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# A Spatial Analysis of Effectiveness of Eradication of Invasive Species in Improving Grazing for Marginal Livestock Economies in Dryland of Matabeleland South Region, Zimbabwe: A Focus on *Lantana camara* and *Opuntia fulgida.*

Oliver Dube[1], Joy-Noeleen Gugulethu Ndlovu[1], Ntandoyenkosi Ayanda Ncube[1]

*Department of Environmental Science and Health, Faculty of Applied Sciences, National University of Science and Technology, Bulawayo, Zimbabwe.*

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**Abstract:** Invasive alien plant species proliferation is accelerated by land disturbance such as recurrent droughts. The invasive species of concern in this study are *Lantana camara* and *Opuntia fulgida* with occurrence frequency of 43.8 % and 33.8% respectively in the dryland areas of Zimbabwe. This study was conducted in ward 14 and Ward 16, Gwanda and Bulilima Districts, respectively. The first step involved mapping the distribution and extent of eradicated areas in the two sites. A survey was carried out on randomly selected respondents where an assessment of knowledge, attitude, and economic gains due to eradication of invasive species, was determined. The study found that the actual reported loss of livestock in Bulilima resulting from *Lantana camara* poisoning was estimated at USD$7920/year. However, eradication recovered grazing potential of 37.6 hectares, an average carrying capacity of seven heard of cattle with a conservative total market value of $3500.00/yr. Nonetheless, this behavioural change was found to be strongly embedded in external monetary incentives with a frequency score of 88%, indicating an economic response to common property management. The study recommends an extensive use of multidisciplinary approach in the eradication of invasive species; a structured and pragmatic use of incentives.

**Key words:** behaviour change, attitude, incentives, common property resources, opportunity cost

**Corresponding author:** Oliver Dube, Department of Environmental Science and Health, Faculty of Applied Sciences, National University of Science and Technology, Bulawayo, Zimbabwe.

# 1. Introduction

Invasive Alien Species (IAS) are species that are non-native to the ecosystem under consideration and whose introduction causes or has the potential to cause economic, environmental and human health harm [1]. Invasive alien species have negatively impacted a wide range of ecosystems and biodiversity globally through predation, competition or transmission of pathogens. Invasive alien species also cause significant negative impacts to human and animal health and facilitate the spread of diseases [2, 3]. There are over 800 known invasive alien species worldwide. The difficulty to control and eradicate invasive alien species has become an imperative issue globally. Invasive alien species have become one of the serious threats to the ecological integrity of almost every habitat on earth, aggravating rural poverty and irrevocably impacting biological diversity. Africa is under threat from invasion of non-native species which are negatively impacting productivity, undermining development and threatening livelihood opportunities [4, 5, 6]. Africa is home to more than a hundred invasive alien species both plant and animal but the magnitude of negative impacts that these invasive alien species poses varies from country to country and from ecosystem to ecosystem [5,7].

The alien species are one of the most significant threats to biodiversity and sustainable economic development worldwide affecting the very fabric of human lives, diminishing water yields, threatening human health and altering unique places and species deemed valuable [6]. People living in developing countries often bear the huge consequences of plant and animal invasions the most as they are directly dependent on natural resources for their survival [6, 8]. About 48% of the total African population rely on natural resources for all or part of their livelihood [9]. Zimbabwe's ecosystems serve many different ecological functions that form the basis of the country's local livelihoods. According to the Government of Zimbabwe's Ministry of Environment, Water and Climate (MoEWC) (2014), 76% of the rural households in Zimbabwe are poor and heavily dependent on land, livestock and natural resources as a source of living and sustenance. Infestations of invasive alien plant species are a cause of food scarcity and economic hardship in many regions where people are dependent on subsistence, hand to mouth agriculture [6, 10].

***Lantana camara***

*Lantana camara* also known as Cherry Pie is a native plant of America that was first introduced in other regions of the world as an ornamental plant [11]. The invasive plant is also known as *Ndzindzibila* in the Xhosa language, *Ubuhobe besikhiwa* in Ndebele and Mbarapati in Shona [12]. *Lantana camara* has been listed among the world's hundred worst invasive species and among the world's ten worst invasive plants [13, 14]. The plant is now found in more than 47 countries globally, has invaded millions of hectares of grazing land

globally and is of serious concern affecting the production of 14 major crops including coffee, tea, rice, cotton, oil palm and sugarcane [14, 15].

*Lantana camara* is a short stout perennial shrub native to the tropical and sub-tropical regions of Central and South America. The woody shrub often grows 2-4metres tall but sometimes can form dense impenetrable thickets with a height of 10metres. The flowers of the shrub form in clusters varying in colour from red, yellow, orange, pink and white depending on the type, maturity and location [16, 17, 18]. Flowering and fruit production can occur all year round in suitable areas where there is adequate soil moisture, high air humidity and high temperatures. The leaves of *Lantana camara* are ovate-shaped, pointed with serrated margins and heart shaped basins [17, 19]. *Lantana camara* produces clusters of tiny berries that turn purple and black on ripening. The edible berries have a diameter ranging between 6–8 mm. The shrub thrives in areas of high rainfall and warm temperatures and is mostly found in disturbed areas [16, 20].

***Opuntia fulgida***

*Opuntia fulgida* belongs to the Cactaceae family which has an estimated 1 600 species and 130 genera sub-divided into four sub-families; *Cactoideae, Pereskioideae, Maihuenioideae* and *Opuntioideae*. *Opuntia fulgida* originates from arid regions and is drought resistant. The plant can survive up to an estimated period of forty (40) years [21,22]. Opuntiafulgida is a sturdy, compact and perennial succulent plant that grows up to a height of approximately two (2) metres. It has an erect stem, which branches at the tip to form cylindrical, half curved stem joints.

*Lantana camara and Opuntia fulgida* are noxious weeds that have attracted global concern due to their allelopathic impacts on ecosystems. *Lantana camara* is the most common invasive plant in all provinces of Zimbabwe whereas *Opuntia fulgida* has predominantly affected the Matabeleland South Province particularly Gwanda and Beitbridge districts. In a report by Zimbabwe's Ministry of Environment, Water and Climate (2014), it was stated that invasive alien species have had damaging impactsto Zimbabwe's communal lands, forests, grazing lands and aquatic ecosystems. In addition, *Lantana camara* has resulted in the extinction of native species, poisoned grazing animals, altered soil water properties, reduced crop productivity and has reduced the livestock carrying capacity of grazing lands in most of Zimbabwe's communal lands [5, 7, 23]. In Zimbabwe, the Environmental Management Act (EM Act) Chapter 20:27 of 2003 places upon every individual the responsibility to clear or cause to be cleared any invasive alien species growing or occurring on the land in respect of which he is responsible.

The occurrence of *Lantana camara* in Ward 16 of Bulilima District in 2015 was almost double the combined occurrence of the other five (5) invasive alien plants found in the district in 2013 highlighting the magnitude of

the invasion of *Lantana camara* in the ward and the need for eradication. Six invasive alien plants including *Lantana camara* covered a total area of 70.07 hectares in Bulilima district in 2013 [24] but according to EMA 2015 [25], *Lantana camara* had infested 127.9 hectares of available grazing lands in Ward 16 of Bulilima in 2015 thus not only reducing the carrying capacity of the lands but also poisoning grazing animals. In addition, livelihoods of communities that are dependent on the sale of livestock as a source of income were negatively impacted. Matabeleland South province has been infested by *Opuntia fulgida* with four districts namely Insiza, Bulilima, Gwanda and Beitbridge being affected. Over the past 2 years, Gwanda and Beitbridge have been the most affected while the other two districts had very few cases. The presence of *Opuntiafulgida*in Zimbabwe dates back to the 1970s from its source areas at the confluence of Umzingwane and Limpopo rivers. The shrub has been spreading from its source areas and has infested upstream of Umzingwane River. *Opuntia fulgida* initially occupied an area less than half an acre in Beitbridge and Gwanda but after decades it has infested over 3000 hectares of land in Matabeleland South [26].

The main objective of this study was to map the spatial distribution and extent of eradication of the invasive species in the study area. Also, the study sought to assess the knowledge, attitude and determine how the creation of pastures through eradication can improve economic productivity**.**

## 2. Materials and Methods

### Study Areas

The study was conducted in Bulilima and Gwanda districts located in the Matabeleland South Province on the south-western side of Zimbabwe. Bulilima district is made up of 22 wards and covers an area of approximately 553637 hectares. The district is located in Agro-ecological regions 4 and 5 which are extensive farming regions. Average rainfall in these agro-ecological regions usually ranges from 350mm to 650mm with a mean annual temperature range of 21-25˚C which makes the area suitable for extensive cattle or game ranching and the production of drought resistant crops [27,28]. The dominant ethnic groups in the area include the Kalanga and Ndebele but other language spoken to a lesser extent in the region include Setswana [29]. The major source of income for the majority of the households is the sale of livestock. The households that do not have adequate livestock for sale survive by means of petty trading, remittances and casual labour [27]. Gwanda district is characterized by short and variable rainfall seasons receiving below 500mm per year. The residents of Gwanda are mainly engaged in activities such as gold mining, cement production, livestock production and game ranching as sources of income. The ethnic groups in the Gwanda area include the Ndebele, Venda, Shangani, Nyanja but the majority speak Sotho language [30, 31].

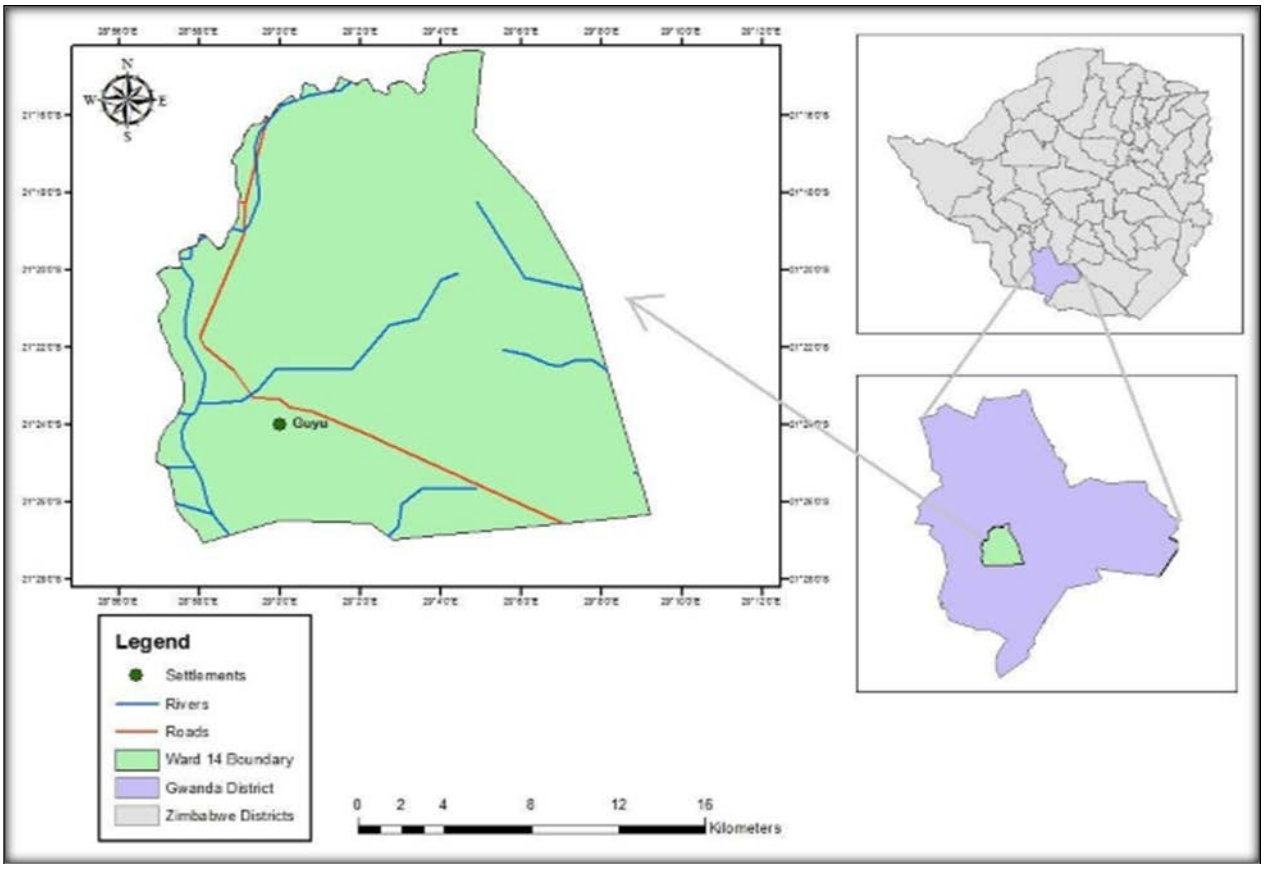


Figure 1: Map showing Gwanda District and Guyu Ward 14

Map showing Bulima District and location of ward 16.

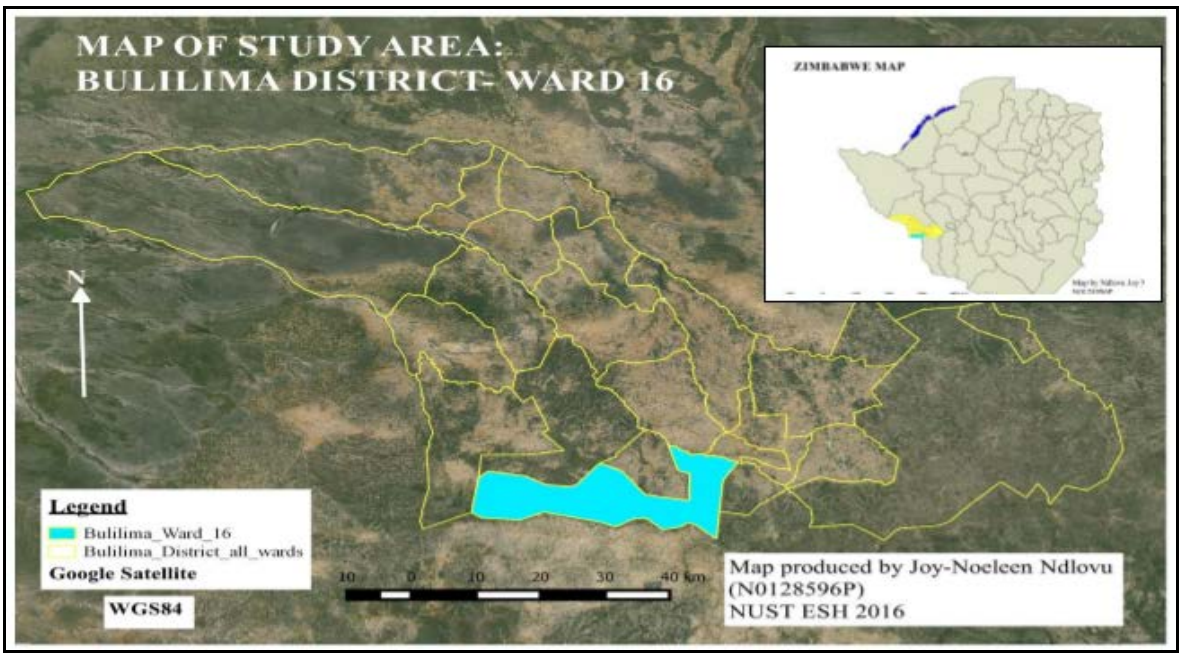


Figure 2: Map Showing Study Location: Bulilima District Ward 16

## Research Design and Sampling

A cross sectional survey was carried out in 2016. A combination of probability and non-probability sampling techniques was used in conducting this study.Purposive sampling was used to select the districts and ward of study because active eradication programs were implemented in the areas at the end of 2015. An assessment of knowledge, attitude and practice towards eradication was carried out on randomly selected respondents/households based on a 35% sample size for each village. Systematic random sampling was used to select households as targeted respondents to the survey. A questionnaire with binary questions, open ended questions, closed ended questions and the Likert Scale for opinion related issues such as measure of knowledge was used.

## Field Survey

A field survey was conducted to map the distribution and extent of areas eradicated of *Lantana camara* and *Opuntia fulgida.* A Garmin etrex 30 Global Positioning System (GPS) device with a geo-accuracy of ±3 meters was used. The device was used to capture coordinates of the areascleared of *Opuntia fulgida* and *Lantana camara.*

**Data Analysis**

Qualitative data wasanalysedusing the grounded theory method. The grounded theory method involves coding and categorization of data into themes, grouping of related information according to the collective responses of the respondents and quantification of responses under each theme [32]. Quantitative data generated during the study was analysed using descriptive statistics where uni-variate and bi-variate analysis techniques were used.

Google Earth and Google Earth Pro were used to for study area map extracts and ultimate mapping of the spatial distribution of the invaded and eradicated regions in the respective wards.

## 3. Results and Discussion

The focus of this section was the spatial extent of the eradication. This enables quantification in economic terms and the gains of eradication process using production valuation method. The following maps show the area that has been gained for grazing in both Bulilima and Gwanda wards.

Map showing ward 16 and study villages.

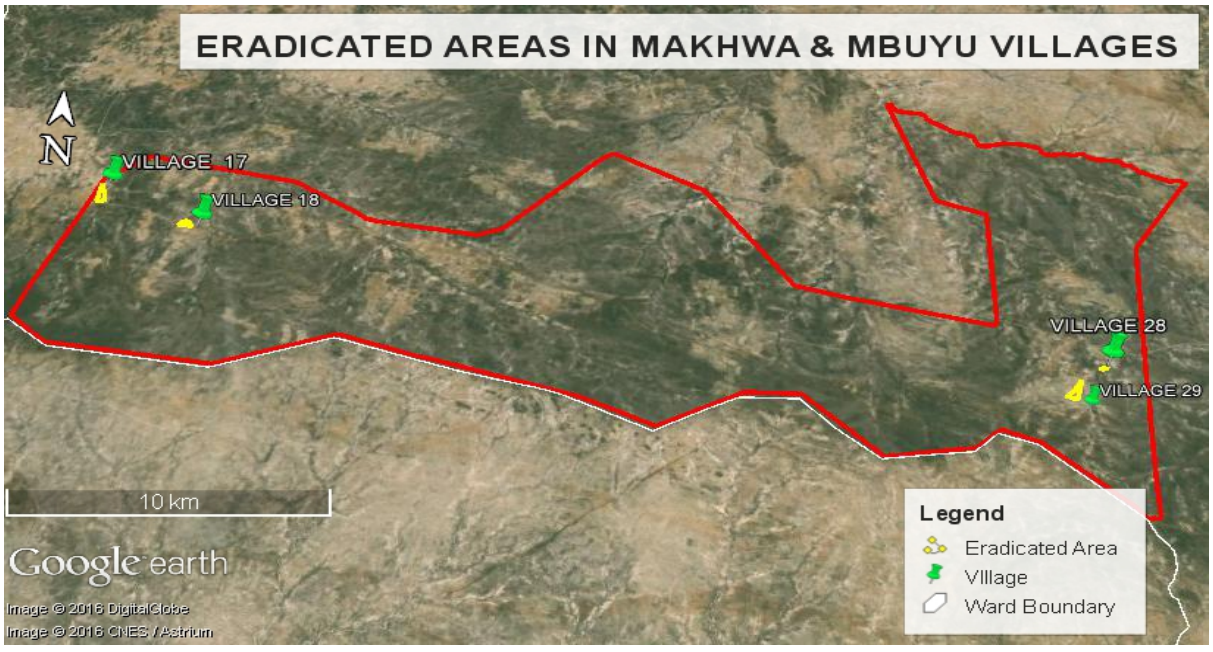


Figure 1: Map of Bulilima Ward 16: Makhwa and Mbuyu and Sub Villages

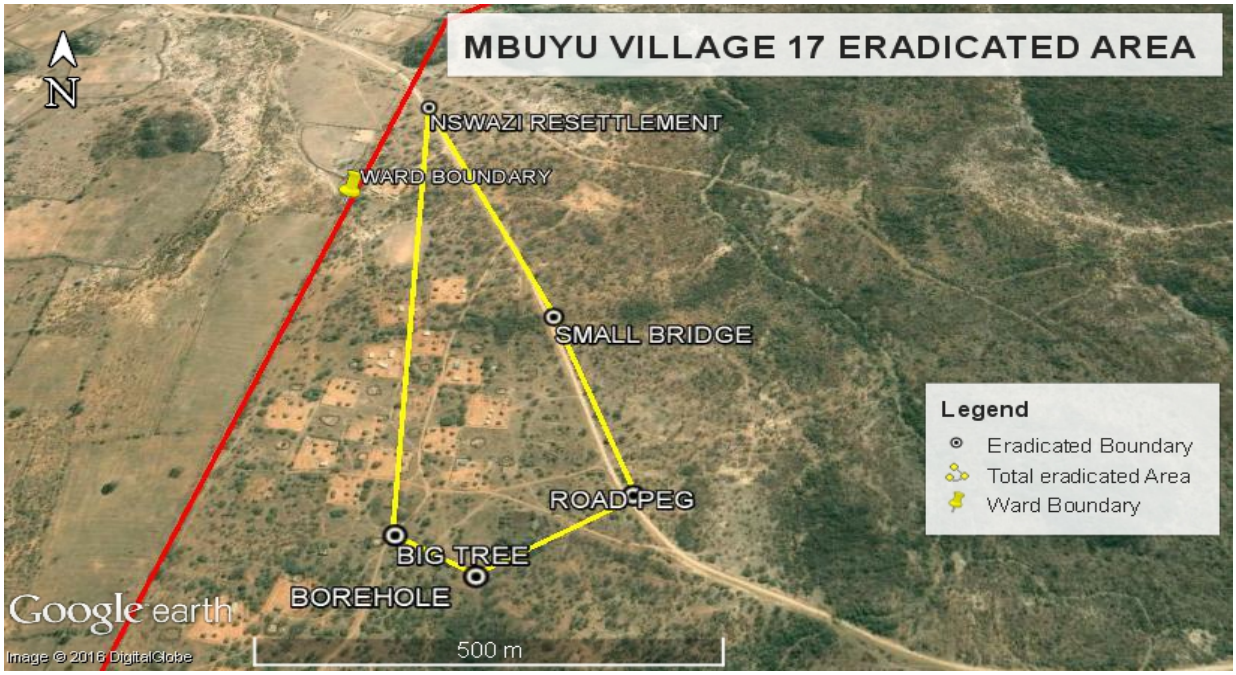


Figure 2: Map of the Eradicated Area in Ward 16: Mbuyu: Sub-village 17

The total estimated area that has been eradicated in Mbuyu village: Sub- village 17 is 14.0 hectares with total perimeter being 2.12 kilometres.

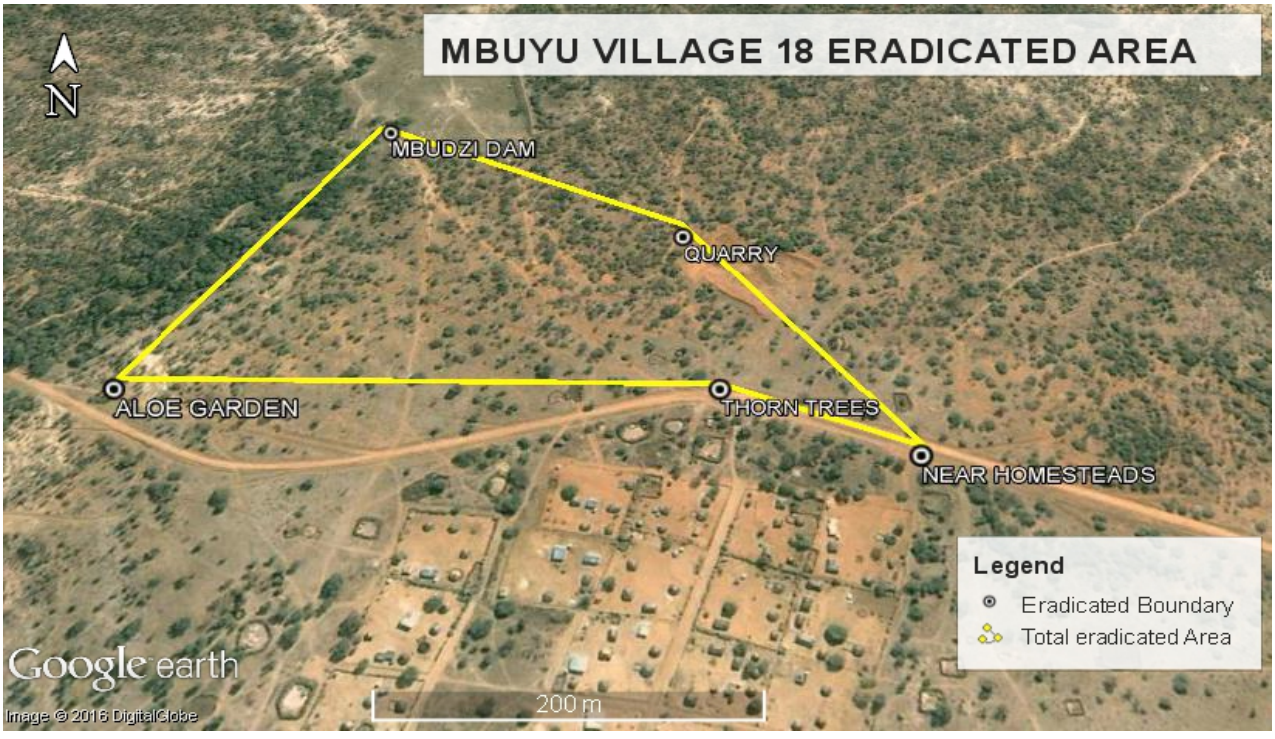


Figure 3: Map of the Eradicated Area in Ward 16: Mbuyu: Sub-village 18

The total estimated area that has been eradicated in Mbuyu village: Sub- village 18 is 8.11 hectares with total perimeter being 1.35 kilometres.

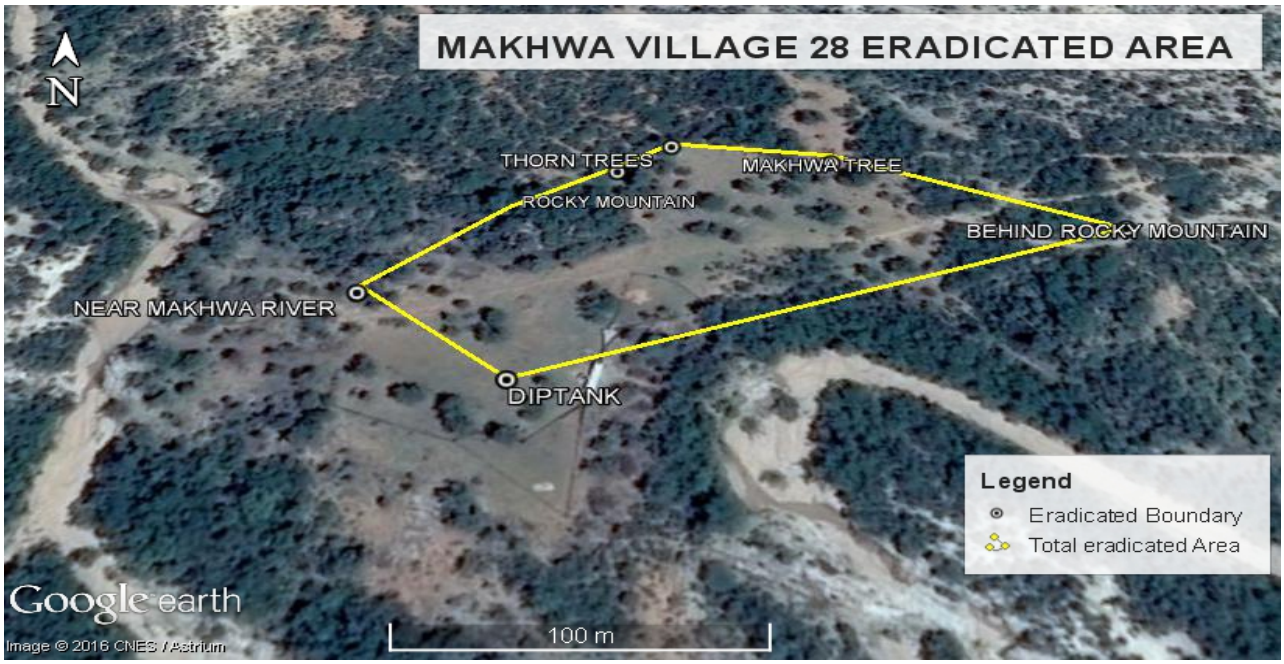


Figure 4: Map of the Eradicated Area in Ward 16: Makhwa: Sub-Village 28

The total estimated area that has been eradicated in Makhwa village: Sub- village 28 is 1.73 hectares with total perimeter being 0.60 kilometres.

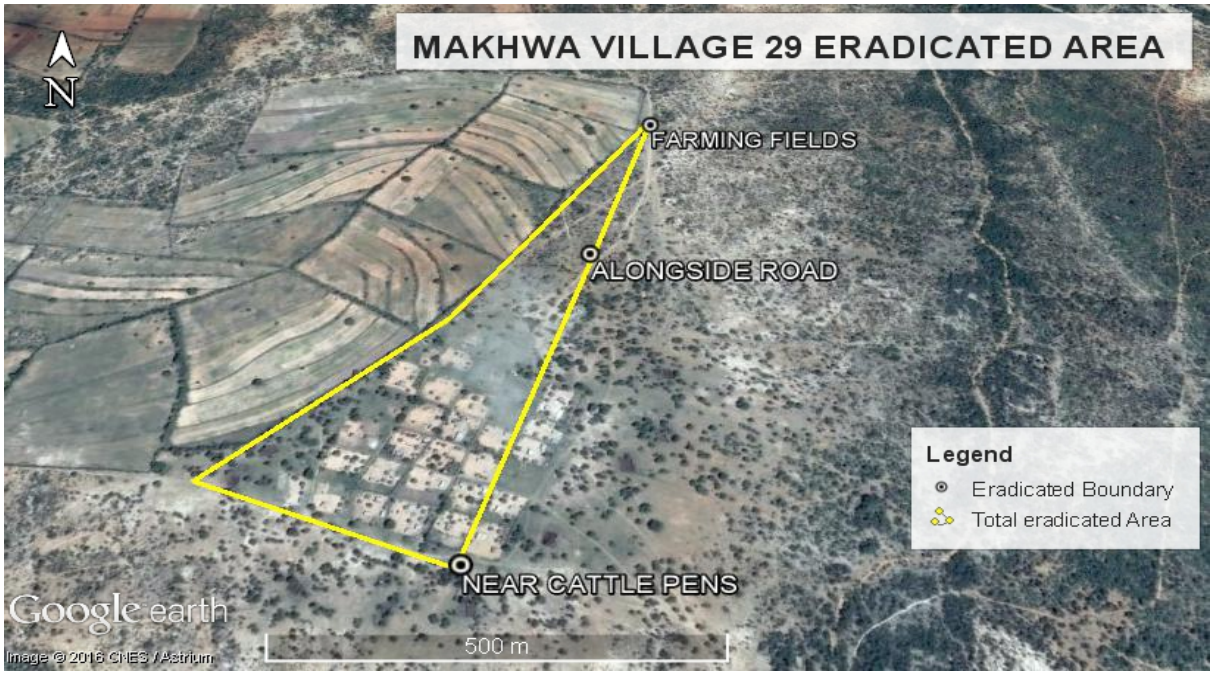


Figure 5: Map of the Eradicated Area in Ward 16: Makhwa: Sub-village 29

The total estimated area that has been eradicated in Makhwa village: Sub- village 29 is 13.8 hectares with total perimeter being 2.15 kilometres.

Table 4. 1: Table Showing Degree of Invasion and Eradication

| Village | Initial Area invaded by *L. camara* | Total area eradicated as of March 2016 | Percentage area eradicated |
|---|---|---|---|
| **Makhwa** | 17.2 | 15.53 | 90.29% |
| **Mbuyu** | 28.9 | 22.11 | 76.50% |
| **Total** | 46.1 | 37.64 | 81.65% |

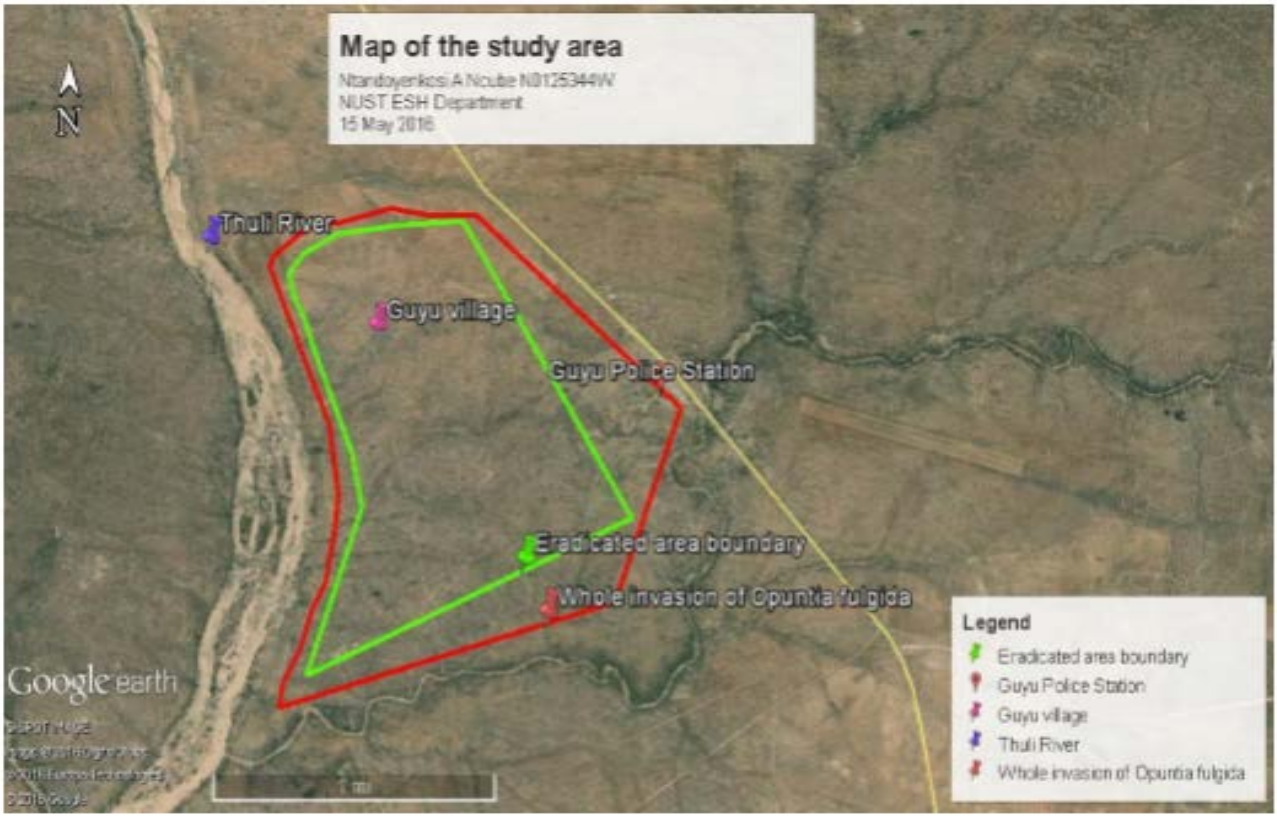


Figure 6: Map Showing the Invaded and Eradicated Area in Ward 14: Guyu village

The area which was invaded by *Opuntia fulgida* before eradication was 380 hectares and up to May 2016 the area eradicated was approximately 249 hectares. This creates grazing for domestic animals such as cattle and goats and at the same time promoting ecosystem recovery.

## Production Function Valuation

The assessment of the area lost to *Lantana camara* equites to the area no longer accessible for production through grazing. By eradicating *Lantana camara* the production capacity of the land is regained hence the production analysis on table 1.

Table 4.2: Economic Value of *Lantana camara* Eradication

| **Ward 16; Villages** | **Initial Area invaded by Lantana camara (ha)** | **Total area eradicated (ha)** | **Carrying Capacity per hectare** | **Carrying capacity x Area eradicated** | **Unit Value of Cattle as of May 2016** | **Total economic value gained based on market unit value** |
|---|---|---|---|---|---|---|
| **Makhwa** | 17.2 | 15.53 | 1 livestock unit per 5 hectares | 3cattle | USD $400 | USD $ 1 200 |
| **Mbuyu** | 28.9 | 22.11 | 1 livestock unit per 5 hectares | 4 cattle | USD $400 | USD $ 1 200 |
| **Total** | 46.1 | 37.64 | 1 livestock unit per 5 hectares | 7 cattle | USD $400 | USD $ 2 800 |

Table 1. production value of eradicated area **(***Source of 1 Livestock Unit per 5 hectares in Zimbabwe: CFU Report (2014)*

All other things being equal, the total economic value that Makhwa village can gain from the sale of livestock grazed on the area that has been cleared was approximately $1200/yr, whereas Mbuyu village was able to gain approximately $1600/yr from the sale of livestock that may be grazed on the eradicated area. This subsequently leads to a total economic gain of $2800 USD/yr per 38 hectares of grazing land that is recovered through eradication.

However, failing to clear invasive species means the gains are mirrored as loss. Added to these losses are the losses incurred with poisoning of cattle and goats are shown in table 2.

| Livestock Type | Actual Number Affected | %household loss | Unit Value | Economic Value |
|---|---|---|---|---|
| Cattle | 16 | 48 | USD400 | USD$6400.00 |
| Goats | 38 | 40 | USD$40 | USD$1520.00 |
| | **Total** | | | **USD$7920.00** |

Table 2. Loss Resulting from Invasive Species

The per capita loss for the sampled village based on a conservative arithmetic calculation of total loss/sample was worked out to be USD$330.00 for the intervening period of around half a year. This means the yearly loss would be equivalent to USD$660.00. For an agro – pastoral based economy this translates to a loss equivalent to paying school fees for 2 terms in a boarding school.

A similar production valuation was carried out for the eradication of *Opuntia fulgida*, a more deadlier plant that once it invades an area, itmakes it completely inaccessible to any mammals due to its fatalistic pricking effects.

**Economic Value of Opuntia *fulgida* eradication**

| Beneficiary animals | Area Invaded by o.fulgida | Total area cleared | Carrying capacity | Carrying capacity created (area cleared /carrying capacity) | Unit value of animal as of May 2016 | Total economic value gained |
|---|---|---|---|---|---|---|
| Cattle | 380 ha | 249 ha | 1 livestock unit/5 ha | 50 cattle | USD$400.00 | USD$20 000.00 |
| Goats | 380ha | 249ha | 8 livestock unit/ha | 249 goats | USD$40 | USD$9 900.00 |
| Total | | | | | | USD$29 960.00 |

The total economic value that Ward 14could gain from the sale of cattle grazed on the area that has been eradicated was approximately $20000 whereas goats value based on grazing capacity was able to give a value of approximately $9900. This leads to a total economic gain of USD$29960 per 249 hectares of grazing land that was recovered through eradication.

Further to the assessment of environmental valuation, eradication knowledge was carried out to determine relationship with education level.

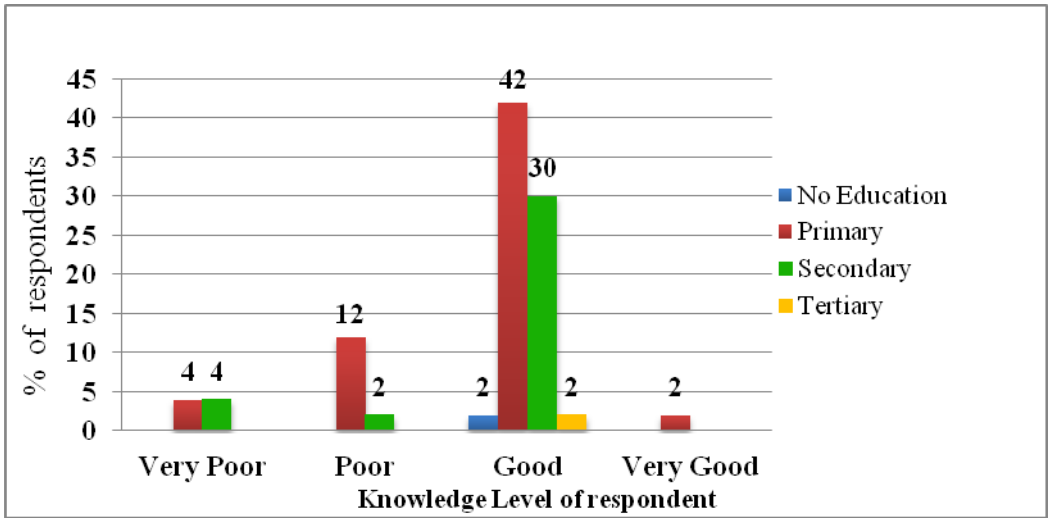


Figure 7 Shows the Relationship between the Respondents Education Level and Knowledge Level on Eradication

The assessment revealed that knowledge of the eradication of invasive species is good and literacy level appear to influence this knowledge. Similarly, Fig 8 reveals that positive attitude influence participation which in turn makes the community choose an effective method for the eradication of the invasive species as shown in Fig 9 and 10 for the respective species.

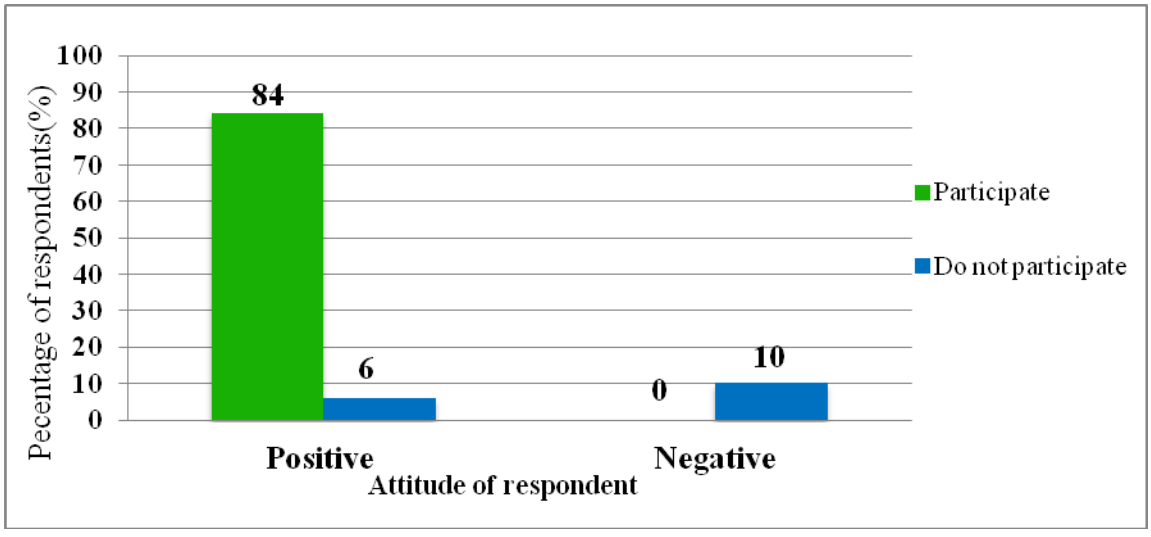


Figure 8 Shows the Relationship between the Respondents Attitude and Participation during Eradication

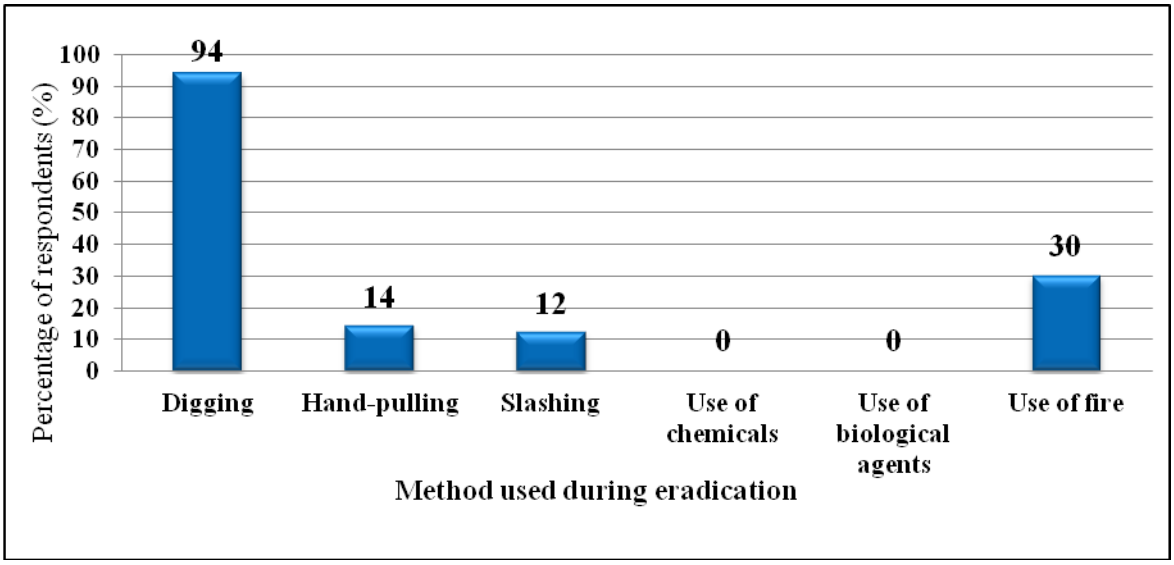


Figure 9 Shows the Practices and Methods Used during Eradication of *Lantana camara*

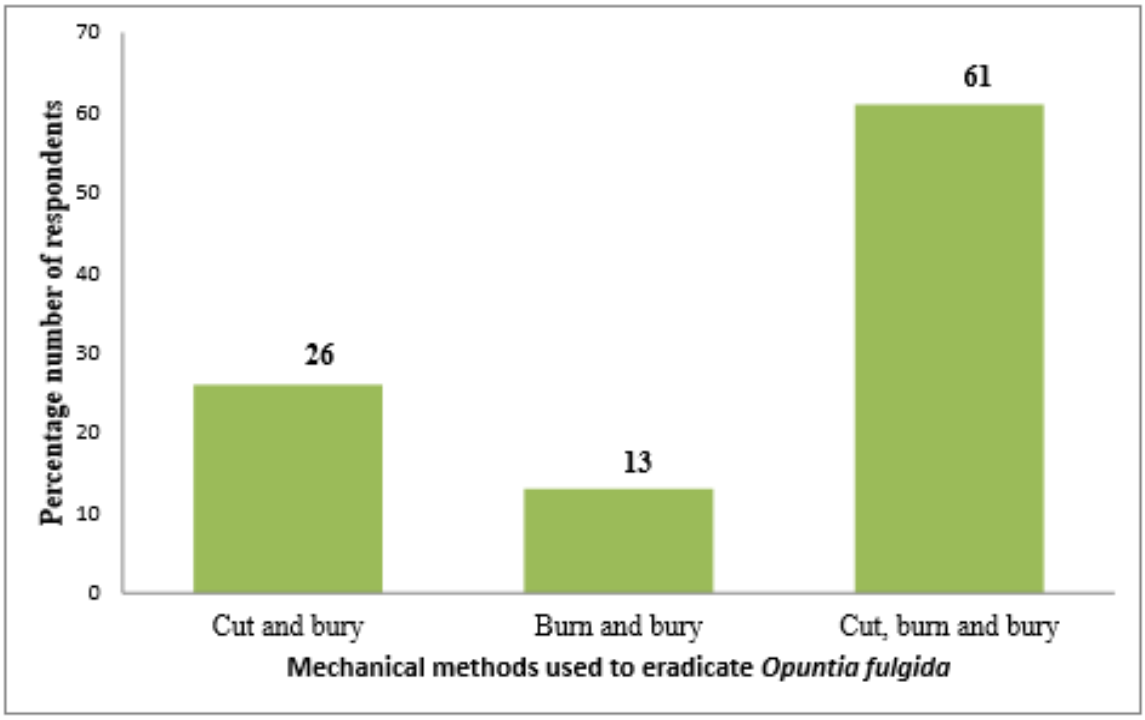


Figure 10 Shows the Practices and Methods Used during Eradication of *Opuntia fulgida*

However, the participation in the eradication also seems to be closely associated with provision of incentives in the form of money (Fig 11). This provides an important measure for the sustainability of the programme in the wake of the recurrence of the invasion.

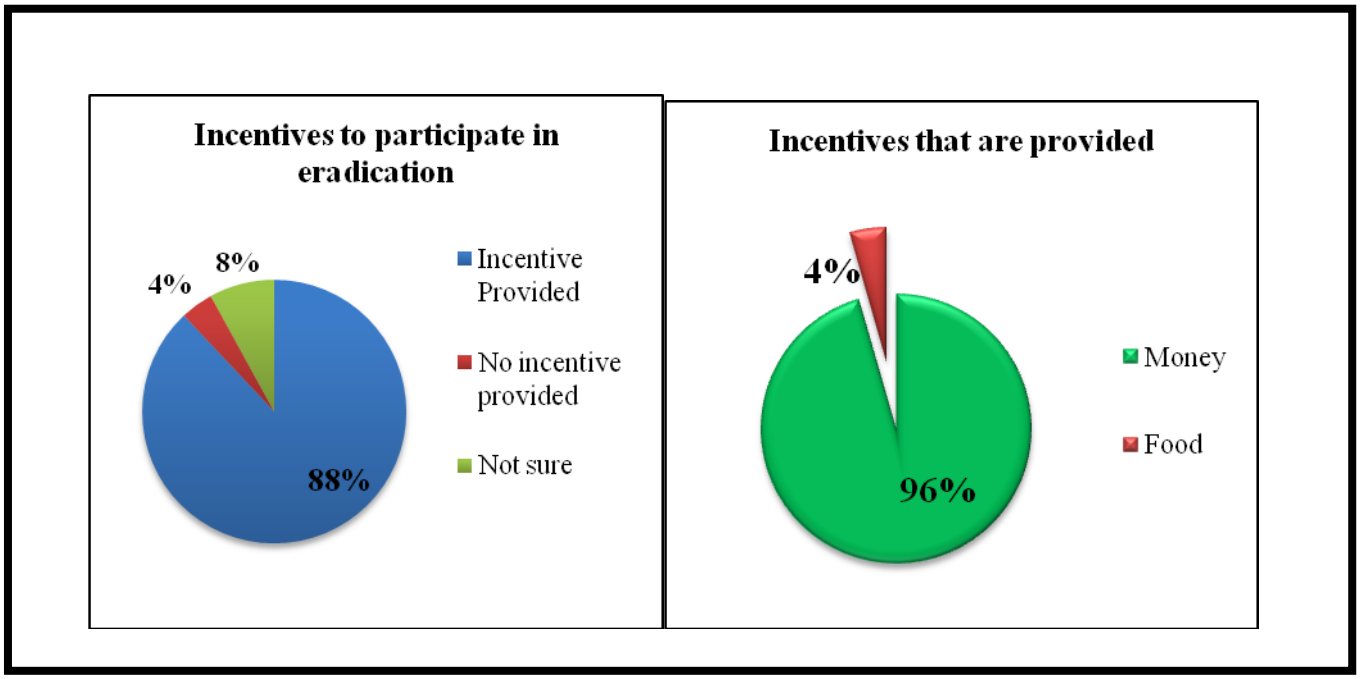


Figure 11 Shows the Incentives Provided and the Type to Encourage Participation during Eradication

Money is the main incentive mentioned by residents which reveals a strong stimulus to participate without which communities might not have achieved the eradication level recorded. The incentive is provided by a Non-Governmental Organization (NGO). Each community member earns $30 for every 15 days they are involved in eradication programmes. It appears that eradication activity are a form of a piece job providing a source of income and livelihood.

This section measured the area cleared of *Lantana camara* and *Opuntia fulgida* and the related grazing area recovered. The valuation of the area recovered was found to be equivalent to the carrying capacity of the domestic animals of concern in each respective area of study. In addition, assessment of knowledge, attitude, methods of eradication, participation and incentives were investigated.

## 4. Discussion

The value created by the eradication of the invasive species gives an indication of the magnitude of the loss of means of production and livelihood by the colonization of grazing area by the invasive species. Since a production valuation method was used to assess the value of the grazing area recovered this method was consistent with local community tag to wealth and livelihood. It is observed that people of Matabeleland are agro – pastoralist who value domestic animals and use them as a measure of wealth [33]. It comes as no surprise that communities under study have developed a positive attitude towards the eradication of *Lantana camara* because of the hazards associated and risk to their livestock such as poisoning and death respectively. However, the stimulus for this attitude and ultimate behavior was explored.It was surmised that the positive attitude of the community towards the eradication of invasive species might be driven by the fact that in eradicating the species the community is protecting their livestock, a source of their livelihoods, wealth and status. According to Prager [34] attitude and beliefs of current environmental surrounding production conditions shapes and activates the need for change.

Further the study found a close association between attitude and participation. In this case, positive attitude seemed to translate to high participation in the eradication activities. Similarly, a study conducted by Brenner and Park [35] in Scotland in 2007 to assess the attitudes of the public towards the management of invasive alien species revealed that 84% of the respondents had a positive attitude towards the eradication of non-native species. Verbrugge et al (2013) [36] highlights that the attitude of the public plays a pivotal role in the prevention, management and eradication success of invasive alien species.

However, it must be emphasized that the attitudes vary from the species being controlled to the method used for control or eradication. Both *Lantana camara* and *Opuntia fulgida*, the latter is listed by the Global Invasive Species Database as a noxious allelopathic weed, are eradicated through uprooting and burning. This is a time consuming and laborious activity with serious opportunity cost [37]. This means that the benefits of carrying out the activity must outweigh the cost. When opportunity cost was factored in the management of common property resources (Ibid) then the issue of incentives becomes an important feature.

The intervention of the Non-Governmental Organisationsin providing incentives in the form of money, $30 for 15 days' work,has helped in achieving positive attitude and high participation by the community. Based on Figure 11,88% of the respondents indicated that incentives are provided by the Non-Governmental Organisations to encourage participation in eradication activities. Of the 88% who stated that incentives were the motivator for participation, they indicated that monetary incentives were their preference. The fact that USD$30 per 15 days' workpaid was attractive enough for members to forego other household activities, gives

an indication of income average and correspondingly, labour cost. Given that the average livestock loss resulting from invasive species was estimated to be USD$660/household/year, implies livestock are key income earners than paid work engagement for these subsistenace farmers. This reinforces the salient, albeit inherent in human nature, of the role of opportunity cost driving human behavior. Carson (2004) [38], states that behaviour and actions of people are often motivated by a variety of incentives such as praise, rewards, recognition and money. These findings are like those of the Wildlife Society, an organization in North America that offered incentives to the public to help in the management or removal of invasive Burmese pythons, *Python bivittatus,* in the Everglades, South Florida [39]. Further the society in February 2016 the organization offered USD$3500 to the person who captured the most pythons and USD$1000 to the person who captured the longest python, hence monetary provision became a tool in luring the public to help in the management of the invasive species (ibid). This corroborates the notion that incentives are critical component in getting common property related projects done. The question among southern African pastoralist caught – up in a web of common property regime is the sustainability of this approach. This means that a strong institutional arrangement would be a key factor in achieving self-governance to bring about self-sustenance [37,40].

Asresult of invasive species such as poisoning of cattle and destroying pastures, knowledge onthe existenceand need for eradication of invasive species quickly gets institutionalized within the community. In this study over 80% had good knowledge. These findings are consistent with findings of a study done by Verbrugge*et al* [36] inthe Netherlands in 2011 where 80% of the respondents had good knowledge about invasive species and 72% of the respondents had an idea of how to control the invasive species. Nevertheless, this does not automatically translate to knowledge of methods of eradication. This is where the nexus with the external organization for knowledge impartation is critical. A study conducted by Reis *et al* (2013) [41] in Portugal revealed that less than half of the respondents knew how to control invasive plants whereas only 7% knew the problems associated or caused by invasive species. This implies that identifying the problem is part of human self – preservation niche which is literally a first step in solving the problem whereas the locus of the solution might be on the other end of the spectrum, method of eradication.

To effectively eradicated both *Lantana camara* and *Opuntia fulgida,* community adopted mechanical methods in controlling invasive species which was digging, burning/ use of fire, cutting and slashing.This is where the expert knowledge played a pivotal role in factoring multidisciplinary approach in the quest for solution without which the community would take longer to find one. Dickinson and Bonney (2012) [42] state that differences between expert and citizen knowledge are a major reflection in the reasoning and practices concerning invasive alien species. Vidal et al (2005) explains that the type of eradication method or practices adopted largely depends on the invasive species itself, the ecosystem affected, the duration of the eradication

and the availability of labour. For instance, *Opuntia fulgida* does not need a lot of water for its survival and germination. Therefore, the villagers need to be meticulous in dealing with such a species byfollowing closely all the steps involved in the eradication such as cut/ uproot, bury in deep holes filled with manure to avoid germination. The burying in holes with manure isan indication of understanding of the favoured conditions by this species which are aridity associated with dry, stony and rocky soils [44]. Indirectly this confirms the increase desertification in the Gwanda district, southern Zimbabwe, where there has been aggressive proliferation of *Opuntia fulgida* in the widespread stony and rocky soils.

## 5. Conclusion

The eradication of the invasive species in the two wards was effective leading to a creation of grazing areas which were otherwise lost enabling increase in productive land for pastoral activities. Given the productive value of the pasturescreated among common pool resource users, the factors contributing to this were assessed. Among these factors, attitude seemed to be a key factor in the process change. But on close analysis of the stimulus to the high positive attitude it was found that the attitude is a proxy for monetary gains associated with incentives. This isa paramount issue in the sustainable development discourse since the desired outcome is rather, a spontaneous behavior which is akin to self-sustenance. In the absence of the element of spontaneity in driving the eradication process, the questions raised here are: what would be the ideal condition for agro – pastoralists caught – up in debilitating environmental conditions to spontaneously initiate change? Are these communities devoid of spontaneity regardless of the knowledge of the effects of looming environmental hazards orare they devoid of adaptive reactive instincts to control the environmental danger or hazards that potentially threatens their livelihood? Are the incentives the only way to stimulate positive reaction control of environmental degradation? Drawing from the fact that incentives were provided by an NGO, implies that in the absence of the NGO which is synonymous to incentives, the community would resign to the whims of fate. These questions are central for sustainable development and ecological stability in marginal dry land areas characterized by common pool resource use.

Following the findings and questions raised in this investigation the study recommends that; further studies be carried out on effectiveness of self-governance in the management of common pool resource among southern African pastoralists, and the modelling of a carbon tax to give proprietorship at household level for common pool resources sustainable use in marginal areas.

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## References

1. Priyanka N and Joshi P.K; 2013; A review of Lantana camara studies in India; *International Journal of Scientific and Research Publications*, Volume 3, Issue 10.
2. European Union; 2014; Invasive Alien Species: A European response; Publication of the European Commission; Brussels.
3. Convention on Biological Diversity; 2010; Invasive Alien Species; fact sheet; http://www.cbd.int/invasive.
4. Global Invasive Species Database; 2014.
5. Foxcroft L.C, Richardson M.D, Rejmanek M &Pysek P; 2010; Alien Plant Invasions in tropical and sub-tropical Savannas: Patterns, Processes and Prospects;*Springer Link Journals*; 12; pages 3913-3933.
6. Boy G and Witt A; 2013; *Invasive Alien Plants and Their Management In Africa*; Synthesis Report of the UNEP/GEF Removing Barriers to Invasive Plant Management in Africa Project; Gutenberg Press Limited; Kenya.
7. Chenje M and Katerere J; 2006; *Africa Environment Outlook: Our Environment, Our Wealth*: Chapter 10: Invasive Alien Species; United Nations Environment Programme.
8. IUCN; 2006; An introduction to the African Convention on the Conservation of Nature and Natural Resources*: IUCN Environmental Policy and Law Paper Number 56 Revision*; 2nd Edition; Gland; Switzerland; page 287-288.
9. Blein R, Bwalya M, Chimatiro S, Faivre-Dupaigre B, Kisira S, Leturque H &Wambo-Yamdjeu A; 2013; *Agriculture in Africa: Transformation and Outlook*; Publication submitted to the African Union by NEPAD (New Partnership for African Development); South Africa.
10. Miller D and Gwaze D. 2012.*Zimbabwe Biodiversity and Tropical Forest Assessment (118/119); Publication* produced for review by the United States Agency for International Development (USAID).
11. SaxenaM, Saxena J &Khare S.2012.A brief review on Therapeutical values of Lantana camara plant*; International Journal of Pharmacy and Life Sciences;* 3, (3).
12. Bisi-Johnson M.A, Obi C.L, Hattori T, Oshima Y, Li S ,Kambizi L, Eloff J.N &Vasaikar S.D. 2011.Evaluation of the antibacterial and anticancer activities of some South African medicinal plants; *BMC Complementary and*

*Alternative Medicine*, 11 ( 14); pages 1-5.

13. Pimentel D. 2011.*Biological Invasions: Economic and Environmental Costs of Alien Plants, Animal and Microbe Species*; Second Edition; CRC Press; USA.
14. AravindN.A, Rao D, Ganeshaiah K.N, Shaanker R.U, & John G. Poulsen; 2010; Impact of the invasive plant, Lantana camara, on bird assemblages at MaléMahadeshwara Reserve Forest, South India; *Tropical Ecology***;** 51 (2S); page 325-338.
15. Hanley N. Shogren J. and White B. 2013. *Introduction to Environmental economics* (2nd edition). Oxford university press, Oxford.
16. Enseby R; 2008; P*rime Facts: Lantana*; New South Wales Department of Primary Industries; http://www.dpi.nsw.gov.au accessed 17/11/15.
17. Chatanga P; 2007; *Impact of Invasive Alien Species Lantana Camara (L) on native vegetation in Northern Gonarezhou National Park Zimbabwe*; A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Tropical Resource Ecology Programme; University of Zimbabwe.
18. Taylor S, Kumar L, Reid N & Kriticos D.J; 2012; *Climate Change and the Potential Distribution of an invasive shrub Lantana camara (L);* Open Access Article; PLOS ONE; Vol 7 Issue 4.
19. National Heritage Trust; 2003; *Lantana camara*; Australia.
20. IUCN; 2010; *Extent And Distribution of Some Invasive Plant Species In Asian Elephant Habitat; Report from preliminary online survey*; pages 27-32.
21. Henderson L and H G Zimmerman.2003. (*Opuntiafulgida*Engelm) misidentified as rosea cactus (OpuntiaRosea DC) in South Africa. *South African Journal of Plants and Soil*. 20. Pages 46-4.
22. Raymond M Turner, Janice E Bowers and Tony L Burgess. 1995. *Sonoran Desert Plants: An Ecological Atlas.* The University of Arizona Press. United States of America.
23. Government of Zimbabwe: Ministry of Environment, Water and Climate; 2014; *Zimbabwe's Fifth National Report to the Convention on Biological Diversity*.
24. Environmental Management Agency; 2013.
25. Environmental Management Agency; 2015; Bulilima District Invasive Alien Species Report.
26. Environmental Management Agency. *Opuntiafulgida* eradication project 2014. Available at www.ema.co.zw/idex.php/2014-06-12-03-49-33/enviromental-projectsinitiatives/75-opuntia-fulgida-project.html (Accessed 16/02/2016)
27. Bulilima Rural District Council; 2014; District Profile for Bulilima- Document acquired from the RDC office.
28. Mugandani R, Wuta M, Makarau A &Chipindu B; 2012; Re-Classification Of Agro-Ecological Regions Of Zimbabwe In Conformity With Climate Variability And Change; *African Crop Science Journal*, 20.

29. Moyo J; 2002; *Lexical Metamorphosis of the Kalanga Language: Towards an analysis of the impact of Ndebele denomination of the Kalanga Language.*
30. Hyde. M. A. Nursten. B.T. Ballings. P and Palgrave C.M. 2015. Flora of Zimbabwe: Species Information : *Opuntiafulgida.*
    Available at www.zimbabweflora.co.zw/speciesdata/species.php?species-id=170160 (Accessed 02/05/2016)
31. Earle A; Goldin J; Machidza R; Malzbender D; Manzungu E; TiegoMpho; 2006; Working paper 112:Indigenous and Institutional Profile of Limpopo River Basin; Google books.
32. Martin V and Gynnild A; 2011; *Grounded Theory: The Philosophy Method and Work of Barney Glaser*; First Edition; Brown Walker Press; USA.
33. Hall M. 1986. The Role of Cattle in Southern African Agro – pastoral Societies: More Than Bones Alone Can Tell.*JSTOR* 5.
34. Prager K; 2012; *Understanding Behaviour Change*; James Hutton Institute; UK.
35. Bremner A and Park K; 2007; Public attitudes to the management of invasive non-native species in Scotland*; Biological Conservation* 139: 306-314.
36. Verbrugge L; Van der burg R & Lenders R; 2013; *Exploring public perception of non-native species from a visions of nature perspective*; **Springer Journals.**
37. Ostrom E, Gardiner R. Walker J. 1994. *Rules, Games and Common Pool resources*. The university of Michigan, Michigan.
38. Carson-Arenas Aggie; 2004; *Introduction to Psychology: Understanding Human Behaviour*; First Edition; Rex Publishers; Phillipines.
39. Wesdock N; 2016; *Competition seeks to manage invasive pythons in Everglades*; http://www.wildlife.org/competition-seeks-to-manage-invasive-pythons-in-everglades , accessed 13 May 2016.
40. Ostrom E. 2006. The value-added of laboratory experiments for the study of institutions and common-pool resources *Journal of Economic Behavior& Organization.* 61 (2006) 149–163.
41. Reis C, Marchante H, Freitas H &Marchante E; 2013; Public perception of invasive plant species: Assessing the impact of workshop activities to promote young students' awareness;*International Journal of Science Education*; 35 Issue 4, pg 690-712.
42. Dickinson J & Bonney R; 2012; Citizen Science: *Public Participation in Environmental Research*; First Edition; CornstockPublising Associates; USA.
43. Mooney; 2005; *Invasive Alien Species: A New Synthesis; A project of the Scientific Committee on Problems of the Environment (SCOPE) on behalf of GISP with partners CAB international and IUCN*; Published by Island Press; USA.

44. Raymond M Turner, Janice E Bowers and Tony L Burgess. 1995. *Sonoran Desert Plants: An Ecological Atlas.* The University of Arizona Press. United States of America

45. Derickx L and Antunes P; 2013; *A guide to the identification and control of exotic invasive species in Ontario's hardwood forests*; Publication of the Invasive Species Research Institute; Canada.