Valuation of pollinator forage services provided by *Eucalyptus Cladocalyx*

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Abstract

We assess the monetary value of forage provisioning services for honeybees as provided by an alien tree species in the Western Cape province of South Africa. Although *Eucalyptus cladocalyx* is not an officially declared invader, it is cleared on a regular basis along with other invasive *Eucalyptus* species such *as E. camaldulensis, and E. conferruminata* (which have been prioritised for eradication in South Africa). We present some of the trade-offs associated with the clearing of *E. cladocalyx* by means of a practical example that illustrates a situation where the benefits of the species to certain stakeholders could support the containment of the species in demarcated areas, while allowing clearing outside such areas.

Given the absence of market prices for such forage provisioning services, the replacement cost is used to present the value of the loss in forage as provided by *E. cladocalyx* if the alien tree species is cleared along with invasive alien tree species. Two replacement scenarios formed the basis for our calculations. The first scenario was an artificial diet as replacement for the forage provisioning service, which yielded a direct cost estimate of US$7.5m per year. The second was based on a Fynbos cultivation/restoration initiative aimed at substituting the forage provisioning service of *E. cladocalyx*, which yielded a direct cost of US$20.2m per year. These figures provide estimates of the potential additional cost burden on the beekeeping industry if *E. cladocalyx* is completely eradicated from the Western Cape. The cost estimates should be balanced against the negative impacts of *E. cladocalyx* on ecosystem services in order to make an informed decision with regard to appropriate management strategies for this species. The findings therefore serve as useful inputs to balance trade-offs for alien species that are considered as beneficial to some, but harmful to other.

Keywords

alien trees; forage provisioning; valuation; trade-offs

1. Introduction

Economic activity often leads to the degradation of the resilience of ecosystems, which consequently increases their vulnerability to biological invasion; which in turn giving rise to further degradation. These effects have become even more prominent in an era of , extremely long value chains due to globalized trade liberalization (Barbier, 2001). Biological invasions are thus one of many unintended consequences of economic activities which pose serious challenges to human well-being (Perrings et al., 2002). Economic principles are increasingly employed to 'value' the market and non-market impacts of biological invasions, in an effort to assess important trade-offs among various management alternatives. Quantifying these trade-offs in monetary terms greatly supports the decision-making process for managing the risks of invasion, because economic insights often improve the transparency of the decision-making process, by providing justifications for the measures being implemented (Barbier, 2001).

Invasive alien plants (IAPs) are a pronounced form of biological invasion in South Africa. These plants decrease the resilience of their host ecosystems through biodiversity degradation, which then changes the configuration of ecosystem services from these ecosystems in a negative way (Barbier, 2001). Of particular concern in South Africa are the impacts of IAPs on water supply (Versfeld et al., 1998). Government has responded to these concerns by implementing a number of control initiatives, of which the Working for Water programme (WfW) is the largest and most well-known. Apart from being a poverty alleviation scheme, the primary benefit associated with this programme is to increase water yield in South Africa (Buch and Dixon, 2008). The benefits of controlling IAP's are of a public nature, which implies that clearing and control services will be under-supplied by the private sector in the absence of government intervention in the market. Government intervention is therefore required for effective control.

WfW follows an integrated approach to control invasive species, which consists of a combination of mechanical clearing, chemical clearing and biological control (De Lange, 2009, Hosking and du Preez, 2004, Marais et al., 2004, Van Wilgen and Moran, 2007). These control measures are expensive, and trade-off analyses are often used to compare costs and benefits of control measures in a structured way. Monetary valuation plays an important role in these types of analyses, since it provides a common denominator (monetary units) for all variables, which then allow for easier comparison. However, the presence of externalities and numerous non-market players in the IAP arena limits the accuracy of such monetary valuations. This creates uncertainty and often scepticism in these value estimates, and implies that the assumptions and methods used in deriving the estimates should be made as explicit and transparent as possible.

Furthermore, invasive alien plants often give rise to benefits to certain stakeholders, and costs to others; thereby resulting in potential conflicts of interest. For example, IAPs often provide important inputs to commercial industries; while in other cases they support commercial industries indirectly (De Lange et al., 2012). Through their impact on food webs, IAPs often create opportunities for new species to survive in areas where they would have not have been able to survive in the absence of such alien species. In turn, the species which depend on IAPs can provide inputs to commercial industries. This phenomenon could therefore result in commercial industries becoming dependent on alien plants over time. Conflicting interests are therefore created when clearing and eradication programmes are implemented; of which policymakers should take cognisance of when formulating alien management strategies. In some cases the associated benefits of an alien could outweigh the cost of eradication. In such situations, the continued use (combined with management and control) of a declared weed could be justified in demarcated areas, while eradicating the plant in areas outside (Morandin and Winston, 2006). This paper investigates a South African example of this type of trade-off: a case where the eradication of an alien tree will have negative consequences on the South African beekeeping and deciduous fruit industries.

The significance and value of pollination services as derived from honeybees has been widely documented in the literature (Klein et al., 2007). Several attempts have been made to value this service in monetary terms (Winfree et al., 2011, Gallai et al., 2009, Losey and Vaughan 2006, Morse and Calderone 2000, Robinson et al., 1989, Southwick and Southwick 1992, Brugett et al 2004, Gill 1991, Allsopp et al., 2008). However, the international beekeeping industry is under severe pressure to serve increasing pollination demands (Cox-Foster, 2009, Oldroyd 2007, Ellis et al., 2010, Kremen et al., 2002, Steffan-Dewenter et al., 2005, Van Engelsdorp et al., 2009) and although, the beekeeping industry in South Africa has not been exposed to the same extent to these pressures, it is under increased pressure to serve the domestic demand for pollination services in the country’s economy (Johannsmeier and Mostert, 2001). For example, disregarding some unique characteristics of the Cape honeybee *Apis mellifera capensis*, the deciduous fruit industry is already suffering losses due to insufficient pollination (Allsopp et al., 2008). Furthermore, colony collapse disorder outbreaks along with increases in sightings of predatory *Vespula Germanica* (German wasp or “yellow jackets”) in the Western Cape not only add to the pressure on the beekeeping industry, but also the wild pollinator species. A recent intensified focus on the eradication of *Eucalyptus* species in the country and the Western Cape could be the metaphorical final straw that collapses pollination service provision (managed and wild) in South Africa. This paper attempts to quantify some of the benefits of *Eucalyptus cladocalyx,* via replacement cost estimates of the forage value of this species to the beekeeping industry. The paper provides a practical example in the Western Cape province of South Africa, where the benefits of *E. cladocalyx* might justify the need for increased investment to improve training and implementation of alien management programmes to avoid unintentional clearing of useful alien plants.

With regards to the chosen method, we are of the opinion that it is inappropriate to value a (ecosystem) service (where market prices are absent) in terms of the production value impacts if such service becomes extinct (unavailable). Stated more formally, we argue that it is inappropriate to value a production input (for which no market price exists) in terms of the yield impacts if such input becomes unavailable. Output related impacts cannot be used as proxies to value those intermediate inputs of which no market price exists. The main reason for this point of view relates to the problem of attribution, where intermediate inputs become so inherently part of the product or service that it is not possible to distil the unique contribution of that particular intermediate input in the production process and use it as basis to model the value of the intermediate input. For example it would be inappropriate to use changes crop yield (due to changes in water supply) as a proxy to value the water, because the changes in yield is merely a result of the change in water supply, not an estimate of the water itself. We argue that in the absence of appropriate market prices (which is the case with ‘ecosystem-based’ services), a service should be valued in terms of the cost of the intermediate inputs required to substitute the service while maintaining output levels (as closely as possible) if the service becomes unavailable. Last mentioned requirement is pivotal if any form of comparison is to be made between substitutes. Consequently, replacement cost scenarios needs to maintain output and to a lesser extent, quality levels, in order to allow comparison with the service being replaced. Stated more formally, replacement cost scenarios should be constructed in such a way that the substitute is a near perfect substitution for the service. Replacement cost approaches are part of the so-called cost-based approaches, which are sub-divided into (Lange and Hassan, 2006):

- Benefits (and costs) of preventing a decline in the product or service (sometime referred to as the prevention cost or the maintenance cost), and
- Opportunity costs which assess the economic value of the product or service in terms of the cost associated with alternative options for supplying the product or service (replacement with an alternative).

The replacement cost approach has been used by Allsopp et al 2008 for pollination, and has been carried through here as well. However, this time the focus is on an intermediate input of pollination, i.e. forage provisioning by an alien species. If the forage provisioning service (of which no market price exists) of *E. cladocalyx* is becoming unavailable, one could value its forage provisioning service in terms of the costs associated with providing suitable (i.e. near perfect) alternative(s), i.e. replacement scenarios which will serve the *"ceteris paribus"* assumption as closely as practically possible. We aimed to do that in this study.

Here, we highlight some of the important benefits associated with *E. cladocalyx*, and with a scenario analysis where survey data was used to construct relevant scenarios, examine the importance of *E. cladocalyx* as a forage source for pollinators in the Western Cape province. The paper concludes with a discussion on the trade-offs of costs and benefits associated with this species.

2. Methods

Sustained losses of natural vegetation and increased use of pesticides have increased the dependency of modern agriculture on managed pollination services in the Western Cape. Allsopp et al. (2008) estimated the replacement value of managed and wild honeybee pollination services for the deciduous fruit industry in the Western Cape. This assessment of the forage value of *E. cladocalyx* for the beekeeping industry followed the same methodological approach and is based on the assumption that the value of a service can be estimated in terms of the costs of replacing the service with a substitute service. The replacement cost approach assumes that in the event of a decrease or complete loss of an ecosystem service, growers will try to adjust their production practices to compensate (or minimize) for the expected negative impacts of the loss (noticeable decreases in yield), to minimise their losses, but at the cost of increasing production costs if a premium for such efforts is justifiable. Addressing the full value chain impacts associated with all pollination-dependent produce was beyond the scope of this paper, which is intentionally limited to farm-gate implications of forage replacement. We have maintained the production value estimates of Allsopp et al. (2008), and investigate the cost implications to maintain production within the deciduous fruit industry under different forage replacement scenarios (i.e. the demand for pollination services was assumed to remain constant).

Although *E. cladocalyx* has been introduced in 1865 in South Africa, it is limited to the poor, sour shallow soils of the temperate winter rainfall (summer droughts) area of the Western Cape with only experimental plantings elsewhere. It yields high quality and very hard timber which is used in various applications, especially for poles. The specie is also used in tannin production and for woodlots. Allsopp and Cherry (2004) surveyed and quantified the relative importance of CARA (Conservation of Agricultural Resource Act No.43 of 1983), (Republic of South Africa, 1983) listed gums to the beekeeping industry in the Western Cape and found that, unlike other *Eucalyptus* species, *E. cladocalyx* is an important forage source for the upkeep of the bulk (approximately 39359 from 50780 colonies) of managed honeybee colonies in the Western Cape during the hot and dry summer months (December to February), when little or no alternative forage is available. *E. cladocalyx* should therefore be distinguished from other *Eucalyptus* species because it fulfils a niche role in terms of forage provisioning to the beekeeping industry, since it flowers when the supply of forage is at its lowest (December and January, which is also a critical time to start building colony health for the next pollination season). Table 1 presents the main and alternative forage sources for the beekeeping industry though a typical forage-calendar year in the Western Cape

INSERT TABLE 1 HERE

The pollination season for the deciduous fruit industry starts in spring (September), when 87% of all colonies in the Western Cape are utilised for pollination purposes within this industry (Allsopp and Cherry, 2004) (the rest are unfit for pollination and are used for honey production and will be utilised for pollination during the next season). It implies that the flowering season of *E. camaldulensis* (which is an excellent forage source) cannot be utilised for the upkeep of colony health (see Table 1) and that colonies experience a rapid decrease in colony health during the pollination season.

The majority of honeybee colonies in the Western Cape utilise *Eucalyptus* sites as a forage source after the deciduous fruit pollination season (Allsopp and Cherry, 2004). Table 2 presents the relative significance of *E. cladocalyx* as a forage source in terms of the number of colonies utilising this particular forage source relative to other sources. Note that more than half of all colonies depend on *E. cladocalyx*. The species is therefore an important forage source during the dearth periods (January and February) of the forage calendar, since no suitable replacement are available during that time.

INSERT TABLE 2 HERE

We have constructed two forage replacement scenarios, which can be distinguished based on their suitability to maintain colony health. The first replaces *E. cladocalyx* with an artificial diet; while the second scenario substitute the service with a selection of Fynbos species which flower at the same time as *E. cladocalyx.* The exact timeframe in which these scenarios would come into play could vary slightly, but we used the indicative forage calendar as per Table 1, to determine the relative health of colonies throughout a calendar year under the above-mentioned scenarios. It should be mentioned that the determination of colony health is not an exact science but is used for colony management decision-making. Colony health was measured in terms of the number of frames of honey and brood within the hive. A beekeeper has several options with regard to colony management depending on the number of full frames within the hive. If a colony has nine or more frames of honey and/or brood in August (90% + colony health), it will be earmarked for the spring pollination season. Colonies with less than nine full frames are utilised for honey production and will only be used for the next pollination season. This implies that he same colony will not be used for pollination and honey production within a particular season. Figure 1 presents the scenarios in terms of colony health.

INSERT FIGURE 1 HERE

The "status quo" represents a situation in which *E. cladocalyx* is still part of the forage calendar. The "status quo" follows the forage calendar as per the "main forage sources" in Table 1. The target is to have a full hive (100% colony health during the first week of September, i.e. the beginning of the deciduous fruit pollination season). A rapid decline (approximately 5% per week) in health is then experienced during the pollination season. By the end of November the colony health reaches a level of 40% of what it started with at the beginning of the pollination season. This shortfall needs to be regained while still servicing the vegetable industry during February and March and the canola industry during August. *E.cladocalyx* provides a much necessary improvement in colony health between December and January by taking colony health up to approximately 70% which leave enough time for Fynbos top up the difference resulting in a full hive during the first week of July, well before the next deciduous fruit pollination season. The “status quo” thereby allows enough time to have a healthy colony ready for the deciduous fruit pollination season (beginning in September). However, in the absence *E.cladocalyx*, scenario 1 is unable to restore colony health to the same levels as compared to when *E. cladocalyx* is part of the forage calendar. It must also be noted that any artificial diet stresses the colony, by making it less robust and more susceptible to disease or other perturbations, which could result in declines in pollination services relative to the status quo scenario. Johannsmeier (2000) argued that Cape honeybees in particular do not respond well to artificial diets. Also, Winston (1994) suggests that bees maintained on supplementary diets are of inferior quality, which will affect long-term performance. We accommodated these aspects by allowing a conservative 0.5% (instead of the observed 1%) increase in colony health per week over the ten week period during which an artificial diet was fed (refer to Table 1). This realised a situation where colony health is restored to only 93% of the *E.cladocalyx* forage equivalent. It is therefore unlikely that colonies under scenario 1 would be used for pollination purposes in two consecutive years (the colony will be earmarked for honey production and could only be used for pollination during the next season). Scenario two manages to restore colony health to 100% of *E. cladocalyx* forage equivalent albeit a month later (first week of August), which increases the risk of not having a full hive at the beginning of the deciduous fruit pollination season, however we assumed that pollination efficiency will not be influenced under this scenario.

3. Calculation of results

Scenario 1 represents a sugar-based artificial diet, supplemented with protein and carbohydrates. The diet is fed to colonies for the period of approximately ten weeks during the period when *E. cladocalyx* would have been in flower, i.e. from early December until the end of January (i.e. a 10 week period). Cost components of this scenario include the direct cost of the artificial diet itself, the loss in pollination service delivery for the coming season, and a loss in honey production every second year.

We calculated a direct cost per colony of US$38.20 for this artificial diet (sugar and supplements) over the 10 week period in which the replacement will need to be done. This calculation was based on the following assumptions:

- 1kg of sugar is required per colony per week
- Sugar price of US$0.57/kg
- 0.5kg of supplements is required per colony per week
- Supplement price of US$6.5/kg

The total cost per colony was therefore estimated on US$3.82 per week, or US$38.20 for the 10 week period. This figure becomes US$1.5million for the artificial diet during the 10 week period for the 39359 colonies in the province which depends on *E.cladocalyx*. Given that scenario 1 is only able to restore colony health to 93% of the *E.cladocalyx* forage equivalent, the value of this difference was considered to be a 7% opportunity cost in the number of pollinations for the following pollination season. This figure represents 3555 lost pollinations (given a total of 50780 per season, as per Allsop and Cherry (2004). We multiplied this figure with an average value estimate of US$1259 per pollination (obtained from our previous work, see (Allsopp et al., 2008 to gives rise to an estimated US$4.5 million opportunity cost in terms of lost pollinations.

INSERT TABLE 3 HERE

Furthermore, an artificial diet also results in a loss in honey production because beekeepers are not allowed to feed artificial diets for honey production in South Africa. A six week window period is needed to rid hives from sugar contaminated honey (Allsopp and Cherry, 2004). The average annual yield for honey is approximately 13.4 kg per colony in the Western Cape (Allsopp and Cherry, 2004). Nevertheless, we assumed that approximately 250gr of honey is produced per colony per week throughout the year. The artificial scenario substitute results in a 16 week (10 weeks for the substitution and 6 weeks for recovery) loss in honey production, or a 4.12kg loss per colony. This represents a total of 162280 kilograms of honey being lost per annum. This loss translates to a total annual loss in income of US$1.5 million (given a market price of approximately US$9.4/kg). The total cost of for this replacement scenario is estimated at US$7.5 million per annum for the Western Cape.

The native vegetation of the Cape Floral Kingdom (called Fynbos) is an important forage source for honeybees from April until the end of the winter in August (see Table 1, as well as Allsopp and Cherry, 2004). Certain species of Fynbos such as *Erica articularis, Erica hirtiflora*, *Helichrysum cymosum*, *Lobelia coronopifolia*, and *Protea aurea* flower during the same period as *E. cladocalyx* (Johansmeier, 2000), and are therefore a potential substitute forage source. However, Fynbos has been subjected to land clearing for agricultural and other development purposes for decades. A significant amount of cultivation/restoration will thus be required to establish the forage before substitution could take effect. This scenario therefore replaces *E. cladocalyx* with restoration of selected Fynbos species. The cost of this scenario is estimated in terms of the direct costs of restoring a selection of above-mentioned Fynbos species.

The area required to substitute *E. cladocalyx* with Fynbos was captured in the differences in colony stocking densities. We employed a stocking density of 5 hives per hectare (Allsopp and Cherry, 2004) for *E. cladocalyx*, which implies that 7,872 hectares of *E. cladocalyx* are needed in total, and 1.1 hives per hectare for the Fynbos substitute (Allsopp and Cherry, 2004, Van Eeden, 2008, Allsopp, 2007), which implies that approximately 35,781 hectares of Fynbos is required to serve as a suitable substitute for the 39,359 colonies as per Table 2.

Restoration costs were obtained from Van Eeden (2008), which amount to approximately US$8250 per hectare. This includes initial clearing cost of invasive alien plants at US$134 per hectare (depending on the level of infestation and species involved) (Marais, 2011), soil sterilisation at US$1250 per hectare and chemical balancing at US$1875 per hectare (soil sterilisation and chemical balancing is required to counter the detrimental effects of accumulated resins and waxes in the soil and associated potential allelopathic impacts of *Eucalyptus* species, (May and Ash, 1990)), seedbed preparation at US$2500 per hectare, cluster planting of US$1875 per hectare, and two follow-up operations (US$375 per hectare each), which then amount to US$8384 per hectare. The restoration and cultivation of the required hectares implies a capital outlay of approximately US$ 300 million (US$8384 multiplied by 35781hectares). However, unlike scenario 1, this would be a once-off investment rather than an annual cost, because an asset is created which will serve as a future forage source. We have consequently converted the capital outlay to an annual flow value (to allow comparison with the first scenario) by means of a discount rate of 3% over a period of 20 years, and obtained a value of US$20.2 million per annum. This cost includes the cost of prescribed burning and annual follow-ups to keep the area free from alien plants (calculated at US$0.32 million per annum based on the Working for Water database (Marais, 2011 and Marais et al., 2004). It should be noted that this calculation did not account for land acquisition cost as it was assumed that it would not be necessary to purchase land for this purpose since enough land is available if properly cleared from aliens.

4. Discussion and conclusions

Landowners in South Africa are legally responsible for controlling invasive alien plants on their land in terms of the CARA (Conservation of Agricultural Resource Act No.43 of 1983), (Republic of South Africa, 1983). The CARA distinguishes between three categories of declared weeds and invaders. Category 1 refers to prohibited weeds that must be controlled in all situations while category 3 refers to ornamental plants that may no longer be planted or traded (current specimens may remain subjected to a permit and steps to control their spread). *E. cladocalyx* and numerous other *Eucalyptus* species, are classified as 'category 2' alien plants which are considered to be *"useful for commercial plant production purposes but are proven plant invaders"* and may therefore "*not occur on any land or inland water surface other than a demarcated area*" (Republic of South Africa, 1983). This category thus refers to plants with commercial value that may be kept in demarcated areas which is subjected to a permit and displayed steps to control the spread of the species outside the demarcated area (Versfeld et al., 1998). Planting of these species are not allowed in riparian zones and wetlands. However, although South African legislation allows landowners to retain *E. cladocalyx* provided that they assume responsibility to curb the spreading of the species, private landowners are more than often not prepared to take on this responsibility and consequently allow the clearing of *E. cladocalyx* in much the same way as other invasive species on their properties. The clearing of *E. cladocalyx* along with other Eucalyptus species has thus created a conflict of interest because of the dependence of among other the beekeeping industry on the species as a forage source. Such clearing of several *Eucalyptus* species not listed in the CARA by WfW, has been critisied by interest groups which can potentially undermine public support of the programme. Beekeepers also raised concerns with regard to potentially negative impacts of such clearing on the supply of forage for the apiculture industry which could have serious consequences for the deciduous fruit industry (explained by the authors in a previous publication, see Allsopp et al., 2008). Consequently, WfW has commissioned a rapid survey to assess the invasive status of *Eucalyptus* species as mentioned in the CARA. The study confirmed that *E. cladocalyx* is not considered to be invasive, but rather regarded as naturalised (Forsyth et al., 2004). The study recommended that clearing projects should prioritise riparian zones and nature reserves for overall clearing (all *Eucalyptus* have negative impacts here) while clearing outside these areas should be targeted on species known to be invasive until the invasive status of the other *Eucalypts* (notably *E.cladocalyx*) are confirmed (Forsyth et al., 2004). However, little evidence exists of such targeting in practice, resulting in the clearing of *E. cladocalyx* along with invasive species such as *E. camaldulensis, E. grandis and E. conferruminata.* (previously incorrectly known as *E. lehmannii* in South Africa). We have presented a value estimate of the consequences of this practice and emphasized the need for increased investment to improve training and implementation of alien control programmes to avoid downstream costs of clearing useful alien plants. The justification for the argument rests on the value of the forage provisioning service of *E. cladocalyx* to the Western Cape beekeeping industry. The valuation was based on the calculation of the replacement cost of the service with two scenarios. Scenario 1 (artificial diet) estimated the value of the service on $7.5m per year, while scenario 2 (Fynbos cultivation/restoration) estimated the value of the service on $20.5m per year. These values need to be compared with the value of the negative impacts of the *E. cladocalyx* in order to justify management decisions with regard to the species. For example an estimate of the value of water (De Lange and Kleynhans 2007) as used by the species (as a proxy of the negative impacts of the species, i.e. excluded negative impacts biodiversity but also excluding other services for example fire wood provisioning) yielded a figure of only $348 148 per year (based on infestation rate and water use measurements of the species, Versfeld, 1998) which is far less than the value of the forage provisioning service of the species. Forage provisioning and water is only two of several impacts of the species, however a complete cost benefit analysis of *E. Cladocalyx* is beyond the scope of this paper. It is expected that such a complete account of all the prominent benefits and cost associated with the impacts of *E. cladocalyx* will provide satisfactorily evidence to make an informed argument for the future management of the species.

Budget limitations with regard to invasive alien plant clearing programmes emphasise the need for prioritisation requirements that consider the inter-dependencies of alien plants in the prioritisation of species. A recent study by Forsyth et al., (2012) has provided a structured approach towards the prioritisation of invasive alien species in South Africa. Within such prioritisation studies it becomes important to balance the trade-offs and conflicts of interest associated with the species under investigation. Such comparisons requires the monetary valuation of the impacts which then becomes a common denominator to compare such trade-offs which then allow policymakers to structure and motivate budget defences aimed at biodiversity conservation and research on alien invasive species. In so doing, the credibility and public buy-in for biodiversity conservation can be promoted.

Despite its assumptions (Winfree et al., 2011), transparent value estimation procedures reduce the reliance on arbitrary value judgements within prioritisation procedures of invasive alien clearing programmes. Valuation procedures also emphasize the fact that ecosystem services such as pollination and forage provisioning do indeed have value, and that losing such services would result in significant costs (Winfree et al 2011, Gallai et al., 2009, Losey and Vaughan 2006, Morse and Calderone 2000, Brugett et al., 2004, Allsopp et al., 2008).

Case examples of the value of alien (conflicting interest) species when making management policies and drafting strategies, are worth mentioning in the global debate on invasive alien policy making. This paper provides a practical example of a case where the benefits of *E. cladocalyx* supports the management of the species in demarcated areas. This work emphasised a case where an alien species has become part of functional production and that certain dependencies can indeed develop upon them over time. It emphasised the fact that the species has become an important input for the apiculture industry as more and more natural vegetation is cleared for agricultural development. It is suggested that the beneficiaries of the *E. cladocalyx* forage provisioning services (beekeepers) should contribute to the cost of controlling this species outside demarcated areas. The valuation is extremely helpful to present trade-offs with regard to strategic management and policy-making decisions with regards to alien plant control. The replacement cost estimates calculated in this paper could be considered as the maximum theoretical willingness to pay by these beneficiaries to keep and manage the *E.cladocalyx* within demarcated areas because a cost greater than these estimates would leave beneficiaries indifferent between having the species available for forage or replacing the species with either scenario as presented in this paper.

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Table 1: Forage calendar for the apiculture industry in the Western Cape.

Month	***Main forage source***	***Other forage sources (if the preferred source is not available)***
February	Vegetables (pumpkins, onions, leeks, beetroot and carrots are grown on a large scale within the Western Cape; however, none of these are preferred forage sources for bees)	Ruderals (plant species that is first to colonise in disturbed land, and is in most cases recognised weeds. It is not considered to be a forage source of suitable quality.)
March	Vegetables	Ruderals
April	Fynbos	Ruderals
May	Fynbos	Ruderals
June	Fynbos	*E. sideroxylon*
July	Fynbos	*E. conferruminata* (previously incorrectly known as *E. lehmannii* in South Africa)
August	Canola	Fynbos (if canola is not available)
September	Deciduous fruit	*E. camaldulensis* (for those colonies not on deciduous fruit)
October	Deciduous fruit	*E. camaldulensis*
November	Deciduous fruit	Ruderals
December	*E. cladocalyx*	Artificial diet or some Fynbos species
January	*E. cladocalyx*	Artificial diet or some Fynbos species

Table 2: Relative importance of *Eucalyptus* (and *E. cladocalyx* specifically*)* in terms of forage provision (Allsopp and Cherry, 2004)

	Colonies	***% of total***
Colonies not on *Eucalyptus*	12035	30.6
Colonies on all *Eucalyptus* species	27324	69.4
Colonies on *E. cladocalyx* specifically	21505	54.6
Colonies on other gums except *E. cladocalyx*	5819	14.8
Total number of colonies	39359	

Table 3: Calculated annual pollination service replacement values for the deciduous fruit industry in the Western Cape of South Africa (values in US$ millions per year according to Allsopp et al., 2008). These monetary values account for fluctuations in labour inputs and production outputs under different pollination practices, and can be seen as representative for the South African deciduous fruit industry. Although still external to the deciduous fruit production input structure, the figures are significant when compared to the total production value of deciduous fruit (US$417.8 million in 2005) (Deciduous Fruit Producers Trust, 2006). Given that current legislation does not allow the importation of bees for pollination services from outside the province, the risk of unsecured forage is increased.

Pollination replacement option	**All insect pollinators**	**Managed pollinators**	**Wild pollinators**
	US$ millions per year		
Pollen-dusting	292.9	107.8	185.2
Hand pollination - option 1 (This option is based on the number of flowers that will need to be hand pollinated to produce the equivalent amount of fruit as are produced during insect pollination, and assumes that it take five seconds to pollinate each flower.)	161.2	44.9	116.3
Hand pollination - option 2 (This option assumed that the pollination of a single flower takes twice as long as hand picking (harvesting) the fruit. If a fifty percent set is obtained from hand pollination, it means that twice as many flowers to fruit ratio of 2:1. Labour cost of pollinating flowers is therefore four times the cost of harvesting. Given that the fruit set and harvesting labour cost components are known (Deciduous Fruit Producers Trust, 2006), the labour component for hand pollination could be determined.)	433.8	122.8	310.9
Hand pollination – option 3 (This option assumed a 180 man-day labour input per hectare for hand pollination.)	77.0	28.0	49.1

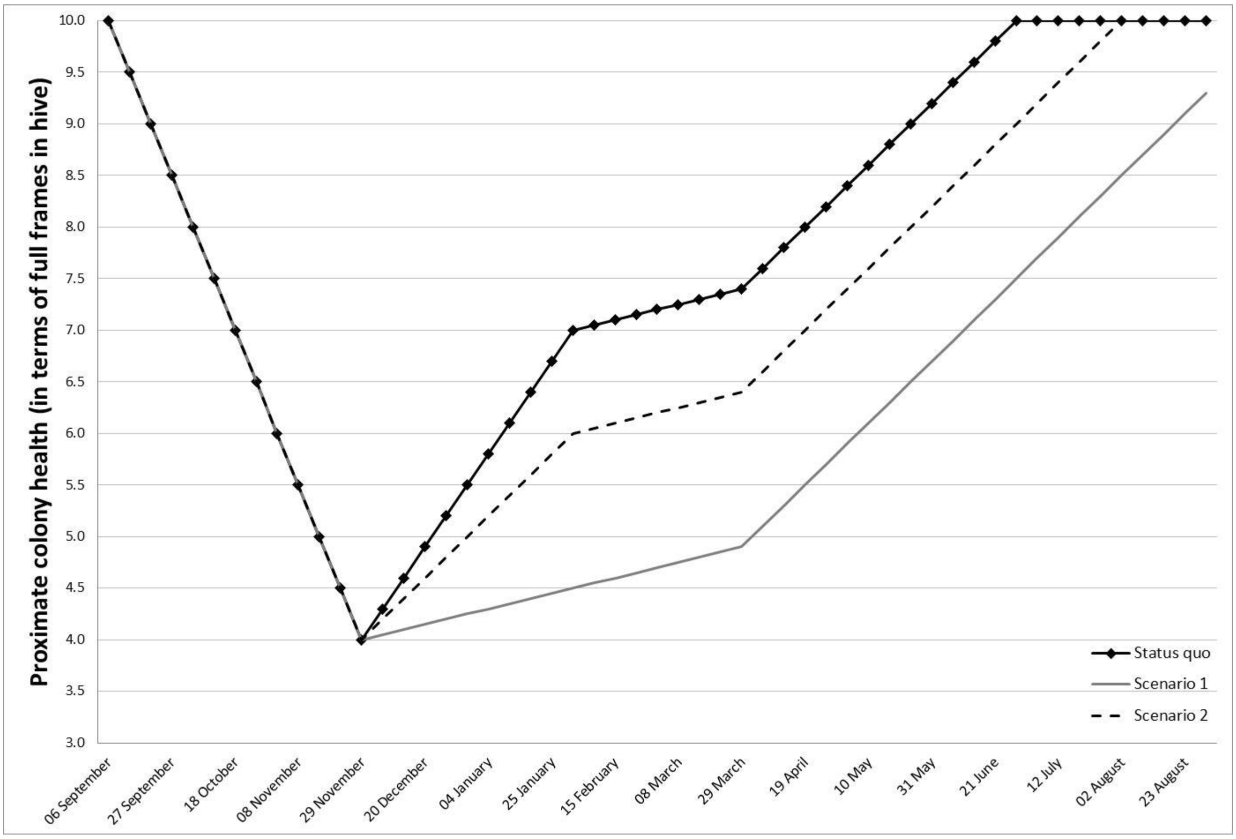

Figure 1: Proximate colony health (in terms of the number of full frames of honey or brood in a standard ten-frame Langstroth bee hive) as per the status quo and two different scenarios of the forage calendar for the Western Cape beekeeping industry.