Quantitative impacts of invasive *Senna spectabilis* on distribution of welfare: a household survey of dependent communities in Budongo forest reserve, Uganda

By

Mungatana, Eric and Ahimbisibwe, Peter Beine

Poster presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010

Quantitative impacts of invasive *Senna spectabilis* on distribution of welfare: a household survey of dependent communities in Budongo forest reserve, Uganda

Eric Mungatana[1,*] and Peter Beine Ahimbisibwe[2]

1. Current affiliation: Center for Environmental Economics and Policy in Africa (CEEPA), Department of Agricultural Economics, Faculty of Agricultural and Natural Sciences, University of Pretoria. Pretoria 0002, South Africa.
2. UNEP/GEF-IAS Project, National Agricultural Research Organization, P.O.Box 295, Entebbe, Uganda and Center for Environmental Economics and Policy in Africa, (CEEPA), Department of Agricultural Economics, Faculty of Agricultural and Natural Sciences, University of Pretoria. Pretoria 0002, South Africa.

   *Corresponding author: E-mail: Eric.Mungatana@up.ac.za

   Phone: +27 12 420 3253, Fax: +27 12 420 4958

Abstract

This paper presents the results of a household survey designed to qualitatively evaluate the impacts of the invasive alien species *Senna spectabilis* on the distribution of welfare across dependent communities in Budongo forest reserve (BFR) in Uganda. BFR is the largest forest reserve in Uganda with globally significant conservation values. The study establishes that households in BFR have high levels of knowledge on its conservation values, they are aware of the invasiveness of *S. spectabilis* and its potential to compromise the conservation values of BFR, and that *S. spectabilis* confers tangible benefits to dependent households, whose levels significantly vary with proximity to the reserve. The study concludes by evaluating strategies designed to manage the spread of *S. spectabilis* in BFR which consider its demonstrated socio-economic impacts.

Keywords: Invasive *Senna spectabilis*, distribution of impacts, Budongo forest reserve, Uganda

1. Introduction

Understanding the impacts of invasive alien species (IAS)[1] on the distribution of welfare across dependent sectors of society is of considerable interest to IAS management approaches (e.g. Pasiecznik 1999, Pasiecznik et al., 2001). For example, Cock (2003) reports that some invasive trees provide useful products or services to society and when their eradication is not possible, management options should be identified that balance their positive and negative aspects. Understanding such distribution issues raises general awareness on losers and gainers in the event a decision has to be made to either eradicate or control, thus providing fundamental support to the IAS management decision making process. Previous research effort establishes that IAS have significant negative (costs) and positive (benefits) impacts on socio-ecological systems and socioeconomic livelihoods (e.g. Baskin 2002, Perrings et al., 2002, McNeely et al., 2001, Pimentel et al., 2001, Hettinger 2001, Pasiecznik et al., 2001, Tewari et al., 2000, Zavaleta 2000, Pasiecznik 1999, Saxena 1997, Van Wilgen et al., 1996). Costs are incurred when the IAS inhibits the effective functioning of local social and ecological systems, such as when they become weeds within agricultural or forestry systems, inhibit vital ecosystem functions or affect animal or human health (Pimental et al, 2001). Benefits are experienced when the IAS promotes the effective functioning of local social and ecological systems. For example in the drylands of India, the invasive *Prosopsis juliflora* is considered one of the most valuable tree species (Pasiecznik et al. 2001) and yet it has been rated as one of the world's 100 least wanted species (Lowe et al, 2000). A study by Le Maitre, Versfeld and Chapman (2002) concluded that IAS control programs were justified after a cost-benefit analysis of their management in four catchment areas across South Africa. Considering that the magnitude of the IAS problem has increased considerably over the past few decades (e.g. Richardson 1997), improved understanding of their costs and benefits is essential from both academic and management perspectives.

Although a number of studies on the net benefits of IAS management have been conducted in developed and some developing countries, there still remain some glaring knowledge gaps. To

[1] The Convention on Biological Diversity defines an invasive alien species (IAS) as those that are non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (CBD, 2002, 2004). Specifically, invasive tree species are species that are able to survive, reproduce and spread, unaided, and sometimes at alarming rates across an ecosystem causing a detrimental effect on the growth of commercial tree species and giving rise to particular management problems (Van Wilgen & Van Wyk, 1999). Invasions by alien species are considered to be one of the largest threats to the ecosystems of the earth, and the services that they provide to humanity (e.g. Kaiser, 1999, Glowka et al 1994, Heywood 1995, Williamson 1998, Parker et al 1999).

flag this point, Cock (2003) notes that while there is a growing national and international awareness of the possible risks of invasiveness of forestry trees, it is likely that some stakeholders in forestry remain ignorant of the risks, particularly since there is a general lack of quantitative information on the ecological and economic impacts of invasive forestry trees. Cock (2003) recommends that case studies should be conducted in countries that have a high dependence on forestry, which should cover a range of forestry situations (e.g. commercial and environmental), and they should include the development and promotion of tools for making ecological and economic assessments. In addition, the case studies should pay particular attention to those regions of the world where there is little information on the invasiveness of exotic forestry trees (e.g. tropical and temperate regions). It is the general lack of relevant information and methodologies that prevents many countries from implementing IAS risk assessments, control and management schemes (Cock, 2003).

There is a dearth of information regarding the biodiversity, status and socio-economic impacts of IAS in Uganda. This point is emphasized in a report released by the Uganda National Agriculture Research Organization which observes there exists a very weak policy and institutional environment concerning IAS management as manifested by the gaps, overlaps and inconsistencies in existing policies, regulations, strategies and institutional arrangements (NARO, 2004). The report further observes that there exists no institutional co-ordination mechanism for ensuring that IAS issues are addressed with the necessary broad, multi-sectoral ecosystem approaches that it deserves. This weak policy and institutional environment results in critical information for informed decision making being unavailable. The report specifically singles out the lack of information on the socio-economic impacts of IAS as a major barrier to the implementation of comprehensive national IAS management programs in Uganda, and as one of the main reasons for the failure of IAS issues to feature prominently in the mainstream agenda of most countries.

In response to this need, this paper reports on results of a study undertaken to understand the distribution of costs and benefits from exploiting an IAS, *S. spectabilis,* by dependent rural households in Budongo forest reserve (BFR) in Uganda. The paper also seeks to identify demographic factors that could potentially explain the variation in the distribution of the costs and benefits from the exploitation of *S. spectabilis*. The rest of the paper is organized as follows: section 2 rationalizes the choice of BFR as the study site. Section 3 presents the approaches and

methods used in this study, the results and discussions are presented in section 4, the conclusions and recommendations in section 5 and finally the policy recommendations in section 6.

2. Study area

Budongo forest reserve (1037' and 20 0' N and 31022' and 310 6' E), which was gazetted as a central forest reserve in 1932, is situated in the western Uganda districts of Masindi, Hoima and Bulisa (Forestry Department Inventory, 1992). Its vegetation comprises of a mixture of tropical high forest with a large population of mahoganies, woodland and savanna grasslands, and covers an area of 825 km2 (82,530ha) making it Uganda's biggest forest reserve (Langoya et al, 1997). With a history dating back to the colonial era, it was established to protect and conserve its rich Guinea-Congoliean forest biological resources. It is of exceptional biodiversity importance, ranking 3rd in overall importance in the country (Nature Conservation Master Plan, 1997). To date 465 tree species, 366 bird species, 289 butterfly species and 130 species of large moths have been recorded. BFR also contains what is likely to be the largest population of wild chimpanzees in Uganda, estimated at between 600 and 800 individuals (Langoya et al, 1997). These chimpanzees are the subject of high profile conservation and tourism efforts in Uganda (NARO, 2004). BFR is also Uganda's second most important bird area after Semiliki national park for species of the Guinea–Congo forests biome and it was recently designated as an important bird area (Birdlife International, 2003). According to the collaborative community forestry management plan being currently implemented in BFR, local inhabitants are privileged to obtain free of charge and into reasonable quantities fuel wood, poles and sand for domestic use only in accordance with section 33 (1) of the Forestry Act 2003. Consequently, forest dependant resident communities, timber harvesters and ecotourism operators do exploit, according to the law, the resources of BFR. Humans live in communities within and around BFR, while timber harvesters and tour operators exploit the forest deep into the interior, excluding the restricted zone.

The most important challenge facing the management of BFR is that it is fast being colonized by the invasive *Senna spectabilis* (spectacular cassia), which is thought to have been introduced by Indian sawmill operators or Europeans, for firewood as well as live boundary marking in an attempt to preserve BFR[2]. *S. spectabilis* is a medium to large tree native to tropical America. It is

[2] Concern about deforestation, desertification and fuelwood shortages prompted the introduction of *S. spectabilis* and other hardy tree species to new environments across the world. *S. spectabilis* has since invaded most forestry ecosystems where it has out competed the native tree species with its fast colonization and thicket establishments. It grows in deep, moist, sandy or loamy soils but flourishes even in poor, black cotton soils.

extremely fast-growing, flowers and sets seed profusely. It also re-sprouts readily when cut. Out of the 82,530 ha of BFR, *S. spectabilis* had covered more than 1,000 ha as of 2004 (NARO, 2004). Today, it covers about 20% of BFR, being mainly concentrated in one area of the reserve. It is also common along logging trails, where it forms pure stands at the expense of other species, making BFR one of the most *S. spectabilis* invaded forests in Uganda. *S. spectabilis* is generally not popular with timber loggers, and is also largely unpalatable to forest herbivores including chimpanzees (NARO, 2004)[3]. It however produces high quality fuel wood because of its fast growth, low cleavage resistance, good calorific value and its ability to coppice making it popular with local households who exploit it to satisfy their domestic energy needs. For the rest of this paper, the *S. spectabilis*-infested forest area will be used in reference to that part of BFR with extensive concentration of *S. spectabilis,* while the non-infested area will be used in reference to the rest of BFR.

A comprehensive pilot study and a rapid rural appraisal were conducted in BFR in 2006 under the UNEP/GEF-IAS project[4] development phase to study the status of the forest in relation to the *S. spectabilis* infestation. The study concluded that the spread of *S. spectabilis* in BFR had exceeded alarming levels and recommended that a follow-up study be carried out to assess the present and potential impacts of *S. spectabilis* on dependent stakeholders, with a view to guiding possible management interventions. Uganda being a very poor country with meager income sources compels government and local communities to rely heavily on available natural resources to sustain welfare. The challenge in BFR is thus to balance conservation of forest biodiversity and ecological processes (tourism sector), production of timber on a sustainable basis (timber sector) and the needs of local communities for domestic energy needs among others. To substantiate an argument to control or manage *S. spectabilis*, quantification of its costs and benefits, stakeholder perception evaluation and the distribution of its impacts is required. Whereas an improvement in the ecological knowledge of invasive species is necessary to understand anthropogenic impacts on landscapes and ecosystems, an enhanced knowledge of the social processes is also required in order to inform both species management and conservation policy, which underlies the need to

[3] These factors partly explain its rapid spread in BFR.
[4] UNEP/GEF-IAS Project is a project mandated to remove barriers to invasive plant management in Africa. It is running in Ethiopia, Uganda, Zambia and Ghana. The four categories of identified barriers which form the basis for the intervention are: weak policies and institutional environment, unavailability of critical information and particularly information on socio-economic impacts of IAS, inadequate implementation of prevention and control as well as lack of capacity to manage IAS. This study tries to contribute to the alleviation of all the four identified barriers.

carry out a comprehensive assessment like the present study. It was against this background that this study was designed to address the following objectives:

1. To assess the households' knowledge on the conservation values of BFR by forest condition[5].
2. To assess the households knowledge of the invasiveness *S. spectabilis* and its potential to compromise the conservation values of BFR by forest condition.
3. To quantify the effect of the *S. spectabilis* invasion on the physical flows and revenues of *S. spectabilis* derived fuel wood, charcoal and construction poles by forest condition.
4. To assess the households perception of other positive and negative effects of the *S. spectabilis* invasion by forest condition.

3. Approaches and methods

People's perceptions of invasive species depend on whether and how their economic needs are met by the species (Pasiecznik et al. 2001). Income levels and dominant livelihood strategies are also pertinent determinants of how individuals perceive invasive species (Pasiecznik et al. 2001). Veitch and Clout (2001) suggest other factors influencing people's perceptions of invasive species as including: how damaging the species is to property and/or natural ecosystems (e.g. weeds in a crop garden, destruction of native trees), whether or not the species is physically appealing in an aesthetic sense, the opinions of powerful, charismatic and influential individuals, the media's portrayal of the species, and the costs of managing the species. Following these remarks, the conceptual framework adopted in this study begins with the observation that BFR was designated to provide and conserve ecosystem goods and services for current and future generations (see section 2). The study thus hypothesizes that households in BFR: (i) are aware of the welfare enhancing ecosystem goods and services it was designated to conserve, (ii) interact with the IAS through exploiting its welfare enhancing benefits and experiencing its welfare decreasing costs, (iii) are aware of the invasiveness of *S. spectabilis* and its potential to compromise the conservation objectives of BFR, and (iv) were interested in the goods and services received from BFR vis-à-vis the potential of *S. spectabilis* compromising their sustainability.

The households levels of knowledge on the conservation values of BFR is an assessment of the degree to which it is aware of the welfare enhancing ecosystem goods and services it receives

[5] Forest condition refers to whether the household is located in the *S. spectabilis* forest-infested area or in the non-infested area.

from BFR. The household's awareness of the invasiveness of *S. spectabilis* is an assessment of the degree to which it knows *S. spectabilis* can spread and displace indigenous vegetation, which could potentially compromise the ability of BFR to continue providing the welfare enhancing goods and services identified above. The magnitude of the net benefits the household receives from *S. spectabilis* are assumed to be influenced by two factors: the quantities of *S. spectabilis* derived fuel-wood, charcoal and construction poles it extracts from BFR, and the levels of other perceived net benefits to the household occasioned by the presence of *S. spectabilis* in BFR. The perceived net benefits are considered to provide an assessment of the degree to which the household believes there are other net benefits occasioned by *S. spectabilis* beyond fuel-wood, charcoal and construction poles.

To assess whether respondents knew and appreciated the importance of BFR and its conservation values, respondents were asked to indicate (in a nominal yes/no question) whether they agreed with the following statements related to the purposes for which BFR was designated to conserve: timber supply, fuel wood supply, construction materials supply, tourism purposes, resource conservation, climate regulation and carbon sequestration. From the way individuals responded to these questions, one can deduce the extent to which they were familiar with the construct under measurement. To assess the household awareness of the invasiveness of *S. spectabilis* and its potential to compromise the conservation values of BFR, respondents were initially asked whether they could identify *S. spectabilis*[6]. Respondents were then asked to indicate (in a nominal yes/no question) whether they agreed with the following statements related to the invasiveness of *S. spectabilis* and its potential to compromise the conservation objectives of BFR: awareness of the invasiveness of *S. spectabilis*, knowledge that *S. spectabilis* can potentially endanger conservation in BFR, whether they would experience a welfare loss if *S. spectabilis* compromised conservation objectives in BFR and whether they would be willing to join a campaign designed to control the spread of *S. spectabilis* in BFR to avoid potential welfare losses. From the way individuals responded to these questions, one can deduce the extent to which they were familiar with the construct under measurement. To assess the quantities of *S. spectabilis* derived fuel wood, charcoal and construction poles dependent households derive from BFR[7], the study asked households to estimate the bundles of *S. spectabilis* derived fuel-wood it collects on average per

[6] The study had to verify that respondents could distinguish *S. spectabilis* from the related but non invasive *Senna didymobotrye* and *Senna siamea*. *S. spectabilis* has long pods and narrow long leaves which distinguishes it from the other relatives.

[7] These goods were selected for inclusion in the questionnaire because in the pre-survey, respondents indicated they were the most important benefits they receive from *S. spectabilis*.

week[8], the sacks of *S. spectabilis* derived charcoal it collects on average per week[9] and the quantities of *S. spectabilis* derived construction poles it collects on average per week. Finally, to assess whether households perceived other net benefits occasioned by the presence of *S. spectabilis* beyond those already analyzed, respondents were asked in an open question to state any other benefits or costs they perceive could be attributed to the presence of *S. spectabilis*.

A household survey questionnaire was used to achieve the objectives of this study. In the initial design of the questionnaire, effort was taken to ensure that questions were asked to address the objectives of the study. In addition, questions that sought to collect information on the socio-economic characteristics of respondents (gender, age, average household size, marital status, education level, occupation and income) were also asked. Gross household income was measured as an aggregate of incomes from agricultural activities, non-agricultural activities, remuneration and salaries as well as transfer earnings per annum. The questionnaire was tested for internal consistency through a peer review process at the University of Pretoria before being pre-tested in the Nyabyeya and Nyatonzi parishes, which represent the infested and non infested forest parts respectively. The objective of the pre-test was to ensure that respondents understood the questions the way they were designed to be understood. An examination of the pre-test responses confirmed that the questionnaire was a suitable tool for this study.

The survey sample was selected so as to have representation from the *S. spectabilis* infested and non-infested forest areas. Basing on the *S. spectabilis* spread map provided by the UNEP/GEF-IAS project, respondents were purposely selected from Buruli, Bujenje and Bulisa counties. From these counties, three sub-counties that had a fair representation of infested and non-infested parishes were selected (Pakanyi, Budongo and Biiso). Finally, six parishes were purposively selected from the three sub-counties, of which three were from the non-infested (Kihaguzi, Nyatonzi, and Kasenene) and the rest were from the infested forest area (Nyabyeya, Biiso, and Kabongo). From each parish, random numbers were used to select 42 respondents from each parish such that each forest condition had 126 households randomly selected for the interviews.

The study used six enumerators who were trained in the translation of the questions from English to local languages for effective communication as needed. During the data collection phase, the household head was the targeted respondent. In the absence of the head, the interviewer

[8] A fuel wood bundle was defined as a bundle of air dry pieces of wood weighing approximately 20-25 kgs.
[9] A charcoal sack was defined as a sack of burnt charcoal weighing approximately 45-50 kgs.

administered the questionnaire either on the spouse or the most sound-minded family member present at that moment (usually the oldest person). Finally the collected data was coded, entered into spreadsheet, cleaned and analyzed using the SPSS statistical software package. Following the cleaning process, some responses were dropped meaning that the study ended up with a sample of 124 households per forest condition.

Demographics, perceptions of respondents on the *S. spectabilis* invasion and the knowledge of the importance of BFR were assessed using descriptive statistics. The effect of *S. spectabilis* on the flow of quantities of fuel wood, construction poles, and charcoal harvested was assessed through computation of mean differentials by forest condition and using appropriate inferential statistics.

4. Results and discussions

The sample consisted of 248 respondents of which 124 (50%) were drawn from the non-infested forest area and 124 (50%) from the infested forest area. Of the former, 42 (34%) were females and 82 (66%) were males. Of the later, 47 (38%) were females and 77 (62%) were males. On the overall, 36% of the sample was female and 64% male. Considering the study targeted household heads as the desired respondents, the observed gender distribution closely conforms to the statistics reported in the Uganda National Household Surveys (UNHS, 2002/03 and 2005/06)[10]. The average household size in both the non-infested and infested forest areas was six persons, in close conformity with the statistics reported in UNHS (1999/00, 2002/03 and 2005/06). Following the age-group categorization adopted in UNHS (2005/06), the results show that 97% (94%) of the sample from the non-infested (infested) forest areas was in the age group 15-64, and 3% (7%) over 65. On the overall, the productive age group of 15-64 had a representation of over 95%, which is consistent with UNHS (2005/06)[11]. 13% (9%) of respondents from the non-infested (infested) forest area were single, 79% (85%) married, 3% (2%) widowed and 5% (5%) separated, in close agreement with UNHS (2005/06)[12].

The results show that 19% (41%) of respondents in the non-infested (infested) forest area had no formal education, 44% (46%) had a primary level, 30% (12%) secondary level and 7% (< 1 %)

[10] Male headed households in Uganda are 72% and 73.6% of the population, respectively (UNHS, 2002/03 and 2005/06).
[11] UNHS (2005/06) reports that the age group of 65 and above comprises 3.2% of the population in Uganda.
[12] UNHS (2005/2006) reports that 73.2% of the population in Uganda is married.

post secondary level. On the overall, 70% of the sample was literate[13] and thus closely conforming to UNHS (2005/06)[14]. 76% (90%) of respondents from the non-infested (infested) forest area were subsistence farmers, 15% (2%) worked in the public service, 6% (5%) were self employed and 3% (3%) were classified as miscellaneous. Subsistence farming was the major sector of employment with 83% of the entire sample, which is consistent with UNHS (2005/06)[15]. Finally, over 70% of the sample earned an annual income of less that 2.4 million Uganda Shillings (1,200 US$ or 200 US$ per capita)[16]. Considering the nominal per capita GDP for Uganda was estimated at 453 US$ (2008), the study interviewed a relatively poor community[17].

The first objective of the study was to assess respondents' levels of knowledge on the conservation values of BFR. We stated in the methodology that to operationalize this construct, respondents were asked to appraise various statements the answers to which were used to deduce whether they knew the ecosystems goods and services BFR was designated to provide and conserve. These statements are recorded in column I of table 1. Columns II and III report the number (and percentages) of respondents answering in the affirmative by forest area [non-infested (NI) and infested (I)]. Column IV reports on non-response rate. In column V, the chi-square approach is used to test for equality in the distribution of responses by forest condition.

Table 1: Knowledge of respondents on the goods and services provided and conserved by BFR

	Yes (% Yes) by Forest Condition		**Non-Response**	**χ^2 Tests (p-value)**
	NI	**I**		
To supply timber	118 (95.2%)	123 (99.2%)	1 (0.4%)	3.770 (0.152)
To supply fuel wood	116 (93.5%)	123 (99.2%)	1 (0.4%)	5.705 (0.058)

[13] Literacy is defined as the ability to read with understanding and write meaningfully in any language (UNHS 05/06). Following this definition, respondents who had completed seven years of primary school education were considered literate.
[14] UNHS (2005/06) reports that 69% of the population is literate and 20% illiterate. It also reports that about 55% and 17% of the population completed primary and secondary school levels of education, respectively.
[15] UNHS (2005/06) reports that 73% of the population is employed in the agricultural sector, specifically in subsistence farming.
[16] Given an average household size of 6 persons, this translates to a per capita income of 200 US$.
[17] http://en.wikipedia.org/wiki/Uganda

To supply building materials	118 (95.2%)	122 (98.4%)	1 (0.4%)	2.352 (0.308)
As a tourism attraction	120 (96.8%)	122 (98.4%)	3 (1.2%)	0.683 (0.711)
To conserve flora and fauna for current and future generations.	120 (96.8%)	118 (95.2%)	1 (0.4%)	2.017 (0.365)
For climate regulation	112 (90.3%)	99 (79.8%)	1 (4.4%)	5.535 (0.063)
For carbon sequestration	69 (55.6%)	64 (51.6%)	19 (7.7%)	1.504 (0.771)

The results show that majority of respondents in both forest conditions apparently know that BFR was set up to provide society with the named flows, and also to conserve some values that are important to society. These rather impressive results could be attributed to the sensitization works of various government agencies, NGOs and projects that have promoted sustainable forestry management in the region for many years[18]. The relatively low responses reported for the carbon sequestration service could be attributed to its abstract nature. This is a service that society derives from forests but is only finding its way into public vocabulary presently (as opposed to services like "the role of forests in timber provision"). Although we earlier stated that in BFR we are dealing with a literate community, their levels of education are basic with majority having a primary level. It is thus not surprising that most are not aware of the carbon sequestration service of BFR.

For most of the variables designed to operationally capture this objective, the results of the χ^2 tests appear not to reject the null hypothesis of equality in the distribution of responses. This suggests that forest condition does not seem to have an influence on the strength and direction of these variables. Statistically speaking, it was only in the cases of fuel wood supply and climate regulation where forest condition appears to have some rather weak influence (at the 10% level of significance). This homogeneity could potentially be attributed to the fact that the aforementioned sensitization work done by the various agencies has public goods characteristics[19]. Statistically,

[18] Examples of government agencies involved in promotion of sustainable forestry management in Uganda include the National Forestry Authority, the National Forestry Research Institute and the National Agricultural Research Organization.
[19] Sensitization targets all people regardless of the forest conditions they live in.

this homogeneity justifies our grouping of the two sub-samples into one large sample for further analysis. Finally, the observed low non response rates (except for the case of the carbon sequestration service) suggest that non-response may have little influence on the generalizations the study has made on these variables.

To further investigate the robustness of the above inferences, the study ran some χ^2 tests on the entire sample with a view to establishing whether some moderators (in particular the social variables of sex, age, education and income) may have some influence on the variables used to operationally capture this objective. In table 2, the magnitude of the χ^2 tests are reported together with the p-values in brackets.

Table 2: Influence of sex, age, education and income on the knowledge of respondents

Variable	**Sex**	**Age**	**Education**	**Income**
To supply timber	1.564 (0.457)	0.366 (0.833)	2.681 (0.848)	14.395 (0.156)
To supply fuel wood	2.552 (0.279)	0.475 (0.789)	4.723 (0.580)	9.935 (0.446)
To supply building materials	2.043 (0.360)	0.420 (0.810)	7.426 (0.283)	7.441 (0.683)
As a tourism attraction	1.712 (0.425)	0.313 (0.855)	3.292 (0.771)	11.867 (0.294)
To conserve flora and fauna for current and future generations.	3.083 (0.214)	0.844 (0.656)	3.406 (0.756)	9.317 (0.502)
For climate regulation	3.148 (0.207)	13.315 (0.001)	30.940 (0.000)	18.086 (0.054)
For carbon sequestration	12.604 (0.002)	2.230 (0.328)	48.645 (0.000)	9.644 (0.472)

The main conclusion that can be drawn from the results presented in table 2 can be stated as follows; for variables designed to measure concepts at low levels of abstraction (timber supply, fuelwood supply, building materials supply, tourism attraction and conservation), these social variables do not seem to have an influence on the nature and strength of relationships one could hypothesize to exist. However, for variables designed to capture constructs at higher levels of

abstraction, in particular climate regulation and carbon sequestration, education and age appear to have an influence on the nature and strength of relationships one could hypothesize to exist. The influence of education appears to be obvious—the more educated an individual is the higher the likelihood he/she would know of the relationship that exists between the conservation of forests and climate regulation (or carbon sequestration). Also, there is some fairly simple and clear established correlation between age and education achievement.

In the second objective, the study sought to establish whether households were aware that *S. spectabilis* is invasive and that it has potential to compromise the conservation objectives of BFR. Following the approach of table 1, the results of this analysis are presented in table 3.

Table 3: Awareness of the invasiveness of *S. spectabilis* and its potential to compromise conservation in BFR

	Yes (% Yes) by Forest Condition		**Non-Response**	**χ^2 Tests (p-value)**
	NI	**I**		
Ability to identify *S. spectabilis*.	116 (93.5%)	118 (95.2%)	0 (0%)	0.303 (0.582)
Awareness of the invasiveness of *S. spectabilis*.	78 (62.9%)	82 (66.1%)	0 (0%)	4.301 (0.596)
Knowledge that *S. spectablilis* can potentially endanger cons in BFR.	82 (66.1%)	86 (69.4%)	0 (0%)	0.816 (0.665)
Welfare loss if *S. spectabilis* compromised cons objectives of BFR.	85 (68.5%)	93 (75.0%)	7 (2.8%)	1.280 (0.524)
Willingness to control *S. spectabilis* to avoid potential welfare losses.	103 (83.1%)	109 (87.9%)	5 (2%)	1.176 (0.555)

These results suggest that the levels of awareness on the invasiveness of *S. spectabilis* and its potential to compromise the conservation values of BFR are generally high within the community. Just as in the first objective, the χ^2 tests appear not to reject the null hypothesis of equality in the distribution of responses. Following the procedure used to generate table 2, in table 4 we report on the influence of sex, age, education and income on the variables used to operationally capture objective 2.

Table 4: Influence of sex, age, education and income on the variables used to operationally capture objective 2

	Sex	**Age**	**Education**	**Income**
Ability to identify *S. spectabilis*.	2.914 (0.088)	0.754 (0.385)	3.895 (0.273)	5.501 (0.358)
Awareness of the invasiveness of *S. spectabilis*.	1.495 (0.221)	0.250 (0.873)	5.571 (0.134)	6.838 (0.223)
Knowledge that *S. spectablilis* can potentially endanger cons in BFR.	0.574 (0.751)	1.491 (0.475)	3.449 (0.751)	5.159 (0.880)
Welfare loss if *S. spectabilis* compromised cons objectives of BFR.	2.059 (0.357)	3.038 (0.219)	6.966 (0.324)	17.030 (0.074)
Willingness to control *S. spectabili*s to avoid potential welfare losses.	2.876 (0.237)	0.486 (0.784)	7.741 (0.258)	10.930 (0.363)

The results presented in table 4 generally suggest that these moderating variables appear to have no influence on the nature and strength of relationships one could hypothesize to exist between these and the variables used to operationally capture this objective. These findings could be attributed to the anti-*S. spectabilis* campaigns fronted by the UNEP/GEF-IAS project which has been on the ground for close to four years (since 2006). We stated earlier that these campaigns have a public goods characteristic and we would expect them to benefit everyone equally.

In the third objective, the study assessed the impacts of *S. spectabilis* on the quantities of fuel wood, charcoal and construction poles dependent households derive from BFR. Table 5 reports on the results deriving from the analysis in columns II and III. In column IV, we use the F-test approach to test for equality of means. In column V, we quantify the percentage increase in the quantities of the different benefits received by households living in the infested areas compared to those in the non-infested forest areas.

Table 5: Average quantities derived from *S. spectabilis* (HH per week) by forest condition

Product	**Forest Condition**		**F-Test (p-value)**	**% Increase in Benefits**
	NI (Mean)	**I (Mean)**		
Bundles of firewood	0.73	2.12	106.953	190%

collected per week.	(n=120)	(n=123)	(0.000)	
Sacks of charcoal collected per week.	0.13 (n=120)	0.70 (n=123)	40.272 (0.000)	438%
Number of poles collected per week.	1.38 (n=120)	5.41 (n=123)	60.790 (0.000)	292%

The results show that households living in the infested forest areas obtained higher quantities of all the named benefits in comparison to their counterparts in the non-infested forest areas. In our assessment, these differences could be attributed to proximity and availability. Most respondents reported harvesting these products for own consumption, which means these products count for savings in household income. The tests for equality of means reveal there are statistically significant differences in the quantities of products harvested by households by forest area. The analysis in column V suggests that by living in the infested areas, the increase in the magnitude of benefits received by the household is phenomenal.

The study then used market prices prevailing at the time of the survey to convert the quantities of Table 5 to corresponding revenues. The objective here was to estimate the financial returns to the household from harvesting the named products from BFR. At the time of the survey, a bundle of *S. spectabilis* firewood was trading at an average of Ushs 3,000, a bag of *S. spectabilis* charcoal was trading at an average of Ushs 15,000 and a *S. spectabilis* construction pole was trading at an average Ushs 2,000. Since the objective here was to estimate financial (as opposed to economic) returns, the uncorrected market (or farm-gate) prices were used for valuation. The results of this analysis are presented in table 6.

Table 6: Revenues obtained from *S. spectabilis* products (HH per week) by forest condition (Ushs)

Product	**Forest condition**		**% Increase in Benefits**
	Non-infested	**Infested**	
Fuel wood	2,190 (n=120)	6,360 (n=123)	190%
Charcoal	1,950 (n=120)	10,500 (n=123)	438%
Construction poles	2,760	10,820	292%

	(n=120)	(n=123)	
Total	6,900 (n=120)	27,680 (n=123)	301%

The analysis shows that by living in the proximity of the infested forest area, households generate average benefits amounting to UShs 27,680 (13.8 US$) from the named forest goods on a weekly basis, which is at least 300% higher than the amount generated from the same goods by household living further away from the infested areas[20]. The analysis shows that construction poles contributed the greatest share to revenues, followed by charcoal and finally firewood. These results concur with the findings of Swallow et al (2008) who record that a woody invasive species (*Prosopis juliflora*) provided the main economic benefits to the local people in form of construction and fencing poles, as well as fuel wood.

In the final objective, the study assessed whether respondents received other benefits occasioned by the invasion of *S. spectabilis* beyond those analyzed in objective 3, using an open question. Respondents were also asked in an open question to state the costs they perceive could be attributed to the *S. spectabilis* invasion. Following the approach of table 1, the results of this analysis are presented in table 7.

Table 7: Other positive and negative effects of *S. spectabilis* on forest dependent households

	Yes (% Yes) by Forest Condition		**Non-Response**	**χ^2 Tests (p-values)**
	NI	**I**		
Other positive attributes of *S. spectabilis*				
Provision of medicine	24 (19.4%)	20 (16.1%)	0 (0.0%)	0.442 (0.506)
Provision of shade	58 (46.8%)	59 (47.6%)	0 (0.0%)	0.016 (0.899)
Provision of flowers	14 (11.3%)	8 (6.5%)	0 (0.0%)	1.796 (0.180)
Serve as wind brakes	10 (8.1%)	15 (12.1%)	0 (0.0%)	1.112 (0.292)

[20] Average exchange rate at the time of study was 2000 UShs = 1US$.

As a source of income	6 (4.8%)	1 (0.8%)	0 (0.0%)	3.675 (0.055)
As a source of fencing material	12 (9.7%)	21 (16.9%)	0 (0.0%)	2.831 (0.092)
Perceived negative attributes of *S. spectabilis*				
Un-palatable to livestock	71 (57.3%)	86 (69.4%)	23 (9.3%)	11.216 (0.004)
Harbors malaria transmitting mosquitoes.	74 (59.7%)	81 (65.3%)	15 (6.0%)	5.767 (0.056)

Given the almost non-existent non-response rates, the analysis of table 7 suggests respondents do not consider the stated benefits as important for many reasons. Respondents reported that they have other trees superior to *S. spectabilis* in their compounds that serve the purposes of shade, flower and fence provision, as well as acting as wind brakes[21]. Further, respondents reported that *S. spectabilis* litters compounds with its numerous leaves and petals, which partially explains its undesirability as a compound tree. With the increase in extension of health services nearer to households, access to modern medicines and drugs has been enhanced to the extent that few households value *S. spectabilis* as a medicinal plant.

The main costs that households associate with *S. spectabilis* are that it is unpalatable to livestock and that it harbors insect species harmful to human health. However, considering that livestock in the study area makes a very small contribution to agriculture GDP, this does not appear to be a problem of major concern. Most respondents reported that *S. spectabilis* trees provide good breeding habitats for malaria transmitting mosquitoes, the number one killer disease in Africa[22]. Swallow et al (2008) also report that in Liboi Kenya, the incidence of malaria associated with the expansion of *Prosopis juliflora*[23] thickets was the most frequently mentioned problem among the local communities. On the overall, the negative effects occasioned by *S. spectabilis* were reported more by respondents inhabiting the infested forest areas, which can be attributed to proximity.

[21] Garden trees such as mangoes, oranges and other fruit bearing trees provide fruits for own consumption as well as the benefits listed in Table 7.
[22] This is because *S. spectabilis* trees establish big canopies with massive vegetation conducive for breeding mosquitoes.
[23] *P. juriflora* is an invasive woody tree species in East Africa and other parts of the world and has many characteristics in common with *S. spectabilis*. It was introduced for the same reasons as *S. spectabilis* to provide live boundary markers, alternative fuel wood, charcoal, poles and low value timber sources to save the forest reserves from overexploitation and deforestation.

5. Conclusions and recommendations

Three basic conclusions derive from this study. First, there is ample evidence to suggest that households in BFR have high levels of knowledge on its conservation values. Second, households are aware of the invasiveness of *S. spectabilis* and its potential to spread to the extent that it compromises the conservation values of BFR, in which case households would suffer welfare losses. Finally, the presence of *S. spectabilis* in BFR confers important tangible benefits to households whose levels significantly vary with proximity to BFR. Households close to areas of *S. spectabilis* concentrations benefit by orders of magnitude compared to those located much further. It follows that any strategy designed to manage the spread of *S. spectabilis* in BFR must be informed by its demonstrated socio-economic impacts.

To articulate this point we begin by noting that in Uganda, the Ministry of Agriculture, Animal Industry and Fisheries recently completed an aggressive promotion campaign for planting *S. spectabilis* in Masindi district mainly for fire wood provision. In addition, the National Forestry Research Institute (NAFORI) promotes the growing of *S. spectabilis* in the eastern parts of the country for the same purposes of firewood production. In effect, these public agencies associate *S. spectabilis* with positive welfare effects. On the other hand, the management (or eradication) of *S. spectabilis* on account of its potential ecological impacts would come at a cost since some stakeholders would lose from such action. These conflicting interests present a glaring difficult challenge to its management. A careful strategy to resolve such conflict from the economic efficiency point of view would be to commission a comprehensive cost benefit analysis whose findings would provide a basis for negotiation between the gainers and the losers in the event of either control or eradication.

Other possible approaches to minimizing such conflicts would be to recognize the value of *S. spectabilis* in supporting a vibrant forest industry, using non-invasive alien species to provide the benefits currently being associated with *S. spectabilis* wherever possible, ensuring biocontrol is used at the start of any new agroforestry projects that are based on the planting of alien species to reduce the risk of unwanted invasions, using biocontrol to reduce the invasive potential of otherwise useful species without killing them, recognizing potential invaders early and taking precautionary measures, and educating people as to the dangers and costs of invasive species. Furthermore, research into possible tree species that can provide the same benefits as *S. spectabilis* should be carried out to avail replacement trees that are not invasive so as to mitigate

the resistance to *S. spectabilis* eradication that might stem from those that benefit from its existence.

These conclusions and recommendations are consistent with the widely accepted view that the human dimension is critical for successful IAS management. When we consider the importance of social perceptions, knowledge and stakeholder attitudes in relationship to the management of invasive species, we saw that various issues emerge. For example, our study indicates that different households have different perceptions about the impacts and benefits generated by IAS, and different attitudes toward their management and control. It follows that the positive or negative effects on households occasioned by the presence of *S. spectabilis* should be addressed from the beginning of any decision-making process in order to consider the trade-offs involved in IAS management and facilitate the successful implementation of management practices. In addition, most stakeholders and decision makers have a limited perception of the IAS problem (e.g., see Perrings et al 2002) and therefore, mass sensitization and public awareness campaigns are vital for any successful management of such problems.

Finally, the analysis presented in this paper is necessarily partial to the extent that it does not include the evaluations of other stakeholders with an interest in the sustainability of BFR, in particular, commercial timber harvesters and tourism operators. To comprehensively understand the impacts of *S. spectabilis*, it would be necessary to undertake a survey that includes all these stakeholders. Such surveys should be designed to also understand the dynamic impacts of the invasive on production of ecosystem goods and services, and how that could affect human welfare in the long-run.

6. Acknowledgements

We acknowledge the management of the United Nations Environment Programme/ Global Environment Facility- Invasive Alien Species (UNEP/GEF-IAS) project in the National Agricultural Research Organisation (NARO), Uganda; the University of Pretoria, Department of Agricultural Economics and the Collaborative Masters in Agricultural and Applied Economics (CMAAE) Programme for funding this study. Special thanks to Dr.Gadi Gumisiriza of NARO Uganda for his invaluable support, BFR management staff, enumerators and all who helped in various ways. The contents of this publication remain at all times the sole responsibility of the authors and can in no way be taken to reflect the views of the funding agencies.

7. References

Baskin, Y., (2002). *A Plague of Rats and Rubbervines: The growing threat of species invasions.* Washington D.C: Island Press.

Bertolino, S., Genovesi, P., (2003). Spread and attempted eradication of the grey squirrel (*Sciurus carolinensis*) in Italy, and consequences for the red squirrel (Sciurus vulgaris) in Eurasia. Biological Conservation 109, 351–358.

BirdLife International., (2003). *BirdLife's online world bird database: the site for bird conservation.* [Online] Available at: http://www.birdlife.org.

Bonesi, L., Palazon, S., (2007). The American mink in Europe: status, impacts and control. Biological Conservation 134, 470–483.

Bremner, A., Park, K., (2007). Public attitudes to the management of invasive non-native species in Scotland. Biological Conservation 139, 306–314.

Convention on Biological Diversity (CBD)., (2002). Sixth conference of the parties, The Hague, the Netherlands, 7–19 April 2002: Decision VI/ 23. (Available at www.biodiv.org).

Convention on Biological Diversity (CBD)., (2004). Seventh conference of the parties, Kuala Lumpur, Malaysia, 9–20 and 27 February 2004: Decision VII/13: Alien species that threaten ecosystems, habitats or species (Article 8 (h)) (available at www.biodiv.org).

Cock, M.J.W., (2003). Biosecurity and Forests: An introduction – with particular emphasis on forest pests. FAO Forest health and biosecurity working paper FBS/2E, 2003.

Fischer, A., Young, J.C., (2007). Understanding mental constructs of biodiversity: implications for biodiversity management and conservation. Biological Conservation 136, 271–282.

Forest Department (FD)., (1999). Forestry nature conservation master plan. Volume

Forest and tree planting act, (2003). Ministry of Water, Lands and Environment; The National Forestry and Tree Planting Act, 2003. UPPC, Entebbe

Glowka, L., F. Burhenne-Guilmin, H. Synge, J. A. McNeely, and L. G'ndling. (1994). *A guide to the convention on biological diversity*. International Union for the Conservation of Nature (IUCN), Gland, Switzerland.

Gumisiriza, G., Irumba, D., Beine, A.P (2008). Assessment of the effectiveness of two control options for *Senna spectabilis* in Budongo forest reserve. National Agricultural Research Organisation, Entebbe, Uganda.

Hettinger, N., (2001). Exotic species: naturalization, and biological nativism, Environ. Values 10, pp. 193–224

Heywood, V., (1995). *Global biodiversity assessment*. Cambridge University Press, Cambridge, UK.

http://en.wikipedia.org/wiki/uganda

Kaiser, J., (1999). Stemming the tide of invasive species. *Science,* 285: 1836–1841.

Katende, A.B., Binen, A., Tengnus, B., (1995). Useful trees and shrubs for Uganda, identification, propagation and management for agricultural and pastoral communities, regional soil conservation unit (RSCU)/ SIDA, Nairobi. Page 710.

Langoya C.D.et al (1997). Local communities and ecotourism development in Budongo forest reserve, Uganda. Budongo Forest Ecotourism Project, Nyabyeya Forestry College, Uganda.

Le Maitre, D.C., Versfeld, D.B., & Chapman, R.A., (2002). The impact of invading alien plants on surface water resources in South Africa: A preliminary assessment. *Water SA*, 26:397–408.

Lowe, S., M. Browne, S. Boudjelas et al. (2000). 100 of the world's worst invasive alien species. A selection from the Global Invasive Species Database. Invasive Species Specialist Group (ISSG) of the World Conservation Union, Gland Switzerland.

Marina. G., Berta. M., Gonzalez. A., Paloma. A., (2008). Social perceptions of the impacts and benefits of invasive alien species: Implications for management. Biological Conservation 141 (2008) 2969-2983.

McNeely, J.A., (2001). The great reshuffling: Human dimensions of invasive alien species. IUCN, Gland, Switzerland and Cambridge, UK.

Mutonyi, S., (2007). Assessing the effectiveness of control methods on *Senna spectabilis* in Kibale National Park, Western Uganda. Unpublished thesis, Makerere University Kampala, Uganda

National Forestry and Tree Planting Act, (2003). Government of Uganda.

NARO., (2004). Capacity building, training needs assessment, dissemination and replication strategy for invasive plant management in Uganda. Report submitted to CABI under the PDF-B phase of the UNEP/GEF-IAS Project; Removing Barriers to Invasive Plant Management in Africa. NARO, Entebbe, Uganda.

NARO., (2004). *Implementation of invasive plant prevention and control programmes in Uganda*. Report submitted to CAB International Africa regional centre under the PDF-B phase of the UNEP/GEF-IAS Project; Removing Barriers to Invasive Plant Management in Africa. NARO, Entebbe, Uganda.

Parker, I. M., Simberloff, D., Lonsdale, W. M., Goodell, K., Wonham, M., Kareiva, P.M., Williamson, M.H., Von Holle, B., Moyle, P.B., Byers, J.E. & Goldwasser, L., (1999). Towards a framework for understanding the ecological effect of invaders. *Biological Invasions*, 1:3–19.

Pasiecznik, N. (1999). Prosopis - Pest or Providence, Weed or Wonder Tree? European Tropical Forest Research Network Newsletter 28: 12–14.

Pasiecznik, N., P. Felker, P.J.C. Harris et al. (2001). The Prosopis juliflora- Prosopis pallida complex: A Monograph. HDRA, Coventy, UK.

Perrings, C., M., Williamson, E. B., Barbier, D., Delfino, S., Dalmazzone, J., Shogren, P., Simmons, and A. Watkinson., (2002). Biological invasion risks and the public good: an economic perspective: Conservation Ecology 6(1): 1. [Online] URL: http://www.consecol.org/vol6/iss1/art1/

Pimental, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, C., Wong, E., Russel, L., Zern, J., Aquino, T., & Tsomondo, T., (2001). Economic and environmental threats of alien plant, animal, and microbe invasions. *Agriculture, Ecosystems and Environment:* 84.

Richardson, D.M., (1998). 'Forestry trees as invasive aliens'. *Conservation Biology,* 12: 18–26.

Saxena, N.C., (1997). The fuel wood scenario and policy issues in India. Food and Agriculture Organization of the United Nations, Bangkok, Thailand.

Ssembajwe W., and Banana., (1998). Paper presented at the International Association for the study of common property, British Columbia, June 10-13,
1998

Stokes, K.E., O´ Neill, K.P., Montgomery, W.I., Dick, J.T.A., Maggs, C.A., Mcdonald, R.A., (2006). The importance of stakeholder engagement in invasive species management: a cross jurisdictional perspective in Ireland. Biodiversity and Conservation 15, 2829–2852.

Swallow.B., Mwangi. E., (2008). *Prosopis juriflora* invasion and rural livelihoods in the Lake Baringo area of Kenya. Conservation and Society 6(2): 130-140, 2008.

Tewari, J.C., P.J.C. Harris, L.N. Harsh et al., (2000). Managing *Prosopis juliflora* (Vilayati Babul): A Technical Manual. CAZRI, Jodhpur, India and HDRA, Coventry, UK.

Uganda Bureau of Statistics (UBOS), (1999), Uganda National Household Survey (UNHS) 1999/2000

Uganda Bureau of Statistics (UBOS), (2002), Uganda National Household Survey (UNHS) 2002/2003

Uganda Bureau of Statistics (UBOS), (2005), Uganda National Household Survey (UNHS) 2005/2006

Uganda Bureau of Statistics, (2007), Uganda Demographic Household Survey 2005-06

Van Wilgen, B.W., Cowling, R.M., & Burgers, C.J., (1996). Valuation of ecosystem services; A case study from South African fynbos ecosystems. *Bioscience* 46:184–189.

Van Wilgen, B.W., & Van Wyk, E., (1999). 'Invading alien plants in South Africa: Impacts and solutions'. In: D. Eldridge & D. Freudenberger, (eds.), *People and rangelands: Building the future*. Proceedings of the VI International Rangeland Congress, Townsville, Australia, pp566–571.

Veitch, C.R. and M.N. Clout. 2001. Human Dimensions in the Management of Invasive Species in New Zealand. In: *The Great Reshuffling: Human Dimensions of Invasive Alien Species* (ed. J.A. McNeely), pp. 63–74. IUCN, Gland, Switzerland; Cambridge, UK.

Wakabira, V.J., and Mhaya, J.B., (2002). Possible control *S. spectabilis* (Caesalpininiaceae), an invasive tree in Mahale Mountains National Park, Tanzania. Oryx the International Journal of Conservation 36(4):357-363.

Williamson, M., (1998). Measuring the impact of plant invaders in Britain. Pages 57-70 *in* U. Starfinger, K. Edwards, I. Kowarik, and M. Williamson, editors. *Plant invasions: ecological mechanisms and human responses*. Backhuys, Leiden, The Netherlands.

Zavaleta, E., (2000). The economic value of controlling an invasive shrub. *Ambio,* 29: 462–267.