People’s perceptions and uses of invasive plant *Psidium guajava* in Vhembe Biosphere Reserve, Limpopo Province of South Africa

Sheunesu Ruwanza and Gladman Thondhlana

*Department of Environmental Science, Rhodes University, Makhanda, South Africa; †Department of Environmental Science and Centre of Excellence for Invasion Biology, Rhodes University, Makhanda, South Africa*

**ABSTRACT**

Human perceptions and knowledge of invasive alien plant species are increasingly recognised as important in the management of biological invasions, but there is limited research focus on the social dimensions of plant invasion. Using household surveys, this study assessed the perceptions, knowledge, and uses of *Psidium guajava* Linn. to rural communities in Vhembe Biosphere Reserve, in the Limpopo Province of South Africa. Results showed that most respondents are aware of *P. guajava* and perceive it to be spreading in their locality but do not consider it an invasive alien plant species. *Psidium guajava* is perceived to have a dual purpose and most respondents are aware of its benefits including fruit consumption, medicinal purposes, shading and firewood provisioning and costs such as attraction of problematic animals, displacement of native plants, and reduction of grazing and agricultural space. The benefits associated with use of *P. guajava* are considered greater than the costs, therefore most participants do not implement any control measures. These results highlight the need to incorporate rural community perceptions, knowledge, and uses of *P. guajava* in developing effective management plans that avoid conflicts between stakeholders. To improve the efficacy of managing biological invasions more research is required to understand how communities relate to invasive alien plant species.

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1. **Introduction**

Invasion of natural ecosystems by invasive alien plant species presents severe threats to global biodiversity (Rai and Singh 2020; Richardson et al. 2020). Invasive alien plant species are detrimental to the environment and considered a major driver of biodiversity loss due to their ability to alter natural ecosystem services through multiple mechanisms (Rai and Singh 2020). Recent studies have reported that approximately 17% of the global terrestrial area is vulnerable to invasion by invasive alien species, with current invasion threats being more in the economically developed as compared to less developed countries, owing to human movement (Early et al. 2016).

In South Africa, invasive alien plant species are estimated to have invaded millions of hectares (Zengeya and Wilson 2020), with *Acacia*, *Eucalyptus*, *Lantana*, *Pinus*, and *Opuntia* species being widespread (Richardson et al. 2020). Invasive alien plant species were introduced to South Africa for several reasons, including for agricultural and forest production (e.g. animal fodder and plantation timber), and for ornamental purposes (Richardson et al. 1997, 2020). Threats of invasive alien plant species on South African terrestrial ecosystems include loss of ecosystem goods and services such as water (Richardson et al. 2020), transformation of invaded ecosystems, which results in the loss of native species (Richardson and van Wilgen 2004; Richardson et al. 2007), and severe threats to human wellbeing and livelihoods (Potgieter et al. 2020; Richardson et al. 2020). For example, invasion by Australian *Acacias* in South Africa has resulted in a wide range of negative impacts on terrestrial ecosystem resulting in transformed and altered ecosystems with reduced goods and services (Le Maitre et al. 2011). Similarly, *A. mearnsii* (Le Maitre et al. 2020), *E. camaldulensis* (Hirsch et al. 2020) and *P. radiata* (Dzikiti et al. 2013) invasion in South Africa has resulted in severe water loss with negative effects on human livelihoods and the economy.

However, despite the negative effects of invasive alien plant species, some plant species contribute positively to ecosystems and people through provisioning of goods and services that are important for human wellbeing (Vaz et al. 2017; Shackleton et al. 2019, 2020). For example, recent studies in rural South Africa have shown that *A. dealbata* is an important source of fuelwood and fodder, whilst harvesting and selling of poles for fencing provide employment and cash income for rural people (Ngorma and Shackleton 2019). Similarly,
*E. camaldulensis* provides multiple benefits to local communities such as timber, firewood, shelter, and nectar (Hirsch et al. 2020). Shackleton et al. (2011) highlighted that *Opuntia ficus-indica* (prickly pear) plays a key role in generating cash income for poor families in the Eastern Cape Province of South Africa. Given the contribution of some invasive alien plant species to human wellbeing, there is a need to understand the social dimensions of invasive alien plant species.

Relative to ecological studies, there is a limited focus on perceptions, knowledge, and role of invasive alien plant species on rural livelihoods (Shackleton et al. 2017, 2019). Human perceptions, defined as the process 'wherein people select, organise, interpret, retrieve, and respond to the information from the world around them’ (Schermehorn et al. 2005), can produce mental expressions and constructions, which in turn, shape behavioral outcomes. Shackleton et al. (2019) suggest that knowledge and perceptions of invasive alien plant species are influenced by individual attributes, characteristics of the species, effects of the species, socio-cultural context, landscape context and institutional and policy context. For example, the invasive alien species *O. ficus-indica* (Shackleton et al. 2011) and *A. dealbata* (Ngorima and Shackleton 2019) are often perceived as native and, in most cases, local communities fail to distinguish them because they are part of the landscape. The positive benefits accrued from an invasive alien plant might contribute to positive perceptions by users of the plant (Shackleton et al. 2019). Similarly, the appearance of an invasive alien plant e.g. flower color or leaf shape might influence people’s perception and knowledge about the plant. In addition to perceptions and knowledge about invasive alien plant species, limited work has been done to understand benefits and costs of invasive alien plants to rural local users in South Africa (Shackleton et al. 2017; Ngorima and Shackleton 2019). Some invasive alien plant species such as Australian *Acacias* and *Eucalyptus* offer both benefits and costs resulting in conflict of interest regarding how such species should be managed (Dickie et al. 2014; van Wilgen and Richardson 2014; Zengeya et al. 2017). Therefore, differences in the perceived benefits and costs of invasive species can result in conflicts over their management due to opposing views on methods of control (Zengeya et al. 2017). Thus, understanding both the benefits and costs of invasive alien plant species can inform management options that minimize conflicts.

Although several frameworks have been developed to assess the impact of invasive alien species on livelihoods, the sustainable livelihoods framework (Scoones 1998) has been used by Shackleton et al. (2007) to develop a framework that helps interpret the impacts of invasive alien species on livelihoods. The livelihoods framework is useful in guiding research questions towards understanding how invasive alien species influence people’s choices, activities, and resource use for livelihood benefits (Siges et al. 2005; Shackleton et al. 2011; Kannan et al. 2014; Ngorima and Shackleton 2019). The livelihoods framework suggested by Shackleton et al. (2007) categorises invasive alien species into four categories based on the benefits and costs they supply to livelihoods. The four categories are (i) desirable and weakly competitive (species with high benefits and low costs), (ii) desirable and strongly competitive (species with both high benefits and costs), (iii) undesirable and weakly competitive (species with both low benefits and costs), and (iv) undesirable and strongly competitive (species with low benefits and high costs). In South Africa, Shackleton et al. (2011) categorised *O. ficus-indica* as desired and weakly competitive because it provides several socio-economic benefits (e.g. food and fodder) for rural livelihood sustenance, yet its population densities remain stable with low environmental effects. However, various communities can categorise invasive alien species differently given that socio-ecological and cultural contexts can influence benefits and costs. For example, *Acacias* e.g. *A. mearnsii* and *A. dealbata* are categorised as desired and weakly competitive in Madagascar because they are viewed as highly beneficial with low spread and impacts (Kull et al. 2007), yet in South Africa, they are categorised as desirable and strongly competitive due to high benefits to communities and high environmental costs since they create monospecific stands that displace native plants (Ngorima and Shackleton 2019). In applying the livelihoods framing to understand the role of invasive alien species in rural communities, it is important to note that (i) the effects of invasive alien species are not uniform in space, time, and among various users, (ii) the level of invasive alien species use is varied among users, (iii) local livelihoods are adaptive in response to invasive alien species availability, and (iv) the duration and abundance of invasive alien species in an area can influence its integration into livelihoods (Shackleton et al. 2011; Ngorima and Shackleton 2019). Given the varied role that invasive alien species play in rural livelihoods, understanding local people’s perceptions and knowledge of invasive alien plant species is important.

*Psidium guajava* Linn., commonly known as guava, is a shrub that is native to tropical America (Naseer et al. 2018). The plant species belongs to the Myrtaceae family (Naseer et al. 2018). *Psidium guajava* is commercially grown in many countries for fruit consumption and medicinal purposes (Okamoto et al. 2009; Naseer et al. 2018). The evergreen shrub grows on a wide range of soils and environments, and reaches a height ranging from
1.8 m to 7.6 m (Naseer et al. 2018). *Psidium guajava* has a wide-spread network of curved branches and the leaves are oval with prominent veins (Roussif et al. 2008; Naseer et al. 2018). In South Africa, *P. guajava* is categorised as an invasive plant and tends to invade watercourses, forest margins, and disturbed areas such as old agricultural fields, roadsides, and pastures (Ruwanza and Dondofema 2020). A recent study in South Africa reported that *P. guajava* invasion alters soil physico-chemical properties (increases soil P and makes soil underneath it repellent), which likely explains its invasion proliferation (Ruwanza and Dondofema 2020). In the Galapagos Islands, the plant is considered a problematic shrub because of its ability to effectively spread through seed dispersal by birds and humans, and to displace native species through out-competing them for resources such as nutrients (Urquía et al. 2019). In the New Zealand archipelago, *P. guajava* is regarded as a naturalised plant that significantly reduces native species diversity (Sheppard et al. 2014). In Kenya, the species has displaced native plant species, although its presence in forests targeted for ecological restoration has been shown to support growth of shade-tolerant native tree species (Otumba et al. 2020). In East Africa particularly in Tanzania and Kenya, *P. guajava* is regarded as one of the worst invaders that invades unused sites (Witt and Luke 2017). In South Africa, Zengeya et al. (2017) categorised *P. guajava* as a conflict-generating species due to its ability to provide both benefits and costs. Previous studies have shown that *P. guajava* has many uses (Morais-Braga et al. 2017; Naseer et al. 2018). For example, fruits are consumed raw or in processed form such as fruit jam (Omayio et al. 2019), whilst roots, bark, and leaves contain phytochemicals that are used to treat numerous diseases such as dysentery, hypertension, diarrhoea, gastroenteritis, and pain relief (Naseer et al. 2018). Orwa et al. (2009) reported the use of *P. guajava* wood for making fencing pools, axe handles, and charcoal for firewood. By-products of *P. guajava* fruits and leaves are used as animal feeds and fodder (Orwa et al. 2009).

Given the limited research focus on knowledge, perceptions, and benefits of the invasive alien plant species *P. guajava* to rural livelihoods in South Africa, this study aimed to broaden our knowledge base regarding the importance of the plant to rural communities. The objective of the study was to assess perceptions, knowledge, and uses of *P. guajava* to rural communities in Vhembe Biosphere Reserve. The research questions were: (i) what are the perceptions, benefits, and costs of *P. guajava* to rural livelihoods, and (ii) what management interventions are being implemented by rural communities to control *P. guajava*.

### 2. Methods

#### 2.1. Study area

The study was conducted in four villages in Vhembe Biosphere Reserve in Limpopo Province of South Africa. The biosphere reserve has a surface area of approximately 30,700 km and a population of approximately 1.5 million people, of which more than 95% are rural residents. The four villages selected for this study were Duthuni (22.9722°S, 30.3810°E), Ha Maelula (22.9831°S, 30.1402°E), Matshavhawe (22.9755°S, 30.1026°E), and Murunwa (22.9816°S, 30.1633°E) (Figure 1). The above-mentioned villages were selected following a reconnaissance study that showed a high distribution of *P. guajava* in the area and a high number of homesteads with the plant. Most people in the villages are dependent on communal agriculture and social grants from the government.

The four villages are in the Soutpansberg Mountain Bushveld vegetation type which is in the savanna biome (Mucina and Rutherford 2006). Vegetation in the study area is dominated by native trees and shrubs such as *Berchemia zeyheri*, *Grewia occidentalis*, *Podocarpus falcatus*, *Dombeya rotundifolia*, *Cussonia spicata*, and *Vachellia karoo* and poorly developed grasses such as *Setaria sphacelata*, *Coleochloa setifera*, *Trachypogon spicatus*, and *Melinis nerviglumis*. However, recent studies in Vhembe Biosphere Reserve have identified invasion by alien plants like *L. camara*, Australian *Acacias*, *Caesalpinia decapetala*, and *Eucalyptus* species as some of the main drivers of land cover change and biodiversity loss (Evans 2017; Ruwanza and Mhlongo 2020). The study area has a tropical climate, with hot austral summer temperatures (approximately 28°C) and mild austral winter temperatures (approximately 18°C). Mean annual rainfall is approximately 1,050 mm, and soils are acidic with high clay content and are derived from basalt and quartzitic sandstone of the Soutpansberg formation (Mucina and Rutherford 2006).

#### 2.2. Data collection and analysis

The research approach adopted face-to-face interview surveys with the aim of gathering firsthand involvement, knowledge, and experiences of the households. Within each of the four villages, 50 face-to-face interview surveys were conducted, representing about 3% in Duthuni, 13% in Ha Maelula, 12% in Matshavhawe, and 8% in Murunwa, based on existing total household records (Stats SA 2011). Households who participated in face-to-face interviews were purposively selected, and the inclusion criteria were (i) the presence of *P. guajava* in their homesteads and,
(ii) knowledge of the plant that was assessed by showing households a picture panel of the plant that was also embedded in the questionnaire. Purposive sampling ensured that only households who have knowledge of the plant and are familiar with it were selected. We acknowledge that purposive sampling is prone to sample selection bias that minimizes the ability to generalize the findings. Despite this limitation, the value of the study lies in its transferability potential through provision of useful insights on the intersection of perceptions, uses, costs and management of *P. guajava* by rural communities.

At each household, the household head, and if absent a senior adult family member, was interviewed. Surveys were conducted between 08h00 and 16h00 during weekdays. With the assistance of a Venda-speaking research assistant, face-to-face household interviews were administered in the local language of Venda and took approximately 1 hour. The interviews gathered information on (i) presence and invasion extent of *P. guajava* in the area, (ii) knowledge and perceptions of *P. guajava*, (iii) benefits and costs of *P. guajava* to households, (iii) control and management interventions implemented by households, and (iv) the socio-demographic information of the household (see Appendix A for interview guide). The perceived occurrence of *P. guajava* in the area was assessed on a 4-point Likert scale [(1) Common, (2) Moderate, (3) Scarce, and (4) Very scarce]], based on previous work by Shackleton et al. (2015). Perceptions on the impact of *P. guajava* were assessed by asking the respondents to indicate *P. guajava* as either (1) beneficial, (2) harmful, (3) having no impact, or (4) both beneficial and harmful, following Shackleton et al. (2015).

The study was conducted following granting of ethics approval by the Rhodes University’s Human Ethics Committee (Reference Number 2019–0823–898). Participation in the study was voluntary and all participants had the right not to answer any question and to withdraw at any given time without any negative repercussions. Informed consent was obtained from the participants following assurance of confidentiality and anonymity of responses. No personal information was collected, and all data were anonymised prior analysis.

Questionnaire responses were grouped into various categories describing villagers’ knowledge, perceptions, uses, benefits, costs, and management interventions of *P. guajava*. Descriptive statistics was used to show the distribution of data including socio-demographics and proportion of responses and participants in the text or using tables and figures. Differences in responses between the four villages were examined using chi-squared tests. All statistical analyses were performed using TIBCO STATISTICA version 14.0 software (TIBCO Software Inc 2019).

### 3. Results

#### 3.1. Demographics of the sample population

Across all villages, the dominant respondents’ age was above 70 years. Except for Murunwa, most respondents
in Duthuni, Ha Maelula, and Matshavhawe were above 50 years (Table 1). There was a high representation of females (58%) across all villages. Most respondents in Ha Maelula, Matshavhawe, and Murunwa had primary education only (also dominant across all villages), while those in Duthuni had grade 10 (first-year secondary education level in South Africa) (Table 1). Across all villages the mean number of people per household was 8.3 ± 0.5, with highest means in Duthuni and Matshavhawe (8.6 ± 0.5), and lowest means in Ha Maelula (7.7 ± 0.5). Most respondents across all villages were dependent on social grants (Table 1).

3.2. Knowledge and perceptions of P. guajava

All respondents were aware of P. guajava, and more than 70% of the respondents across all villages had P. guajava on their properties. Across all villages, less than a quarter of respondents (23%) knew P. guajava as an invasive alien plant. Comparisons by village showed no significant differences in the proportion of respondents who knew P. guajava as an invasive alien plant (Duthuni and Ha Maelula = 18%, Matshavhawe = 26%, Murunwa = 30%; χ² = 6.367; p > 0.05; Table 2).

Of all the respondents with the plant on their property, less than a quarter had planted P. guajava, with most of these being in Ha Maelula as compared to Murunwa, Duthuni, and Matshavhawe (χ² = 11.742; p < 0.01; Table 2). Those who did not plant P. guajava reported that it naturally occurred on their property with some indicating that they found it on the property upon arrival. Across the sample, less than half of the respondents reported that P. guajava was spreading on their property, with no significant differences among the villages. However, a substantial proportion of the respondents across all villages noted that the plant was spreading in the local environment, with significantly (χ² = 11.742; p < 0.01) more respondents in Murunwa (80%) than in Duthuni (52%), Ha Maelula (50%), and Matshavhawe (64%) reporting so (Table 2). When asked to rank their views on P. guajava occurrence on their property, 38% of all the respondents categorised P. guajava occurrence as moderate and there were no significant differences among the villages (Table 3).

3.3. Benefits and costs of P. guajava

Although most of the respondents (95%) across all villages said that P. guajava provide benefits (Table 2), very few respondents (14%) felt that the benefits outweigh the costs with no significant differences among the villages (Duthuni = 14%, Ha Maelula = 16%, Matshavhawe = 14%, Murunwa = 14%; χ² = 6.317; P > 0.05; Table 2).

Table 1. Demographics of sample population of the different communities interviewed.

| Gender (% of male) | Dominant age range (%) | Dominant race (%) | Dominant education level (%) | Dominant income group (%) | Mean number of people per household |
|--------------------|------------------------|-------------------|-----------------------------|--------------------------|-----------------------------------|
| Duthuni (38)       | 50–60                  | Black (100)       | Grade 10 (46)               | Social grants (42)       | 8.6 ± 0.5                         |
| Ha Maelula (40)    | 60–70                  | Black (100)       | Primary (40)                | Social grants (80)       | 7.7 ± 0.5                         |
| Matshavhawe (44)   | 70+                    | Black (100)       | Primary (54)                | Social grants (80)       | 8.6 ± 0.6                         |
| Murunwa (46)       | 40–50                  | Black (100)       | Primary (48)                | Social grants (64)       | 8.1 ± 0.6                         |
| Across villages (42) | 70+                   | Black (100)       | Primary (45)                | Social grants (67)       | 8.3 ± 0.3                         |

Table 2. Community responses to questions relating to knowledge and perceptions of Psidium guajava in Vhembe Biosphere Reserve.

| Interview questions                                           | Duthuni | Ha Maelula | Matshavhawe | Murunwa | Across villages | χ²-value | P-value |
|--------------------------------------------------------------|---------|------------|-------------|---------|-----------------|----------|---------|
| **Questions relating to knowledge of P. guajava**             |         |            |             |         |                 |          |         |
| Do you know P. guajava? (% of yes – also accepted and used local name) | 100     | 100        | 100         | 100     | 100             |          | -       |
| Do you have P. guajava on your property? (% of yes)           | 70      | 76         | 70          | 76      | 73              | 0.913    | 0.822   |
| Did you plant P. guajava on your property? (% of yes)         | 6       | 24         | 4           | 14      | 12              | 11.742   | 0.008   |
| Is it spreading on your property? (% of yes)                   | 40      | 34         | 26          | 42      | 36              | 6.621    | 0.357   |
| Is it spreading in the area around you? (% of yes)             | 52      | 50         | 64          | 80      | 62              | 32.075   | <0.001  |
| Are you aware that it is an invasive alien species? (% of yes) | 18      | 18         | 26          | 30      | 23              | 6.367    | 0.383   |
| **Questions relating to perceptions around benefits and impacts of P. guajava** |         |            |             |         |                 |          |         |
| Does it cause any negative impacts? (% of yes)                 | 24      | 14         | 10          | 10      | 17              | 14.033   | 0.003   |
| Does it provide any benefits? (% of yes)                      | 90      | 98         | 96          | 96      | 95              | 3.789    | 0.285   |
| Do you think the benefits of P. guajava outweigh the costs? (% of yes) | 14      | 16         | 14          | 12      | 14              | 6.317    | 0.389   |
| Is P. guajava more beneficial to you compared to indigenous/native/local trees? (% of yes) | 10      | 10         | 12          | 8       | 10              | 0.697    | 0.995   |
| Does P. guajava displace any indigenous plants, insects, birds, animals, or plants important for your livelihood? (% of yes) | 58      | 38         | 52          | 28      | 44              | 11.201   | 0.011   |
Table 3. Community views on *Psidium guajava* occurrence on properties in Vhembe Biosphere Reserve.

|                      | Duthuni | Ha Maelula | Matshavhawe | Murunwa | Across villages |
|----------------------|---------|------------|-------------|----------|----------------|
| **P. guajava occurrence level on properties** |         |            |             |          |                |
| Common               | 16      | 20         | 12          | 6        | 14             | 4.582           | 0.205 |
| Moderate             | 28      | 34         | 40          | 48       | 38             | 4.672           | 0.197 |
| Scarce               | 20      | 20         | 18          | 24       | 21             | 0.583           | 0.900 |
| Very scarce          | 6       | 2          | 0           | 0        | 2              | 6.122           | 0.106 |

When asked to compare the benefits of *P. guajava* relative to native plant species, only a handful of respondents (10%) across all the villages said *P. guajava* was more beneficial than native local trees (Table 2). Regarding the specific benefits, at least 62% of the respondents identified *P. guajava* fruit consumption as the most common benefit, with more than 70% in Duthuni, Ha Maelula, and Matshavhawe (Table 4). Fruit consumption was significantly higher in the above-mentioned villages than in Murunwa ($\chi^2 = 34.483; P < 0.01$). More respondents in Ha Maelula (20%) and Murunwa (26%) than in Duthuni (16%) and Matshavhawe (10%) used *P. guajava* for medicinal purposes particularly the use of leaves for treating flu (Table 4). However, comparisons across all villages showed no significant differences in the proportion of respondents reporting the use of *P. guajava* for medicinal purposes ($\chi^2 = 4.607; P > 0.05$; Table 4). Across all villages only 9% of the respondents mentioned that *P. guajava* provides shade to both people and livestock, with a significantly higher proportion of respondents reporting so in Murunwa (18%) than in Matshavhawe (8%), Ha Maelula (6%), and Duthuni (2%) ($\chi^2 = 8.936; P < 0.05$; Table 4). Less than 10% of respondents in Duthuni, Matshavhawe, and Murunwa said that they use *P. guajava* for firewood, with no significant differences across all villages ($\chi^2 = 3.125; P > 0.05$; Table 4). Across all villages, only 5% of the respondents used *P. guajava* fruits to feed pigs, and comparison among the villages showed significantly more respondents in Murunwa (16%) than in Duthuni (2%) reporting so ($\chi^2 = 20.826; P < 0.001$; Table 4).

Concerning costs, less than 20% of the respondents across all villages confirmed the negative impacts of *P. guajava*, with significant differences among the villages (Duthuni = 34%, Ha Maelula = 14%, Matshavhawe and Murunwa = 10%, respectively; $\chi^2 = 14.033; P < 0.01$; Table 2). When asked to list the perceived or experienced costs, between 10% and 13% of the respondents across all villages reported (i) the attraction of problematic animals e.g. monkeys, snakes, and birds, (ii) the attraction of malaria-causing mosquitoes by rotten *P. guajava* fruits, (iii) the displacement of native plants, and (iv) constipation caused by consumption of *P. guajava* fruits (Table 4). The attraction of problematic animals was significantly ($\chi^2 = 34.483; P < 0.01$) higher in Matshavhawe (36%) than in Duthuni (12%), Murunwa (4%), and Ha Maelula (0%) (Table 4). Across all villages, few respondents reported *P. guajava’s* role in reduction of grazing (through displacement of grasses and agricultural space) and water in rivers, but significant differences were observed between Murunwa (8%) and Matshavhawe (2%) ($\chi^2 = 8.882; P < 0.05$; Table 4). Health problems (e.g. constipation) associated with *P. guajava* fruit consumption were reported by a significantly higher proportion of respondents in Duthuni (24%) than in Murunwa (10%), Ha Maelula

Table 4. Community views of costs and benefits of *Psidium guajava* in Vhembe Biosphere Reserve.

|                      | Duthuni | Ha Maelula | Matshavhawe | Murunwa | Across villages |
|----------------------|---------|------------|-------------|----------|----------------|
| **Cost**             |         |            |             |          |                |
| Attracts problematic animals (monkeys, snakes, and birds) | 12      | 0          | 36          | 4        | 13             | 34.483           | <0.001 |
| Rotten fruits attract mosquitoes | 18      | 8          | 6           | 8        | 10             | 4.889           | 0.180 |
| Reduces available grazing and invades croplands | 0       | 0          | 2           | 8        | 3              | 8.821           | 0.032 |
| Displaces and outcompetes native plants | 12      | 14         | 2           | 10       | 10             | 4.827           | 0.185 |
| Scarce               | 24      | 8          | 0           | 10       | 11             | 18.880          | <0.001 |
| Fruits cause health problems (constipation) | 2       | 4          | 0           | 4        | 3              | 2.256           | 0.521 |
| Reduces water        | 2       | 4          | 0           | 4        | 3              | 2.256           | 0.521 |
| **Benefits**         |         |            |             |          |                |
| Fruits               | 70      | 72         | 76          | 30       | 62             | 29.371          | <0.001 |
| Shade provisioning   | 2       | 6          | 8           | 18       | 9              | 8.936           | 0.030 |
| Medicine             | 16      | 20         | 10          | 26       | 18             | 4.607           | 0.203 |
| Firewood provisioning| 4       | 0          | 6           | 6        | 4              | 3.125           | 0.373 |
| Feed for pigs        | 2       | 0          | 0           | 16       | 5              | 20.826          | <0.001 |
(8%), and Matshavhawe (0%) (χ² = 18.880; P < 0.001; Table 4).

3.4. Community management of *Psidium guajava*

Across the sample villages, just over a quarter of respondents would like to see a decrease in *Psidium guajava* population densities in their area, but significantly more respondents in Matshavhawe (36%) and Duthuni (32%) than in Ha Maelula (22%) and Murunwa (16%) felt so (χ² = 14.308; P < 0.05; Table 5). Across all the villages, the proportion of respondents managing *Psidium guajava* is significantly lower (χ² = 27.508; P < 0.001) than those who do not implement any management intervention (Figure 2a). Most of the respondents manage *Psidium guajava* through cutting it, although this provides little management intervention as it coppices, whereas a handful prefer digging and hand pulling the plant (Figure 2a). Significantly more respondents in Duthuni (26%) than in Ha Maelula, Matshavhawe, and Murunwa (all less than 5%) indicated that they receive assistance from government through the Working for Water programme to manage *Psidium guajava* on their property (χ² = 29.891; P < 0.001; Table 5). Furthermore, many respondents in all villages expressed interest in getting assistance from the government to manage *Psidium guajava* (Duthuni (64%), Ha Maelula (52%), Matshavhawe (86%), and Murunwa (52%) (χ² = 16.632; P < 0.001; Table 5). The nature of management support preferred by respondents ranged from information on *Psidium guajava* clearing, management information, and provisioning of chemicals to kill the plant, with significant differences between the different villages (χ² = 35.644; P < 0.001; Figure 2b). Very few respondents in Ha Maelula (4%) received information or news about invasive alien plants in general (Table 5).

4. Discussion

Most respondents in all the villages had knowledge about *Psidium guajava* but very few were aware that it was an invasive alien plant. Low levels of knowledge about the plant as an alien species can be attributed to the invasion extent, history, and time the species has been present in the area (Shackleton et al. 2007, 2019; Kull et al. 2014). In this study, a sizeable number of respondents found *Psidium guajava* naturally occurring on their properties and used it for various purposes meaning that the plant is already integrated in people’s livelihood systems. This is consistent with findings by Ngorima and Shackleton (2019) in the Eastern Cape Province of South Africa who found that *A. dealbata* was so integrated into local people’s livelihoods that it was regarded as native. While a substantial proportion of households reported socio-economic benefits of *Psidium guajava*, very few households perceived the benefits to outweigh the costs. This might be explained by the fact that the benefits of *Psidium guajava* are considered within the context of benefits from other trees, including natives that

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**Table 5. Community responses to questions relating to management of *Psidium guajava* in Vhembe Biosphere Reserve.**

| Interview questions | Duthuni | Ha Maelula | Matshavhawe | Murunwa | Across villages | χ² value | P-value |
|---------------------|---------|------------|-------------|---------|----------------|----------|---------|
| Would you like to see a decrease in *Psidium guajava* population densities in your area? (% of yes) | 32 | 22 | 36 | 16 | 27 | 14.308 | 0.026 |
| Do you receive assistance from government (e.g. the Working for Water programme) to manage *Psidium guajava* on your property? (% yes) (% of yes) | 26 | 0 | 4 | 2 | 8 | 29.891 | <0.001 |
| Do you receive information or news about Invasive Alien Plants (% of yes) | 0 | 4 | 0 | 0 | 1 | 6.061 | 0.109 |
| Would you like the government (e.g. the Working for Water programme) to assist you in managing *Psidium guajava* on your property? (% yes) | 64 | 52 | 86 | 52 | 64 | 16.632 | <0.001 |

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**Figure 2.** Community views on *Psidium guajava* (a) management on properties (χ² = 27.508; p = 0.001), and (b) nature of management support requested (χ² = 35.644; p = 0.001) in Vhembe Biosphere Reserve.
the respondents considered important. Therefore, the mixed perceptions of *P. guajava* reported in this study are linked to benefits (e.g. fruit consumption and medicinal purposes) and negative impacts (e.g. attraction of problematic animals and health effects linked to fruit consumption). People’s knowledge and perceptions are shaped by plant traits that are useful to people such as provision of firewood (*A. dealbata*), edible fruits (*O. ficus-indica* and *P. guajava*), and fodder for domesticated animals (*A. dealbata*) (Shackleton et al. 2015, 2019; Ngorima and Shackleton 2019). Even though few respondents in this study reported the negative impacts of *P. guajava*, negative impacts caused by invasive alien plants tend to increase with invasion expansion, which is likely to change people’s perceptions towards the plant in the future. Invasive alien plants that portray both negative and positive effects, as is the case with *P. guajava*, tend to be viewed as conflicting species (Zengeya et al. 2017). Indeed, recent studies have shown that local people tend to be conflicted about the role of some invasive alien plants such as *A. dealbata*, *E. camaldulensis*, and *P. guajava* play in their lives and communities (Woodford et al. 2016; Ngorima and Shackleton 2019).

Most villagers use *P. guajava* for fruit consumption and medicinal purposes as compared to other provisioning services such as shade and firewood, which were identified by a few participants. Our results collaborate findings by Daswani et al. (2017) which show use of *P. guajava* for food and medicinal purposes by rural communities in India, owing to its perceived medicinal properties e.g. anticancer and antimicrobial that are present in plant fruits and leaves. Similarly, Msomi (2008) reported that rural communities in KwaZulu-Natal, South Africa, use *P. guajava* for firewood, medicine (leaves and barks), fruit consumption, and for cash income generation through fruit and guava jam trade. In rural communities of Nhema, Zimbabwe *P. guajava* is widely cultivated in home gardens for fruit consumption and medicinal purposes including as a remedy for flu and fever especially when its leaves are mixed with other alien plants e.g. *Eucalyptus* leaves and *Citrus limon* fruits (Marojo 2009). Indeed, several invasive alien plants, such as Australian *Acacias*, *P. juliflora*, *O. ficus-indica*, *Eucalyptus* species, and *L. camara* have been shown to support people’s livelihoods, quality of life, and foster rural economic growth (Shackleton et al. 2011; Kannan et al. 2016; Constant and Tshisikhawhe 2018), although negative impacts have also been reported (Ngorima and Shackleton 2019; Shackleton et al. 2019). The importance of *P. guajava* as a food source across all villages except for Murunwa could be attributed to the fact that (i) *P. guajava* fruits are nutritious with high vitamin C and fibre content (McCook-Russell et al. 2012), and (ii) the plant is widely distributed and near households thus making fruit collection easy.

Contrary to reports from other studies on invasive alien trees (Shackleton et al. 2015; Potgieter et al. 2019; Ngorima and Shackleton 2019), provisioning (firewood) and regulating (shade for temperature regulating) services provided by *P. guajava* were reported by very few participants across all villages. This could be because *P. guajava* is a shrub with a spreading network of curved branches, thus its canopy cover and morphology are not well suited for firewood and shade provisioning/regulating as compared to other invasive alien plants e.g. *A. dealbata* (Ngorima and Shackleton 2019) and *Eucalyptus* (Hirsch et al. 2020). It is also possible that other commonly occurring native woody species in the study area e.g. *Brachylaena discolor*, *Prunus africana*, and *V. karroo* provide provisioning/regulating services (Dingaan and du Preez 2018; Constant and Tshisikhawhe 2018; Ramarumo and Marojo 2020) better than *P. guajava*.

This study showed that the costs associated with *P. guajava* are not inconsequential, because participants reported both direct and indirect negative impacts on villagers and the environment. First, *P. guajava* was reported to attract problematic animals that negatively affect human wellbeing. Also, rotten *P. guajava* fruits were reported to attract mosquitoes, well-known vectors for malaria (Müller et al. 2010). Recent studies have acknowledged that some invasive alien plants e.g. *Pontederia crassipes* provide breeding sites for mosquito larvae thus enhancing their vector capacity (Stone et al. 2018; Rai and Singh 2020). In East Africa, the invasive alien plant *L. camara* has been reported to attract tsetse flies (*Glossina* spp.) which are associated with human sleeping sickness (Mazza et al. 2014; Rai and Singh 2020). Second, *P. guajava* fruit consumption was reported as causing constipation, which contradicts reports on the use of *P. guajava* in treating digestive system related disorders such as diarrhoea, dysentery, and constipation (Dakappa-Shruthi et al. 2013; Morais-Braga et al. 2017). Third, participants noted that *P. guajava* displaced and outcompeted native plants, possibly through its ability to alter some soil physio-chemical properties e.g. soil P, total N, pH, and moisture as found by Ruwanza and Dondofoema (2020). Indeed, the ability of most invasive alien plants to alter soil properties and outcompete natives through nutrient resource acquisition and utilisation has been shown to favour growth of invasive alien plant than native species (Richardson et al. 2020). Lastly, it was perceived that *P. guajava* invasion reduces grazing and agricultural space, which can be linked to the displacement of palatable grazing grass
following alien plant invasion (Yapi et al. 2018; Ngorima and Shackleton 2019). In general, invasive woody species such as A. dealbata and L. camara produce large numbers of seeds, grow faster, out-compete other species for soil nutrients and moisture, thus giving them the ability to displace crops in agricultural areas (Bhagwat et al. 2012; Ngorima and Shackleton 2019; Richardson et al. 2020), resulting in reduced agricultural productivity.

Our results showed that very few households wanted P. guajava removal from the area, which could explain why most villagers were not managing the plant. The lack of community action with regard to managing invasive alien plants is very common and has been widely reported elsewhere e.g. for Acacias (Shackleton et al. 2007; Ngorima and Shackleton 2019), O. ficus-indica (Shackleton et al. 2007), Prosopis (Shackleton et al. 2015), L. camara (Shackleton et al. 2017), and E. camaldulensis (Hirsch et al. 2020). The lack of desire by rural communities to manage invasive alien plants could be linked to several factors. First, some invasive alien plants are beneficial to communities as shown in this study, hence they are viewed as an economic asset (Shackleton et al. 2007; Ngorima and Shackleton 2019). Second, for those who may want to remove the plant, most of them lack the human and financial resources to manage invasive alien plants. In this study all households reported not receiving any financial or resource support from government through the WFW programme, although they wanted it. Another potential explanation is that the costs of P. guajava are not huge enough to warrant investment into clearing. Third, some rural communities might lack general information regarding invasive alien plants and specific information on control methods for invasive alien plants. In this study, only villagers in Ha Maelula (4%) acknowledged receiving information or news about invasive alien plants. Lastly, most rural communities view management of invasive alien plants as the responsibility of external agencies e.g. government and non-governmental organisations (Shackleton et al. 2007, 2019; Ngorima and Shackleton 2019).

Overall, there were mixed and somewhat contradictory perceptions of benefits, costs, and the need to clear the plant within and between the sampled villages, which points to the importance of carefully considering both benefits and costs to individual households and villages as a basis for avoiding conflict related to P. guajava management. A key point to note when considering perceptions in designing management interventions is that perceptions can change especially when negative impacts start to outweigh benefits (Shackleton et al. 2019), which is likely to happen as P. guajava invasion extends. Our observations extend those of Gaertner et al. (2017) and Potgieter et al. (2019) who concluded that mixed perceptions of invasive alien plants among respondents and stakeholder negatively affect local based management interventions. Given that P. guajava is a potentially conflict species, its management should be informed by both the benefits and costs associated with its presence in socio-ecological landscapes.

5. Conclusion

The results of this study show that P. guajava has both benefits and costs in Vhembe Biosphere Reserve. Therefore, P. guajava is potentially a conflict generating species which should be a key consideration for management options. Given that P. guajava provides both benefits and costs, any management intervention for controlling or reducing invasion in the area should recognise the diversity of perceptions regarding the plant, noting that the perceptions can be dynamic depending on socio-economic conditions. Crafting of control/clearing interventions should be informed by consultative process with local communities to avoid potential conflicts with and between local users. Perhaps a feasible control option for P. guajava will be to limit invasion expansion through promoting utilisation by communities as suggested by others (Ngorima and Shackleton 2019; Potgieter et al. 2019). This approach can balance the needs of communities dependent on P. guajava while minimising the costs perceived or experienced by other community members. However, more research to examine the efficacy of utilisation as a control method is required given the dynamic nature of perceptions.

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Data availability

The data that support the findings of this study are available from the corresponding author upon request.

ORCID

Sheunesu Ruwanza  
http://orcid.org/0000-0002-4731-0394

Gladman Thondhlana  
http://orcid.org/0000-0002-6141-3314
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