. Stanford University.
- Lipton, D.W., Wellman, K.F., Sheifer, I.C. and Weiher, R.F. 1995. *Economic Valuation of Natural Resources: A Handbook for Coastal Resource Policymakers*. Silver Spring, Maryland: U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Coastal Ocean Office.
- Little, I. and Mirrlees, J. 1974. *Project Appraisal and Planning for Developing Countries*, Oxford, Oxford University Press (The “OECD Manual”).
- Liu, Zhiwei. 2003. Summary of income distribution inequity measure methods, *Productivity Research*, 2003(9): 28-32.
- Louviere, J.J., Hensher, D.A. and Swait, J. 2000. *Stated Choice Methods: Analysis and Application*. Cambridge: Cambridge University Press
- Lowe, S., Browne, M., Boudjelas, S. and Poorter, M.D. 2004. 100 of the World’s Worst Invasive Alien Species: A selection from the Global Invasive Species Database: The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN).
- Lynne, G.D., Casey, F.C., Hodges, A. and Rahmani, M. 1995. Conservation technology adoption decisions and the theory of planned behavior. *Journal of Economic Psychology*, 16: 581-598.

- Maddala, G.S. 1983. *Limited-dependent and Qualitative Variables in Economics*, New York: Cambridge University Press, pp. 257-91.
- Maddala, G.S. 1992. Estimation of dynamic disequilibrium models with rational expectations: The case of the commodity markets. pp. 234–249. In: Winters L.A. and Sapsford D. (eds.), *Primary Commodity Prices: Economic Models and Policy*. Cambridge University Press, Cambridge.
- Mäler, K., Gren, I., Folke, C. 1994. Multiple use of environmental resources: a household production function approach to valuing natural capital. In: Jansson, A., Hammar, M., Folke, C. and Costanza, R. (eds.), *Investing in Natural Capital*. Island Press, Washington DC.
- Manchester. S.J. and Bullock. J.M. 2000. The impacts of nonnative species on UK biodiversity and the effectiveness of control. *Journal of Applied Ecology*, 37: 845–864
- Manski, C. and Lerman, S. 1977. The estimation of choice probabilities from choice-based samples. *Econometrica*, 45(8): 1977–1988
- Martínez-Alier, J., Munda, G. and O'Neill, J. 1998. Weak comparability of values as a foundation for ecological economics. *Ecological Economics*, 26: 277–86.
- Maundu, P., Kibet, S., Morimoto, Y., Imbumi, M. and Adeka, R. 2009. Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods. *Biodiversity*, 10(2/3): 33-50.
- McCay, B.J. and Jentoft S. 1998. Market or community failure? Critical perspectives on common property research. *Human Organization*, 57: 21–29.
- McConnachie, M.R., Cowling, B., van Wilgen and McConnachie, D. 2012. Evaluating the cost-effectiveness of invasive alien plant clearing: A case study from South Africa. *Biological Conservation*, 155: 128-135
- McFadden, D. 1973. Conditional logit analysis of qualitative choice behavior. pp. 105-142. In: Zarembka P. (ed.), *Frontiers in Econometrics*. New York: Academic Press.
- Mcfadden, D. 1974. Conditional logit analysis of qualitative choice behaviour. In: Zarembka, P. (ed.), *Frontiers in Econometrics*. Academic Press, New York.
- MEA (Millennium Ecosystem Assessment). 2005. *Ecosystems and Human Well-being: Biodiversity Synthesis*. Washington, DC. (W.R. Institute)
- Mendola, M. 2007. Agricultural technology adoption and poverty reduction: A propensity-Score Matching Analysis for Rural Bangladesh. *Journal of Food Policy*, 32, 372–393.
- Merrifield, J. 1997. Sensitivity analysis in benefit–cost analysis: a key to increased use and acceptance. *Contemporary Economic Policy* XV, 82–92 (July).

- Mesfin Tilahun, Regina Birner and John Ilukor. 2016. Household-level preferences for mitigation of *Prosopis juliflora* invasion in the Afar region of Ethiopia: a contingent valuation. *Journal of Environmental Planning and Management*, 60: 282-308.
- Mesfin, T., Moeller, C., Rodriguez, D. and Temesgen, M. 2011. Conservation agriculture in dryland agro-ecosystems of Ethiopia. In: World Congress on conservation agriculture 2011 Papers. *5th World Congress on Conservation Agriculture and Farming Systems Design*. Brisbane, Australia, (1-4). 26-29 September 2011.
- Mitchell, R.C., and Carson, R.T. 1989. Using surveys to value public goods: the contingent valuation method. Washington, DC: Resource for the future. *Mountain Research and Development*, 8(2/3): 123-130.
- MoFED (Ministry of Finance and Economic Development). 2002. Ethiopia: Sustainable Development and Poverty Reduction Program. Ministry of Finance and Economic Development (MOFED), FDRE, Addis Ababa.
- Moisander, J. 1996. Attitudes and ecologically responsible consumption. Statistics Finland, Research Reports 218. Helsinki.
- Morey, E., Rowe R. and Watson M. 1993. A repeated nested logit Model of Atlantic Salmon Fishing. *American Journal of Agricultural Economics*, 75: 578–592.
- Mugasi, S.K., Sabiit, E.N. and Tayebwa, B.M. 2000. The economic implications of bush encroachment on livestock farming in rangelands of Uganda. *African Journal of Range and Forage Science*. 17: 64-69.
- Mulindol J.C. and Sang J. 2004. Farmer perceptions and the impact of *Prosopis* spp on food security in the lowlands of Baringo district. KARI-Regional Research Centre, Perkerra.
- Mulugeta, L. and Fisseha I. 2004b. Soil carbon stocks and turnovers in various vegetation types and arable lands along an elevation gradient in southern Ethiopia. *Geoderma*, 123: 177–188.
- Mulugeta, L., Karlun, E. and Olsson M. 2005a. Soil organic matter dynamics after deforestation along a farm field chronosequence in southern highlands of Ethiopia. Agriculture. *Ecosystems and Environment*, 109: 9-19.
- Munda, G. 1995. *Multicriteria evaluation in a fuzzy environment. Theory and Applications in Ecological Economics*. Physica-Verlag, Heidelberg.
- Muthana, K.D. 1988. *Prosopis* (Schwartz) DC, a fast growing tree to blossom the desert. pp. 113-114. In: Mario, A. H and Julio C. S. (eds.), *The Current State of Knowledge on Prosopis*. Recife, Brazil.
- Mwangi, E. and Swallow, B. 2008. *Prosopis juliflora* invasion and rural livelihoods in the Lake Baringo area of Kenya. *Conservation Society*, 6: 130–140.

- Nakamo, H., Nakajima, E., Yoshiharu, F., Yamada, K., Shigemori, H. and Hasegawa, K. 2003. Leaching of the allelopathic substance, L-tryptophan from the foliage of mesquite (*Prosopis juliflora* (Sw.) DC.) plants by water spraying. *Plant Growth Regulation*, 40: 49-52.
- Narain, U.A. and Fisher. 1994. Modelling the value of biodiversity using a production function approach. In Perrings, C., Mäler, K-G, Folke, C, Jansson, B-O, Holling, C. (eds.), *Biodiversity Conservation: Policy Issues Options*. Kluwer Academic Publishers, Dordrecht.
- Ndhlovu T. 2011. Impact of *Prosopis* (mesquite) invasion and clearing on ecosystem structure, function and agricultural productivity in semi-arid Nama Karoo rangeland, South Africa. MSc. Thesis, University of Stellenbosch. South Africa.
- Nijkamp, P.G., Vindigni and Nunes, P. 2006. Economic valuation of biodiversity: A comparative study, *Paper presented to the World Environmental Economics Congress*. Kyoto, Japan.
- Nordstrom, H. and Vaughan, S. 1999. *Trade and Environment*. World Trade Organization, Geneva.
- Norton, W. 1987. Humans, Land, and Landscape: A *Proposal* for cultural geography. *Le Géographe Canadien*, 31(1): 33.
- O'Connor, J. 1988. Capitalism, nature, socialism: A theoretical introduction. *Capitalism, Nature, Socialism*, 1: 11–38.
- OECD (Organisation for Economic Co operation and Development). 1979. Inter Futures Study Team. *Mastering the Probable and Managing the Unpredictable*. Organisation for Economic Co operation and Development and International Energy Agency, Paris.
- OECD (Organisation for Economic Co operation and Development). 2006. Creating value from intellectual assets, Meeting of the OECD Council at Ministerial Level 2006, OECD, Paris.
- O'Neill, R.V. and Kahn, J.R. 2000. Homo economus as a Keystone Species. *BioScience*, 50(4): 333-337.
- Ostrom, E., Dietz, T., Dolšák, N., Stern, P.C., Stonich, S. and Weber, E.U. 2002. *The Drama of the Commons*. National Academy Press, Washington, DC, 534 pp.
- Ouellette, J.A. and Wood, W. 1998. Habit intention in everyday life: The multiple processes by which past behavior predicts future behavior. *Psychological Bulletin*, 124: 54–74.
- Pallant, J. 2001. *The SPSS survival manual: A step-by-step guide to data analysis using SPSS for Windows (version 10)*. St Leonards, NSW: Allen and Unwin.

- Palloni, A. 1994. The relation between population and deforestation: Methods for drawing causal inferences from macro and micro studies. *In Population and Environment: Rethinking the Debate*, A. Lourdes, M.P. Stone, and D.C. Major (eds.), Westview, Boulder, CO.
- Pasiecznik, N.M. 1999. *Prosopis*-pest or providence, weed or wonder tree? (Newsletter No. 28): European Tropical Forest research Network.
- Pasiecznik, N.M., Felker, P., Harris, P.J.C., Harsh, L.N., Cruz, G., Tewari, J.C., Cadore, K. and Maldonado, L.J. 2001. The *Prosopis juliflora*-*Prosopis pallida* Complex: A Monograph. UK: HADRA Coventry. pp. 172.
- Pasiecznik, N.M., Harris, P.J.C. and Smith, S.J. 2004. Identifying Tropical *Prosopis* Species: *A Field Guide*. Henry Doubleday Research Association (HDRA), Coventry.
- Pattanayak, S.K. and Kramer R.A. 2001. Worth of watersheds: a producer surplus approach for valuing drought mitigation in Eastern Indonesia. *Environment and Development Economics*, 6(01): 123-146.
- Patterson, M. 1998. Commensuration theories of value in ecological economics. *Ecological Economics*, 25(01): 105-125.
- Pearce, D.W. and Warford, J.W. 1993. *World With out End: Economics, Environment, and Sustainable Development*. Oxford University Press, Oxford.
- Perman, R., Common, M., Mcgilvray, J. and Ma, Y. 2003. *Natural Resource and Environmental Economics*, Pearson Education Limited, England.
- Perman, R., Ma, Y. and McGilvary, J. 1995. *Natural Resource and Environmental Economics*, Longman Publisher, UK.
- Phaneuf, Daniel J., Jared, C.C. and Joseph, A.H. 2009. Non-Price Equilibria for Non-Marketed Goods. *Journal of Environmental Economics and Management*, 57(1): 45–64.
- Pimental, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, C., Wong, E., Russel, L., Zern, J., Aquino, T. and Tsomondo, T. 2001. Economics and environmental threats of alien plant, animal and microbe invasions. *Agriculture, Ecosystems and Environment*, 84: 1-20.
- Pouta, E., and Rekola, M. 2001. The theory of planned behavior in predicting willingness to pay for abatement of forest regeneration. *Society and Natural Resources*, 14: 93-106.
- Rashid, M., Zimring, C., Wineman, J., Flaningam, T., Nubani, L. and Hammash, R. 2005. The Effects of Spatial behaviors and Layout Attributes on Individuals' Perception of

- Psychosocial Constructs in Offices. *Proceedings of the Fifth International Space Syntax Conference*. Delft, Netherlands
- Ravallion, M. 2005. Evaluating Anti-Poverty Programs: Policy Research Working Paper 3625, World Bank: Washington DC.
- Readon, T., Berdegue, J., Barrett, C. and Stamoulis, K. 2007. Households income diversification in to non-farm activities. *In*: Haggblade, S., Hazell, P., and Reardon T. (eds), *In Transforming Rural Non farm Economy*. Baltimore: Johns Hopkins University Press.
- Roberts, J.T. and Grimes, P.E. 1997. Carbon intensity and economic development 1962–1971: A brief exploration of the environmental Kuznets curve. *World Development*, 25: 191–198.
- Romero and Rehman. 1987. Management and the use of multiple criteria decision analysis. *European Review of Agricultural Economics*.
- Rosembaum, P.R. and Rubin, D.B. 1983. The Central Role of the Propensity Score in Observational Studies for Causal effects. *Biometrika*, 70(1): 41–55.
- Rosenbaum, P.R. 2002. *Observational Studies*. 2nd Edition. New York: Springer. 375p.
- Rosenberger, R., Mark, S., Needham, D., Anita, Morzillo, T. and Caitlin, M. 2012. Attitudes, willingness to pay, and stated values for recreation use fees at an urban proximate forest. *Journal of Forest Economics*, 18(4): 271–281
- Ross, T.S., David C.L.M., Nick, M.P. and David, M.R. 2014. *Prosopis*: a global assessment of the biogeography, benefits, impacts and management of one of the world's worst woody invasive plant taxa. Natural Resources and the Environment, CSIR, P.O. Box 320, Stellenbosch 7599, South Africa Agroforestry Enterprises, Villebeuf, Cussy en Morvan 71550, France.
- Rudel, T. and Roper, J. 1997. The paths to rain forest destruction: Cross-national patterns of tropical deforestation, 1975–1990. *World Development*, 25: 53–65.
- Shiferaw, H., Teketay, D., Nemomissa, S. and Assefa, F. 2004. Some biological characteristics that foster the invasion of *Prosopis juliflora* (Sw.) DC at Middle Awash Rift Valley Area, Northeastern Ethiopia. *Journal of Arid Environments*, 58: 135–154.
- Solomon, D., Fritzsche, F., Lehmann, J., Tekalign, M. and Zech W. 2002. Soil organic matter dynamics in the subhumid agroecosystems of the Ethiopian Highlands: Evidence from ¹³C abundance and particle size fraction. *Soil Science Society of America Journal*, 66: 969–978.
- Stafford-Smith, D.M. and Reynolds, J.F. (eds.). 2002. *Integrated Assessment and Desertification*. Dahlem University Press, Berlin.

- Stahl, C., Cimorelli, A.J. and Chow, A.H. 2002. A new approach to environmental decision analysis: Multi-criteria integrated resource assessment. *Bulletin of Science, Technology and Society*, 22: 443-459.
- Stefan, A. 2005. Spread of the introduction tree *Prosopis* (Sw.) DC in the Lake Baringo area, Kenya. Instituionen for skoglig vegetationsekologi, Grafiska enheten, SLU, Umeå.
- Stern, D.I. 1998. Progress on the environmental Kuznets curve? *Environment and Development Economics*, 3: 173–196.
- Stirling, A. and Mayer, S. 2001. A novel approach to the appraisal of technological risk: a multi-criteria mapping study of a genetically modified crop. *Environment and Planning Government and Policy*, 19(4): 529–555.
- Storck, H., Bezabih, E., Berhanu, A., Andrzej, B. and Hawariat, S.W. 1991. Farming systems and farm management practices of smallholders in the Hararghe Highlands: A baseline survey. Wissenschaftsverlag Vauk Kiel, Germany, ISBN: 9783817501076, Pages: 195.
- Sunil N., Katari B., Y.D. Imran K. 2015. Biodiversity of Semiarid Landscape. Baseline Study for Understanding the Impact of Human Development on Ecosystems. Springer Cham Heidelberg New York Dordrecht London.
- Tassew, W. 2000. Economic Analysis and Policy Implications of Farm and Off-Farm Employment: A Case Study in the Tigray Region of Northern Ethiopia. PhD Thesis, Wageningen Agricultural University, The Netherlands.
- Taylor, S. and Todd, P. 1997. Understanding the determinants of consumer composting behavior. *Journal of Applied Social Psychology*, 27: 602-628.
- Teddlie, C. and Tashakkori, A. 2003. Major issues and controversies in the use of mixed methods in the social and behavioral sciences. In: Tashakkori, A. and Teddlie, C. (eds.), *Handbook of Mixed Methods Research in Social and Behavioural Research*. Thousand Oaks, CA, Sage Publications.
- TEEB (The Economics of Ecosystems and Biodiversity). 2009. The Economics of Ecosystems and Biodiversity for National and International Policy Makers.
- Thurstone, L. 1927. Law of comparative judgment. *Psychological Review*, 34: 273-286.
- Tietenberg, T. 1996. *Environmental and Natural Resource Economics*. Harper Collins College Publishers.
- Tilahun, M., Vranken, L., Muys, B., Deckers, J., Gebreegziabher, K., Gebrehiwot, K., Bauer, H. and Mathijs, E. 2015. Rural households' demand for frankincense forest conservation in Tigray, Ethiopia: A contingent valuation analysis. *Land Degradation and Development*, 26: 642_653.

- Train, K. 1986. *Qualitative Choice Analysis: Theory, Econometrics and an Application to Automobile Demand*. The MIT Press, London.
- Train, K. 1998. Recreation demand models with taste variation. *Land Economics*, 74: 230–239.
- Triandis, H.C. 1977. *Interpersonal Behavior*. Monterey, CA: Brooks/Cole.
- Triandis, H.C. 1980. Values, attitudes, interpersonal behavior. pp. 195–259. In: Howe, H.E. Jr. and Page, M.M. (eds.), *Nebraska Symposium on Motivation*. Lincoln, NE: University of Nebraska Press.
- Trumbo, C.W. and O'Keefe, G.J. 2001. Intention to conserve water: Environmental values, planned behavior, and information effects. A comparison of three communities sharing a watershed. *Society and Natural Resources*, 14: 889–899.
- Turner II, B.L., Matson, P., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Hovelsrud-Broda, G., Kasperson, J.X., Kasperson, R.E., Luers, A., Martello, S., Mathiesen, M.L., Naylor, R., Polsky, C., and Pulsipher, S.A. 2003. A frame work for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Science*, 100: 8074–8079.
- Turner, R.K. 1993. Speculations on weak and strong sustainability, GEC Working Paper 92 26, CSERGE, University of East Anglia, Norwich and University College London.
- Turner, R.K., Pearce, D. and Bateman, I. 1994. *Environmental Economics: An Elementary Introduction*. Hemel Hempstead, Prentice Hall/Harvester Wheatsheaf.
- Van Beers, C. and de Moor, A.P.G. 2001. *Public Subsidies and Policy Failures: How Subsidies Distort the Natural Environment, Equity and Trade and How to Reform Them*. Edward Elgar, Cheltenham, UK, 142 pp.
- Van Beukering, P.J.H., Cesar, H.S.J. and Janssen, M.A. 2003. Economic valuation of the Leuser National Park on Sumatra, Indonesia. *Ecological Economics*, 44: 43–62.
- Vatn, A. and Bromley, D.W. 1994. Choices without Prices without Apologies. *Journal of Environmental Economics and Management*, 26(2): 129–148.
- Veisten, K. 2007. Contingent valuation controversies: philosophic debates about economic theory. *The Journal of Socio-Economics*, 36: 204–232.
- Vojáček, O. and Pecáková, I. 2010. Comparison of discrete choice models for economic environmental research. *Prague Economic Papers*, 1: 35–53.
- Waggoner, P.E. and Ausubel, J.H. 2002. A framework for sustainability science: A renovated IPAT identity. *Proceedings of the National Academy of Sciences*, 99: 7860–7865.

- Wakie, T.T., Evangelista, P.H., Jarnevich, C.S. and Laituri, M. 2014. Mapping Current and Potential Distribution of Non-Native *Prosopis juliflora* in the Afar Region of Ethiopia. *Public Library of science*, 9(11): e112854. doi:10.1371/journal.pone.0112854
- Walker, B.H., Holling, C.S., Carpenter, S.R. and Kinzig, A.P. 2004. Resilience, adaptability, transformability. *Ecology Society*, 9(2): 5.
- Wall, R., Devine-Wright, P. and Mill, G.A. 2007. Comparing and combining theories to explain pro-environmental intentions: The case of commuting-mode choice. *Environment and Behavior*, 39: 731-753.
- White, L.J. 1967. The historical roots of our ecological crisis. *Science*, 155: 1203–1207.
- Whitehead, J.C. 2000. Anchoring and shift in multiple bound contingent valuation: Department of Economics, East Carolina University.
- Whittington, D., Smith, V.K., Okorafor, A., Okore, A., Liu, J.L. and McPhail, A. 1992. Giving Respondents Time to Think in Contingent Valuation Studies: A Developing Country Application. *Journal of Environmental Economics and Management*, 22: 205–225.
- Willig, R. 1976. Consumer's surplus without apology. *American Economic Review*, 66: 589–597
- Winpenny, J.T. 1991. *Values for the Environment: A Guide to Economic Appraisal*. Overseas Development Institute, Her Majesty's Stationery Office, London.
- Witt, A.B.R. 2010. Biofuels and invasive species from an African perspective. A review. *Global Change Bioenergy*, 2: 321–329.
- Wittmer, H., Rauchmeyer, F. and Klauer, B. 2006. How to select instruments for resolution of environmental conflicts? *Land Use Policy*, 23(1): 1-9
- Woldehana, T. 2002. Rural farm/non-farm income linkages in northern Ethiopia. Online. Available HTTP: <http://www.fao.org/docrep/005/y4383e/y4383e0e.htm> (accessed on April 12, 2015)
- Wooldridge, J.M. 2002. *Econometric Analysis of Cross-Section and Panel Data*. Cambridge, MA, MIT Press.
- Wooldridge, M. 2000. *Introductory Econometrics: A Modern Approach*. United States, South western college publishing.
- Xu, K. 2004. How has the Literature on Gini's Index Evolved in the Past 80 Years? Department of Economics, Dalhousie University. Halifax, Nova Scotia, Canada.

- Yibekal, A.T. 2012. Ecological and economic dimensions of the paradoxical invasive species-*Prosopis* and policy challenges in Ethiopia. *Journal of Economic and Sustainable Development*, 3(8): 62–70.
- Yohannes, A., Anke, J., Detlef, M., Simone, R., Clemens, R. and Thomas, K. 2014. Ecosystem engineer unleashed: *Prosopis juliflora* threatening ecosystem services. *Regional Environmental Change*, 15(1): 374.
- York, R., Rosa, E. and Dietz, T. 2003. Footprints on the Earth: The environmental consequences of modernity. *American Sociological Review*, 68: 279–280.
- York, R., Rosa, E.A. and Dietz, T. 2010. Ecological modernization theory: Theoretical and empirical challenges. pp. 77–90. In: Redclift, M.R. and Woodgate, G. (eds.), *The International Handbook of Environmental Sociology*. Cheltenham, England: Edward Elgar.
- Young, O.R. 2002. *The Institutional Dimensions of Environmental Change: Fit, Interplay and Scale*. The MIT Press, Cambridge, MA.
- Zeila, A.A., Mwangi, E., and Swallow, B. 2004. *Prosopis juliflora*: Boon or bane for dryland agroforestry? (No. 1): A quarterly publication of Eastern and Central Africa Region of the World Agroforestry Center.
- Zeray Mehari. 2008. Invasion of *Prosopis* (SW.) DC and Rural Livelihoods. The case of Afar Pastoralists at Middle Awash Area of Ethiopia. MSc. Thesis, Norwegian University of Life Science, Oslo, 3 pp.
- Zopounidis, C. and Doumpos, A. 2002. Multicriteria classification and sorting methods: A literature review. *European Journal of Operational Research*, 138: 229–246

7. APPENDICES

APPENDIX TABLES

Appendix Table 1. Test of independence of irrelevant alternatives

Model	$\chi^2(5)$	Prob>chi2
Multinomial logit	54.73	0.0000
Conditional logit	44.29	0.0000

Source: Own computation results based on survey data, 2015.

Appendix Table 2. Comparison of WTP between the contingent valuation and the choice experiment

	CV		CE : RPL	
	WTPa	%	WTPb	%
Land security	n.d	4.19%	23.84 [13.73, 33.95]	11.53%
Livestock feed	n.d	8.53%	38.49 [9.64, 67.34]	18.62%
Biodiversity	n.d	57.28%	77.92 [32.87, 122.97]	37.70%

Microclimate regn	n.d	30.00%	-66.45 [-34.59, -98.30]	32.15%
Total	224.30 [189.69, 336.03]		223.43 [173.45, 318.43]	

Source: Own computation results based on survey data, 2015.

Appendix Table 3. Choice experiment: Mixed Logit

	Mixed Logit	
	Coefficient	SD
Payment	-0.015 (0.005)***	
Land security	0.3576 (0.235)	0.0001 (0.199)
Livestock feed	0.5772*** (0.132)	0.0008 (0.145)
Biodiversity	1.169 (0.312)***	0.0006 (0.208)
Microclimate regn	-0.9968 (0.262)***	-0.0035 (0.197)
Loglikelihood	-597.977	
LR chi2	12.73	
Prob > chi2	0.0475	
Number of obs	2000	2000

Note: *** means significant at the 1% probability levels

Source: Own computation results based on survey data, 2015.

Appendix Table 4. OLS regression of maximum stated willingness to pay

	Eradication mitigation measure			Control mitigation measure		
	Coef.	Robust Std. Err.	t	Coef.	Std. Err.	t
MaximumWTP						
bid1	0.940	0.027	35.06***	0.591	0.029	20.73***
bid2	0.006	0.014	0.41	0.677	0.073	9.30***
Annual family income	5.61e-07	2.12e-05	0.03	1.681	0.635	2.65**
Age	0.498	0.475	1.05	-0.127	0.202	-0.63
Sex	23.198	13.827	1.68*	4.20	4.705	0.91
Educational level	20.654	11.375	1.82*	5.928	3.959	1.50
Benefit from <i>Prosopis</i>	0.1727	1.223	0.14	0.060	0.321	0.19
Occupation	-1.891	4.032	-0.47	0.158	0.062	2.54**
Size of cultivated land	2.807	1.962	1.43	-1.306	0.816	-1.60
Physical injury	0.124	0.055	2.28**	0.006	0.051	0.12
Family size	-1.519	1.974	-0.77	-0.665	1.405	-0.47
Livestock holding	0.048	0.823	0.06	-0.059	0.234	-0.25
Participation in non-farm	-7.591	9.963	-0.76	0.391	0.146	2.69**
Access to rural credit	.307	0.1571	1.96*	-5.653	3.790	-1.49
Strongly oppose	- 6.766	2.645	-2.56**	-59.429	21.486	-2.77***
Oppose	-72.677	19.163	-3.79***	-47.826	19.174	-2.49**
Support	27.774	13.086	2.12**	1.347	.647	2.08**

Strongly support	3.328	1.535	2.17**	-5.055	6.799	-0.74
_cons	-25.983	32.407	-0.80	17.356	12.630	1.37
Number of obs =241				Number of obs=227		
F(18, 222)=115.43				F(18, 208)=86.17		
Prob > F =0.000				Prob > F=0.000		
R-squared =0.919				R-squared=0.973		
Adj R-squared =0.911				Adj R-squared =0.962		
Root MSE =57.778				Root MSE=10.33		

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

Appendix Table 5. Multi-collinearity test with VIF for variables included SUR and RBVP models

Variables	Eradication mitigation measure				Control mitigation measure			
	WTP1		WTP2		WTP1		WTP2	
	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
bid1	1.28	0.781			1.64	0.608		
bid2			1.10	0.908			1.72	0.581
Annual family income	1.26	0.791	1.07	0.933	1.39	0.721	1.28	0.780
Age	1.24	0.808	1.23	0.811	1.72	0.580	1.78	0.562
Sex	1.15	0.868	1.13	0.888	1.52	0.660	1.47	0.679
Educational level	1.18	0.847	1.18	0.849	1.53	0.652	1.48	0.675
Benefit from <i>Prosopis</i>	1.25	0.799	1.26	0.795	1.34	0.747	1.35	0.739
Occupation	1.33	0.749	1.35	0.739	1.99	0.502	1.56	0.641
Size of cultivated land	1.34	0.747	1.35	0.741	1.66	0.601	1.57	0.638
Physical injury	1.14	0.880	1.14	0.881	1.41	0.707	1.39	0.717
Family size	1.23	0.811	1.23	0.811	1.34	0.744	1.31	0.762
Livestock holding	1.20	0.836	1.23	0.811	1.85	0.541	1.73	0.578
Participation in non-farm	1.21	0.827	1.22	0.822	1.60	0.624	1.59	0.629
Access to rural credit	1.32	0.759	1.33	0.752	2.04	0.491	1.59	0.630
Strongly oppose	1.20	0.835	1.21	0.829	3.68	0.271	1.34	0.747
Oppose	1.22	0.819	1.22	0.817	3.67	0.273	1.26	0.794
Support	1.28	0.784	1.28	0.784	6.90	0.145	3.45	0.290
Strongly support	1.45	0.691	1.46	0.685	6.22	0.161	3.98	0.251
Mean VIF	1.25		1.23		2.44		1.76	

Source: Own computation results based on survey data, 2015.

Appendix Table 6. Multi-collinearity test for all explanatory variables included in impacts evaluation

	Collinearity Statistics	
	Tolerance	VIF
Age	0.537	1.862
Sex	0.894	1.118
Educational level	0.769	1.301
Distance from main road	0.771	1.297
Farming experience	0.449	2.227
Family size	0.736	1.358
Dependency ratio	0.825	1.213
Size of cultivated land	0.775	1.290
Livestock holding	0.720	1.388

Access to irrigation water	0.632	1.583
Access to rural credit	0.706	1.417
Participation in the Safety net	0.696	1.436
Perceive occurrence Drought	0.736	1.359
Marital status	0.931	1.070
Distance to the market	0.822	1.220

Source: Own computation results based on survey data, 2015.

Appendix Table 7. Contingency coefficient among discrete explanatory variables

	EDUHH	IRRGTN	CREDITACC	PIIOHMTN	SAFTYNT	DRTEF	NONFARM
EDUHH	1	0.173	0.041		0.182	0.045	0.019
IRRGTN		1	0.235		0.145	0.183	0.120
CREDITACC			1		0.375	0.112	0.012
SAFTYNT					1	0.157	0.174
DRTEF						1	0.058
NONFARM							1

Source: Own computation results based on survey data, 2015.

Appendix Table 8: Sample households affected by *Prosopis* thorn

<i>Prosopis</i> causes	freq	%	% from total sample	Mean (ill per year)	Mean (missing labour day)	Mean	Std. Err.
			%				
<i>Prosopis</i> thorn	30	22	2.00	39	22.28	22.18	8.43

Source: Own computation results based on survey data, 2015.

Appendix Table 9. Conversion factor for computing calorie intake

Food item	Unit	Calorie	Food item	Unit	Calorie
Wheat	Kg	3574	Beef	Kg	1148
Teff	Kg	3589	Milk	litter	737
Barely	Kg	3723	Butter	Kg	7363
Lentil	Kg	3522	Egg	No	61
Hose bean	Kg	3514	Honey	Kg	3605
Sorghum	Kg	3805	Pepper	Kg	933
Peas	Kg	3553	Maize	Kg	3560
Vetch	Kg	3470	Millet	Kg	3260
Linseed	Kg	5109	Check pea	Kg	3630
Sugar	Kg	3850	Garlic	Kg	118
Coffee	Kg	1103	Edible oil	Kg	8964

Source: EHNRI, 2000

Appendix Table 10. Conversion factor of tropical livestock unit (TLU)

Livestock Category	TLU	Livestock Category	TLU
Ox	1	Horse	1.1
Cow	1	Sheep (adult)	0.13
Woyefen	0.34	Sheep (young)	0.06
Heifer	0.75	Goat (adult)	0.13
Calf	0.25	Goat (young)	0.06
Donkey (adult)	0.7	Hen	0.013
Donkey (young)	0.35		

Source: Storck, *et al.*, 1991

Appendix Table 11. Participation to the intervention of the project

Project participation	No.	%
no	15	6
yes	235	94
Total	250	100

Source: Own computation results based on survey data, 2015

Appendix Table 12. Probit model estimation for the initial and follow-up bid for *Prosopis* eradication measure

MODEL I PROBIT MODEL FOR INITIAL BID RESPONSE				MODEL II PROBIT MODEL FOR FOLLOW-UP BID RESPO		
Wtp1	Coef.	Robust Std. Er.	dy/dx	Coef.	Robust Std. Err.	dy/dx
bid1	-0.014***	0.002	-0.001			
bid2				-0.008***	0.001	-0.003
Annual family income	0.001**	0.001	-1.0e-4	0.001**	3.0-e4	3.0-e4
Age	-0.033*	0.019	-0.002	0.015	0.014	0.006
Sex	1.450**	0.565	0.256	3.635***	0.902	0.639
Educational level	-0.783	0.552	-0.037	-0.170	0.328	-0.068
Benefit from <i>Prosopis</i>	-0.050	0.050	-0.004	0.012	0.039	0.005
Occupation	0.176	0.161	0.012	0.100	0.135	0.040
Family size	-0.101	0.074	-0.007	-0.107	0.100	-0.043
Physical injury	0.277	0.180	0.019	0.061	0.187	0.024
Size of cultivated land holding	0.001	0.053	1.0e-4	-0.098	0.060	-0.039
Livestock holding	-0.031	0.047	-0.002	0.007	0.036	0.003
Participation in non-farm income activities	-0.067	0.349	-0.005	-0.500	0.368	-0.195
Access to rural credit	-0.029	0.319	-0.002	-0.365	0.400	-0.145
Strongly oppose	-2.813***	0.864	-0.762	0.100	0.661	0.040
Oppose	-4.607***	1.053	-0.977	0.035	0.878	0.014
Support	0.841*	0.508	0.110	0.693	0.519	0.254
Strongly support	0.976***	0.390	0.076	1.346***	0.399	0.497
Constnt	5.450***	1.691		6.483***	1.584	
Number of obs = 241				Number of obs = 241		
Wald chi2(18) = 85.38				Wald chi2(18) = 62.07		
Prob > chi2 = 0.000				Prob > chi2 = 0.000		
Pseudo R2 = 0.767				Pseudo R2 = 0.736		
Log pseudolikelihood = -52.639				Log pseudolikelihood = -33.799		

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

Appendix Table 32. Probit model estimation for the initial and follow-up bid for *Prosopis* control measure

MODEL III PROBIT MODEL FOR INITIAL BID				MODEL IV PROBIT MODEL FOR FOLLOW-UP BID		
Variables	Coef.	Robust Std. Err.	dy/dx	Coef.	Robust Std. Err.	dy/dx
bid1	-0.537	0.783	-0.159			
bid2				-0.005	0.004	-0.002
Annual family income	0.178	0.498	0.053	0.356	0.319	0.142
Age	-3.231**	1.318	-0.954	-0.012	0.026	-0.005
Sex	1.626**	0.778	0.259	0.464	0.561	0.182
Educational level	-0.916	0.669	-0.304	0.094	0.530	0.037
Benefit from <i>Prosopis</i>	-0.002	0.054	-0.001	-0.027	0.040	-0.011
Occupation	0.584*	0.329	0.173	0.375*	0.207	0.150
Family size	-1.862**	0.833	-0.543	0.008	0.107	0.003
Physical injury	0.322	0.328	0.095	0.573*	0.315	0.229
Size of cultivated land holding	0.944*	0.537	0.279	0.610***	0.228	0.243
Livestock holding	0.062	0.241	0.018	-0.096***	0.033	-0.038
Participation in non-farm income activities	-0.438	0.494	-0.125	-1.015**	0.504	-0.387
Access to rural credit	0.796	0.751	0.227	-0.839*	0.502	-0.325
Strongly oppose	-4.683***	1.062	-0.896	-1.162	0.982	-0.406
Oppose	-7.898***	1.564	-0.945	-0.845	1.024	-0.313
Support	5.367***	1.056	0.993	1.783**	0.885	0.612
Strongly support	0.921***	0.813	0.983	1.171	0.882	0.439
Constant	18.173***	6.949		3.417	3.760	
Number of obs = 227				Number of obs = 227		
Wald chi2(17) = 354.07				Wald chi2(17) = 31.05		
rob > chi2 = 0.000				Prob > chi2 = 0.020		
Pseudo R2 = 0.323				Pseudo R2 = 0.324		
Log pseudolikelihood = -20.680				Log pseudolikelihood = -27.184		

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

Appendix Table 33. Results of recursive bivariate probit models for WTP eradication and control measures

WTP for Eradication measure				WTP for Control measure		
Model VI Recursive Bivariate Probit				Model VIII Recursive Bivariate Probit		
WTP1	Coef.	Robust Std. Err.	dy/dx	Coef.	Robust Std. Err.	dy/dx
Bid1	-0.014***	0.002	-0.002	-0.011	0.011	-0.002
Annual family income	0.001***	0.000	2.0e-4	0.452	0.378	0.076
Age	-0.029	0.019	-0.005	-0.021	0.033	-0.004
Sex	1.452***	0.540	0.112	0.141	0.723	0.025
Educational level	-0.902	0.575	-0.198	0.227	0.621	0.035
Benefit from <i>Prosopis</i>	0.040	0.051	0.006	0.001	0.042	2.0e-4
Occupation	0.072	0.147	0.011	0.166	0.229	0.028
Family size	-0.071	0.067	-0.011	0.843	0.582	0.141
Physical injury	0.196	0.142	0.031	0.097	0.257	0.016
Size of cultivated land	0.022	0.058	0.003	0.385	0.434	0.064
Livestock holding	-0.067	0.049	-0.011	0.027	0.194	0.005
Participation in non-farm	-0.058	0.323	-0.009	0.268	0.490	0.046
Access to rural credit	-0.022	0.312	-0.004	0.654	0.531	0.109
Strongly oppose	-3.599***	0.619	-0.123	-7.452***	0.597	-0.175
Oppose	-4.115***	0.765	-0.134	0.455	0.556	0.060
Support	0.759*	0.442	0.076	0.019	0.947	0.003
Strongly support	0.934**	0.361	0.148	0.491	1.018	0.079
Constant	4.700***	1.451		-4.195	3.904	
WTP2						
Bid2	-0.011***	0.002	-2.0e-4	0.001	0.003	2.0e-4
Annual family income	0.001	4.0e-4	.013	0.306	0.417	0.051
Age	0.032**	0.016	-0.608	-0.657	1.219	-0.109
Sex	3.506***	1.061	0.100	0.268	0.675	0.039
Educational level	-0.253	0.476	0.019	-0.001	0.585	-0.000
Benefit from <i>Prosopis</i>	0.048	0.041	0.078	0.054	0.042	0.009
Occupation	0.197	0.217	0.001	0.851***	0.259	0.142
Family size	-0.002	0.071	-0.082	-1.648**	0.678	-0.274
Physical injury	0.207	0.165	0.067	0.480	0.313	0.080
Size of cultivated land	0.169**	0.073	0.014	0.679*	0.395	0.113
Livestock holding	-0.035	0.045	-0.122	0.422*	0.234	0.070
Participation in non-farm	-0.315	0.384	-0.321	2.129***	0.711	0.350
Access to rural credit	-0.829**	0.413	-0.266	0.771	0.502	0.133
Strongly oppose	-0.688	0.948	-0.399	-6.228***	1.040	-0.159
Oppose	-1.106	0.742	-0.122	0.842	0.573	0.203
Support	-0.306	0.811	0.552	1.003	0.815	0.183
Strongly support	1.538**	0.407	0.004	2.319**	1.056	0.285
WTP1	4.156***	0.750	0.867	-1.648**	0.651	-0.146
Constant	4.028***	1.350		2.779	712	
/athrho	-13.395***	1.065		16.416***	1.318	
Rho	-1	9.88e-12		1	2.93e-14	
Number of obs = 241				Number of obs = 227		
Wald chi2(34) = 166.02 Prob > χ^2 = 0.000				Wald chi2(34) = 627.69 Prob > χ^2 = 0.000		
Log pseudolikelihood = -59.310				Log pseudolikelihood = -39.621		
Wald test of rho χ^2 (1)=5.235 Prob> χ^2 =0.022				Wald test of rho=0: χ^2 (1) = 155.073 Prob > χ^2 = 0.000		

Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively

Source: Own computation results based on survey data, 2015.

Appendix Table 15. Data of Stakeholder's perception towards environmental problems

ORGANIZATION	Temperature	Rainfall	Flood	Biodiversity	Livestock disease	Food insecurity	Biological invasions	Drought incidence
Rural Development office	4	5	5	5	1	5	5	5
Rural Development office	5	5	5	4	3	3	4	5
Rural Development office	2	1	4	3	4	2	2	3
Rural Development office	5	5	5	5	5	5	5	5
Rural Development office	5	5	3	5	4	5	4	4
Rural Development office	5	2	4	1	4	2	4	5
Rural Development office	5	5	3	5	3	5	5	5
Rural Development office	5	5	3	4	5	5	5	5
Rural Development office	4	5	5	5	1	5	5	5
Rural Development office	5	5	5	4	3	3	4	5
Rural Development office	2	1	4	3	4	2	2	3
Rural Development office	5	5	5	5	5	5	5	5
Rural Development office	5	5	3	5	4	5	4	4
Rural Development office	5	2	4	1	4	2	4	5
Rural Development office	5	5	3	5	3	5	5	5
Environment Protection	5	5	3	4	5	5	5	5
Environment Protection	4	5	5	5	1	5	5	5
Environment Protection	5	5	5	4	3	3	4	5
Environment Protection	2	1	4	3	4	2	2	3
Environment Protection	5	5	5	5	5	5	5	5
Environment Protection	5	5	3	5	4	5	4	4
Environment Protection	5	2	4	1	4	2	4	5
Environment Protection	5	5	3	5	3	5	5	5
Environment Protection	5	5	3	4	5	5	5	5
Environment Protection	4	5	5	5	1	5	5	5
Dire Dawa Environmental	5	5	5	4	3	3	4	5
Dire Dawa Environmental	2	1	4	3	4	2	2	3
Dire Dawa Administration	5	5	5	5	5	5	5	5
Dire Dawa Administration	5	5	3	5	4	5	4	4
Dire Dawa Administration	5	2	4	1	4	2	4	5
Dire Dawa Administration	5	5	3	5	3	5	5	5
Dire Dawa Administration	5	5	3	4	5	5	5	5
Dire Dawa Administration	4	5	5	5	1	5	5	5
Dire Dawa Administration	5	5	5	4	3	3	4	5
Dire Dawa Administration	2	1	4	3	4	2	2	3
Dire Dawa Administration	5	5	5	5	5	5	5	5
Hararghe Catholic Secretariat	5	5	3	5	4	5	4	4
Hararghe Catholic Secretariat	5	2	4	1	4	2	4	5
Hararghe Catholic Secretariat	5	5	3	5	3	5	5	5
Hararghe Catholic Secretariat	5	5	3	4	5	5	5	5
Hararghe Catholic Secretariat	4	5	5	5	1	5	5	5
Hararghe Catholic Secretariat	5	5	5	4	3	5	4	5
Hararghe Catholic Secretariat	2	1	4	3	4	2	2	3
Hararghe Catholic Secretariat	5	5	5	5	5	5	5	5
Hararghe Catholic Secretariat	5	5	3	5	4	5	4	4

Appendix 16. Household survey questionnaire, check list for focus group and key informant

***Prosopis Juliflora* in Dire Dawa – HH questionnaire**

1. GENERAL INFORMATION

1. Name of enumerator _____
 2. Division/Woredas/District _____ 3. Sub-location/Kebele/Wards: _____

2. RESPONDENT'S DETAILS

4. Respondent's Name _____ 5. Age: _____
 6. Gender: Male / Female 7. Relation to HH head _____
 8. Marital status of HH head: _____ 9. Gender of HH head: Male / Female
 10. Years of school: _____ 11. Mobile Phone No.: _____
 12. What is the distance from your house to the nearest tarmac road? _____
 13. Nearest market? _____ Km
 14. How long is your farm experience in years? _____ Years
 15. Occupation (livelihood of the household)
 1 = Agriculture 2 = Business 3=pastoral 4= Agro pastoral
 5 = Cottage Industry 6 = Wage Labor 7=other (please specify)
 16. How many people live in your household?

Age	Sex		Total number
	Male	Female	
Children (< 15) years			
Working age (15 -64)			
Old age (> 65)			

17. Type of shelter owned by respondent. *(If more than one, please characterize the main building)*
 1. Brick walls, tiled or iron sheet roofing
 2. Consolidated mud walls, with iron-sheet roofing
 3. Simple mud walls with thatched roofing

3. GENERAL FARMING ACTIVITIES

18. Do you grow food crops and/or rear livestock? *(Please select only one answer)*

1. Crops 2. Livestock 3. Both

19. How much land do you own and/or rent?

Description	Size (hectare)	Value Birr per hectare
Owned land		
Rented land		
Others: _____		

20. What are the major crops you grew, what were the respective acreage (field size) under cultivation, the yields and the usage of your crops?

Description	Name of the crop	Area under cultivation (hectares)	Production costs (labour & other inputs) (Birr/hectares)	Yield (kg/hectares)	Selling (kg)
Main Crop 1					

Main Crop 2					
Main Crop 3					
Vegetables					
Fruits					
Chat					
Other specify					

* If intercropped, list only the area of the main crop.

21. What are the explicit and implicit costs you incurred to produce the above stated crops on average?

	Activity	Unit	Amount bought/used in kg	Cost per unit	Total cost
1	Chemicals (like pesticide)				
2	Fertilizers				
3	Improved seeds				
4	Irrigation (per week)				
5	Manure				
6	Clearing				
7	Tillage				
8	Weeding				
9	Harvesting				
10	Others				
11	Others				

22. What about your crop yield and income generated from it the last 5 years?

1. Increasing
2. Declining
3. No change
4. I don't know

23. If your answer for question no "22" is "declining", what is the reason for it?

1. *Prosopis* invasion
2. Recurrent draught
3. Crop disease
4. Pest attack
5. Any other (specify) _____

24. If your answer for question no "22" is increasing, what is the reason for it?

1. Increased use of fertilizer and improved seed
2. Increase in soil fertility due to *prosopis* invasion
3. Improved soil and water conservation
4. Any other (specify) _____

25. How many livestock do you keep and what is their value and related information?

Description	Number of heads	Value (Birr per head)	Costs for the last year (ETB) or Cost/month			
			Feeding	Labor	Veterinary	Other
Local cow						
Exotic cow						
Oxen						
Heifer						

Calf						
Local goats						
Exotic goats						
Sheep						
Donkey						
Camel						
Poultry						
Honey bee						
Others:						

26. How much income did you get from selling livestock products last year?

Livestock	Product	Value (Birr/prod.)	Livestock	Product	Value (Birr/prod.)
1. Cow and oxen	Live		3. Sheep	Live	
	Milk			Wool	
	Milk product		4. Camel	Live	
2. Chicken	Live			Milk	
	Eggs		5. Goat	Live	
				Milk	

27. What do you feel about the change in the size of livestock population over the last 5 years?

1. Increasing
2. Declining
3. No Change
4. I don't know

28. If you feel that the size of livestock population is declining what do you think is the reason for it?

1. Decline in grazing land or forage availability
2. Drought
3. Animal disease
4. Wild animals attack
5. Any other (Please specify)

29. How much of the grazing land is invaded by *prosopis* in your kebele?

1. One forth is invaded
2. Half is invaded
3. Three forth is invaded
4. The whole grazing area is invaded

30. Have you lost any livestock due to *prosopis* related problem over the last 5 years.

1. Yes
2. No

31. If your answer for question no 30 is "Yes" how much you lost over the last 5 years? Please indicate the number of livestock by type.

Livestock type	Number	Amount lost
Calves		
Heifers		
Oxen		
Cow		
Camel		
Sheep		
Goat		

32. What do you fill about the change in milk production and income generated from milk sell over the last 5 years?

Species	Increase	Decrease	No change
Cow			
Sheep			
Goat			
Camel			

33. If you feel that milk production and income generated from milk sell is declining/increase, what do you think is the reason for it?

1. *Prosopis* invasion
2. Recurrent drought
3. Animal disease
4. I don't know

4. CAPITAL ASSETS

34. Which of the following items does your household own? (*Multiple answers possible*)

Description	Number	Value (Birr per item)
Car		
Tractor		
Motor cycle		
Radio		
Plough		
Mobile phone		
Satellite dish		
Bicycle		
Solar panel/dish		
Water tank		
Television		
Others: _____		
Others: _____		

5. NON FARM ACTIVITIES

35. Do you have any source of off-farm income? (*Multiple answers possible*)

Source of income	Frequency/year	Income (Birr per period)	Comment
Salary from employment			
Salary from business			
Salary as agricultural worker			
Salary from public work			
Remittances from family/ friends			
Income from sale of charcoal			
Income from sale of fire wood			
Income from sale of <i>Prosopis</i> Pod			
Income from renting land			
(Other Specify): _____			

36. Do you get information on *Prosopis*?

1. Yes
2. No

37. Are you a member of a farmers' association or community based organization?

1. Yes*
2. No

**If yes, please specify what type of association:*

5. Food Consumption

38. Do you tell us the consumption of each of the food items in your family for the last two week?

Food items consumed for the last two weeks	Unit	Quantity	Unit market price	Total value (Birr)	1. Own 2. Gift 3. Purchased 4. Loan 5. aid
Maize					
Sorghum					
Wheat					
Sesame					
Millet (Abish)					
Lentils (Telba)					
Milk					
butter					
Beef meat					
Egg					
Coffee					
Tomato					
Sugar					
Oil					
Pepper					
Potato					
others					

6. Social services

39. Do you have access to irrigation water?

1. Yes 2. No

40. Do you have access to rural credit service?

1. Yes 2. No

41. Do you engaged in food for work program?

1. Yes 2. No

42. Have you faced drought during the last three years?

1. Yes 2. No

7. Behavioral Factors

43. What is your perception or understanding about *Prosopis*?

1. Very good 2. Good 3. Neutral 4. Bad 5. Very bad

44. Do you think the presence of prosopis brings about any problems?

1. Yes 2. No

45. If yes list the perceived problems in order of seriousness? (Prioritize)

1. Loss of grazing land and feed stock for livestock
2. Invasion of arable land
3. Damage to the livestock & people due to its thorny nature
4. Blocking of roads and waterways
5. Host to predators
6. Loss of biodiversity
7. Reduce ground water
8. Competition for labor
9. Increased incidence of malaria

10. Any other (please specify)

46. Do you think the presence of prosopis brings any advantages?

1. Yes 2. No

47. If yes, list the advantages in order of importance? (Prioritize)

- | |
|---|
| 1. Use as a source of feed for livestock (A. Pods B. Leaves)
2. Use as a source of fuel wood or charcoal for sale or domestic consumption
3. Use as a wind break
4. use as a source of construction material or local furniture
5. Use as fencing material
6. Has medicinal value
7. Use as a walking stick
8. Modify the micro climate
9. Enhance soil fertility
10. Apiculture
11. Eat bush meat
12. Any other (specify) |
|---|

48. Do you think the spread of prosopis should be controlled?

1. Yes 2. No

49. Have you ever actively involved in controlling prosopis before (clearing, fencing, chemical, biological etc.)?

1. Yes 2. No

50. If yes, how much do you spent annually? _____ Birr and _____ working days per year.

51. If yes, what types of control do you perform? And which management type do you think should be taken so as to alleviate prosopis negative impact on biodiversity, ecosystem and your livelihood?

1. Utilization 2. Biological 3. Physical 4. Chemical

52. Why do you select the above alternative or alternatives?

53. Do you believe it is your responsibility to control prosopis?

1. Yes 2. No

54. If no, who should take the leading role in the control of prosopis?

1. Government 2. Non-governmental org. 3. Others (specify) _____

55. In your opinion is enough being done to control the tree?

1. Yes 2. No

56. Rank the invasion levels of Prosopis juliflora in different land type.

1. Bush land (communal land) 2. Pasture land 3. Government land 4. Crop land

57. How did you label the benefit obtained from Prosopis juliflora?

1. Fully benefit 2. Partially benefit 3. Little benefit 4. Do not benefit

8. Economic Factors

58. The previous year (2007 EC) Expenditure for Education, Medication, ceremonies and other

	Expenditures	Items	Birr/ year	Items	Birr/
--	--------------	-------	------------	-------	-------

					year
1	For education	Pen and pencil		Uniform	
		Exercise books		Tutor	
		School fee		Other	
		Books			
2	For Medication	For human (your family)		For animals	
4	For ceremonies (for social activities)	Edir		Other	
		Equib			
		Accidents			
		Weeding			
5	For food and non food items	Food			
		Non-food			
6	water supply service	For human (your family)			
7	veterinary service	Livestock			

8. General information about *prosopis*

59. Is there any cultivable or cultivated land that is invaded by *prosopis*?

1. Yes 2. No

60. If your answer for question number “59” is “Yes” by how much your farm land is invaded by *prosopis*?

1. one fourth 4. The whole cultivated area
2. Half 5. None
3. Three fourth

61. For how long do you know *prosopis* in your kebele or village?

1. for the last 10 years 3. More than 20 years
2. 11-20 years 4. I don't know *prosopis*

62. How many household members physical injury by thorn of *Prosopis juliflora* and falling sick of malaria and related information? (Monthly basis last year)

Description	frequently of ill per month	highest missing Labour Day	Cost of treatment (Birr/month)
Prosopis thorn			
malaria			
snake bites			

63. What is your coping strategy against the invasion?

1. Diversification of livelihood 3. Eradication of *prosopis*
2. Migration 4. Using *prosopis* as a source of income
5. Others (If any) _____

64. If your answer for question no 63 is “1” diversification of livelihood, what are those additional activities you are engaged in?

1. Petty trading 4. Bee keeping
2. Selling of fuel wood /charcoal/ 5. Daily labourer
3. Poultry 6. Other (If any) _____

65. If your answer for question No 64 is “2” selling of fuel woods/charcoal, what is the major source of the fuel wood/charcoal you produce?

1. *Prosopis* 2. *Acacia milotica* 3. any other indigenous tree or bush

66. Environmental income obtained from *Prosopis*

Benefit of <i>Prosopis</i>	unit	Approximate quantity extracted per week	Average price per unit	production Cost	transportation Cost	marketing Cost
Fire wood	Bundle					
Charcoal	Sack					
Construction pole	Unit					

Time spent to 1) collect one bundle of fuel wood/charcoal

1. 1-6 hrs
 2. 7-12 hrs
 3. 13- 18 hrs
 4. more than 18 hours
- 2) Produce one sack of charcoal
1. 1 - 3 days
 2. 4 -7 days
 3. > 7 days

67. What is your means of transportation?

1. Carrying on head
2. Loading on donkeys or camels
3. Using vehicles
4. Others (specify)

68. If your answer for question “67” is loading on donkeys and camels and if the donkeys or camels are hired, how much you pay per donkey or camel /day?

-----Birr

69. If the regional Administration decides to eradicate *prosopis*, do you agree on the decision?

1. Yes
2. No

70. Which mitigation policy options would you prefer to avoiding and/or minimizing the negative impacts of *Prosopis juliflora* and maximizing the benefits?

1. Controlling its further expansion through productive use of the *Prosopis juliflora*
2. Eradication of *Prosopis juliflora* from all land uses in their village

9. A Contingent valuation survey Questionnaire for Control/eradication of IAS

As you may notice that if no action is taken the biodiversity, microclimate regulation, reduce mobility (land security), forage availability (livestock feed) that you have in your area will be destroyed within a few years and this means that all the benefits you said you get from these biodiversity, microclimate regulation, reduce mobility (land security), forage availability (livestock feed) will be gone. But the community has the opportunity to regain the biodiversity lost in the area. Consider the *kebele* administration in collaboration with the community wants to propose a project to regain biodiversity, land security, forage availability and micro climate regulation would be controlled and managed by the community itself. If the previous biodiversity keep up as it is you will minimize the damage caused by IAS. However, considering your budget constraint when you contribute for the project you will face shortage in your budget and hence may have to reduce some of your consumption. The project is financed by the contribution of the community with in the PA'S. Given this:

9.1. Do you want to contribute for the proposed community fund?

- A. Yes
- B. No

1. Are you willing to pay ----- Birr every year for five years for the kind of project I have just described above?		
A. Yes	B. No	C. Refusal
2. If Yes in Q.1, What about ----- Birr	A. yes	B. No
3. If No in Q.1, What about ----- Birr	A. Yes	B. No

Then ask

4. What is the maximum amount that you are willing to pay for such a project per year for ten years? ----- Birr
5. *If yes in 1 and yes in 2 and If the respondent maximum willingness to pay in Q.2 is greater than in Q.4, then ask*

You said that you are willing to pay ----- Birr (in Q.2) but when I ask you your maximum willingness to pay you said ----- Birr (in Q.4) which is less than the amount you already agreed to pay previously, Why?

6. *If yes in 1 and no in 2 and If the respondent maximum willingness to pay Q.1 is greater than in Q.4, then ask*

You said that you are willing to pay ----- **Birr** (in Q.1) but when I ask you your maximum willingness to pay you said ----- Birr (in Q.4) which is less than the amount you already agreed to pay previously, Why?

7. *If no in 1 and yes in 3 and If the respondent maximum willingness to pay Q.3 is greater than in Q.4, then ask*

You said that you are willing to pay ----- **Birr** (in Q.3) but when I ask you your maximum willingness to pay you said ----- Birr (in Q.4) which is less than the amount you already agreed to pay previously, Why?

8. *If a respondent accept to pay for the improvement project. The question is: in which percentage will you distribute the accepted amount of payment between the four aspects of the improvement? biodiversity _____%, livestock feed _____%, land security _____% and climate regulation _____%. The sum of the four percentage points is equal to 100%.*

9. *[If no WTP is reported, then ask this] If you are not willing to contribute any amount to the proposed community trust fund for controlling or eradicating Prosopis invasion, would you please state your reason/s?*

A) *I cannot afford to pay.*

B) *I think it should be the government that should finance the proposed control activities.*

C) *I do not believe the control measure could actually able to control the Prosopis invasion effects.*

D) *Only the rich households should pay*

E) *I don't have faith in the kebele unit extension (i.e. proposed body to undertake the program)*

F) *I don't believe controlling or eradicating Prosopis invasion is important (i.e. the scheme is not important to me)*

G) I do not fully understand the question

H) Other reasons, please specify: _____

10. How certain are you that you would be willing to, as well as capable of, paying the agreed amount, if this scenario was carried out in reality?

A. Very certain B. Certain C. Don't know E. Uncertain F. Very uncertain

11. If your answer in Item #10 is UNCERTAIN or VERY UNCERTAIN, why do you have some doubts about your response?

12. Which kind of contribution method do you prefer?

A. Cash B. Labor C. None

13. If your family is asked to contribute labor how many days (8 hours) is your family willing to work for this control/eradication of IAS project for ten years?

Number of adult male ----- Number of days -----

Number of adult female ----- Number of days -----

14. To what extent the respondent supported a mandatory annual fee or labour contribution for control/eradication of IAS.

1. Strongly oppose 2. Oppose 3. Neutral 4. Support 5. strongly support

10. A Choice experiment survey Questionnaire for Control/eradication of IAS

In this part, the researcher wants your opinion on the improvement of the conditions of your pasture and crop lands and water availability from now until 2015. There are three alternatives in each "Choice Set". The choice set consists of two policy alternatives and one option where there is no change from the current policy. Alternatives will be labeled "Intervention A", "Intervention B" and "No change to intervention levels (C)".

At present, there are no successful *Prosopis* tree invasion management activities focusing on its colonization. To implement a sustainable management plan in a changing environment, your local community requires a fund and/or labor contributions. The researcher proposes each household in your locality to participate in implementing the specific policy for a 5-year period, which is included in Intervention A and B. In 'No intervention' no contribution or cost is imposed on the household.

Attributes	Description	Levels	Current Condition
Mobility and Land Security	When inherited clan lands, which are situated at different locations and are used as different seasons grazing lands, are secured from <i>P.juliflora</i> colonization. This allows cultural mobility of the pastoralist community and agro pastoral secure their land so that no household that will be leaving there area.	1. No mobility at all. (Status quo) 2. Mobility is possible twice in the year and two inherited pasture lands are secured. (security up to 50% of their land) 3. Mobility is possible throughout the year and all inherited pasture lands are secured. (security up to 75% of their land)	No mobility at all.
Forage availability	Availability of Forage livestock feed	1. current forge condition 2. increased by 50% 3. increased by 75%	Current forge condition
Biodiversity	The numbers of common and endemic fauna and flora species. Both usable and non-usable indigenous species.	1. Low: the current number of both fauna and flora indigenous species in pastoralist dry land and wet land ecosystems are very scarce and many species of the ecosystems are destroyed. 2. Medium: the improvement and management	Low

		of fauna and flora species at a medium level (improving by 25 per cent.) 3. High: the improvement and management of fauna and flora species at a high level (improving by 50 per cent).	
Microclimate regulation	An enhanced biomass and carbon stock through <i>P.juliflora</i> encroachment is positive for climate change mitigation. It contributes to temperature and flood regulation.	Current encroachment level Decreased by 25 percent Decreased by 50 per cent	Current encroachment level
Labour contribution	Annual volunteer involvement of local community in <i>P.juliflora</i> invasion management.	No labor contribution 9 days per year 36 days per year 18 days per year	No labor contribution
Annual HH payment		No payment 292 583 145	0 Birr

In each situation, please choose the alternative that best describes your expectation. Please consider what you think is best. When you make the selection, please consider your income or available time after necessary expenses such as food, housing and clothing have been met.

- While choosing the preferred alternative, did you consider every part of each alternative?
 - Yes
 - No
- Are some characteristics more important than others?
 - Yes
 - No
 If yes, what are they? 1. _____ 2. _____
3. _____
- If you chose status-quo (no intervention) in all choice situations, describe the reason why you prefer the current situation. _____

GENERAL QUESTIONS ON PERCEPTION AND PROSOPIS JULIFLORA SPECIES CONCERN for the stakeholders

- Which priority would you assign to the problem of biological invasions in relation to the other environmental problems of your area of responsibility?
 - High priority
 - Medium priority
 - Low priority
- Could you assign a number from 1 to 5 to the following environmental problems in the last ten years? (1=strongly disagree; 2= disagree; 3=indifferent; 4=agree; 5 = strongly agree)

Environmental problems indicators	How do you rate these hazards in the last 10 years?				
1. Increased Temperature	1	2	3	4	5
2. Increased Rainfall variation	1	2	3	4	5
3. Increased Flood	1	2	3	4	5
4. Biodiversity Loss Increased	1	2	3	4	5
5. Livestock disease Increased	1	2	3	4	5
6. Increased food insecurity	1	2	3	4	5
7. Biological invasions increase	1	2	3	4	5
8. Drought incidence increased	1	2	3	4	5

8. Other (specify)	1	2	3	4	5
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3. Which priority would you assign to the following management strategies against invasions? (Ranking from 1 to 4: 1 = low priority and 4 = maximum priority)
 - i. Legislation reinforcement ii. Education and outreach
 - iii. Entry prevention iv. Direct population control
4. Which are the main limitations or difficulties for an effective management of alien species in your area of responsibility?
5. Which kind of impacts is it causing *Prosopis Juliflora* species?
 - i. Ecological ii. Economic iii. Social iv. Human health
6. Could you specify the magnitude of the impact caused by *Prosopis Juliflora*?
 - i. High ii. Intermediate iii. Low
7. Could you mention any direct impact of this plant, which associated costs are easily quantified? (i.e., infrastructure damage)?
8. Is there any management strategy over this alien species in your area of responsibility?
 1. Yes 2. No
9. Which kinds of management activities do you carry out?
 - i. Prevention–outreach
 1. *Regional legislation* 2. *Education and information activities* 3. *other (specify)*
 - ii. Eradication
 - iii. Containment (i.e., population control)
 - iv. Restoration (i.e., habitat improvement, reforestation with native species)
10. How long have the management strategies been functioning? _____
11. Which method has been used to control or eradicate the alien species?
 - i. Physical (mechanical, manual...) iii. Physical? Chemical
 - ii. Chemical iv. Biological control
12. With which frequency have the treatments been carried out? _____
13. Are the treatments carried out by technicians or volunteers? _____
14. Do you monitor the success of the management measures over the time?
15. How often do you monitor the state of the invasion? 1. Always 2. Some times 3. Never
16. Have you carried out a restoration of the locations previously invaded by the alien plant? 1. Yes 2. No
17. Could you estimate the total economic cost of the management measures?
 - i. Prevention costs (three-page leaflets, workshops, conferences...) = _____ €.
 - ii. Eradication or control costs (herbicides, salary, material, machinery, etc.) = _____ €.
 - iii. Habitat restoration costs (native species plantation) = _____ €.
18. Do you think that the management strategies have been successful?
 1. Yes 2. No
19. Could you indicate which has been the result of the management measures?
 - i. The species has been eliminated ii. The species has decreased considerably
 - iii. The species has decreased very little iv. The species has not decreased
 - v. The species continues to expand
20. Which mitigation policy options would you prefer to avoiding and/or minimizing the negative impacts of *Prosopis juliflora* and maximizing the benefits?
 1. Controlling its further expansion through productive use of the *Prosopis juliflora*
 2. Eradication of *Prosopis juliflora* from all land uses in their village

21. What stake does your organization do you have on the control and eradication measure of prosopis invasion?

FOCUS GROUP DISCUSSION CHECKLIST

- When and how did Prosopis introduce to Dire Dawa area?
- What benefits does Prosopis provide for the pastoral and agro pastorals community?
- What impacts does Prosopis have on pastoral and agro pastorals community and their livestock?
- What measures the community takes to check Prosopis invasion?
- What do you think the Dire Dawa pastorals and agro pastorals claim about Prosopis?
- What changes have been observed in livestock holdings and pasture availability in the Dire Dawa area during the last decade?
 - What causes the change?
 - How is the changing event responsible?
- How is the grazing area availability after the introduction of Prosopis?
- What are the main changes that took place in the local community since *Prosopis* invasion in the Administration?
- What challenges do you face as a result of *Prosopis* invasion?
- What in your opinion can be done to deal with the challenges?
- What are the negative impacts of *prosopis* you observed in your locality? (If any)
- What is the benefit of *prosopis* you observed in your locality?
- What is your coping strategy against the invasion?
- What should be the *Prosopis* population from:

	Villages	Paths	Grazing areas	Banks of watering points	Other areas; specify
Eradicated					
Reduced					
- If reduced by how much					
Remain as to day					

- Has the vegetation cover of grazing lands changed compared to prior to invasion by Prosopis? Yes/No
Please, explain _____
- Can you mention grass/herb whose population increase or decrease after Prosopis invasion?

Increase	Decrease

- What importance do these grasses/herbs have to the society? _____
- Can you mention tree/shrub whose population increase or decrease after Prosopis invasion?

Increase	Decrease

<ul style="list-style-type: none"> - What importance do these trees/bushes have to the society? - Can you mention wild animals whose population increase or decrease after Prosopis invasion? 	
Increase	Decrease

- What importance/ effect do these wild animals have to the society? _____
- What mechanisms are used to cope with change in grazing availability?
- What measures do you want 1. Control 2. Eradication
- How can you value the control and eradication measures of Prosopis invasion?
- How much each individual do you want to pay for How much each individual do you want to pay for management intervention of Prosopis invasion?
- Is there any additional information you'd like to provide us with?