INVASIVE PLANTS IN MOUNTAINOUS REMNANT FOREST: RECOMMENDATION FOR CHOOSING BEST DECISION FOR INVASIVE SPECIES MANAGEMENT OF *Cestrum aurantiacum* Lindl.

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Abstract

Cestrum aurantiacum Lindl. is an exotic species found in native remnant forest of GPNP which is located inside the Cibodas Botanic Garden (CBG). Risk assessment is an important tool to choose best decision for invasive plant management. Risk assessment analysis on *C. aurantiacum* in Cibodas Botanic Garden was conducted using Multi Criteria Decision Analysis (MCDA) method. Analytical Hierarchy Process (AHP) used in the valuation process. Three sub-criteria used: minimizing the ecological impact, minimizing the management cost, and maximizing the public acceptance. Five management alternatives were used: do nothing (DN), eradication (E), containment (C), bio-control (BC) and harvesting (H). Harvesting (H) recommended as the best management decision for *C. aurantiacumin* at CBG remnant forest. This harvesting decision is not only creating environment/ ecosystem remediation but also as sources of fund in the management activity of the area.

Keywords: *Cestrum aurantiacum*, Cibodas Botanic Garden, invasive plant, plant conservation, risk assessment

Abstrak

Cestrum aurantiacum Lindl. Adalah salah satu spesies invasif yang ada di hutan sisa (remnant forest) yang berada di dalam kawasan Kebun Raya Cibodas (KRC). Analisis resiko dilakukan untuk memilih opsi pengelolaan terbaik untuk *C.aurantiacum*. Analisis resiko pengelolaan tumbuhan *invasife C.aurantiacum* di Kebun Raya Cibodas (KRC) dilakukan menggunakan metode Multi Criteria Decision Analysis (MCDA). Analytical Hierarchy Process (AHP) digunakan dalam proses pembobotan dan penghitungan model hirarkis yang dianalisis. Tiga sub-kriteria yang digunakan dalam model hirarkis adalah: meminimalisir dampak ekologis, meminimalisir biaya dan memaksimalkan penerimaan publik. Lima opsi pengelolaan yang digunakan dalam model hirarkis adalah: do nothing (DN), eradication (E), containment (C), bio-control (BC) dan harvesting (H). Harvesting (H) direkomendasikan sebagai opsi pengelolaan terbaik untuk *C. aurantiacum* di hutan sisa KRC. Opsi ini tidak hanya mengakomodir perbaikan ekosistem tetapi juga dapat menjadi sumber dana untuk mendukung sebagian biaya implementasi pengelolaan *C. aurantiacum*.

Kata Kunci: analisis resiko, *Cestrum aurantiacum*, Kebun Raya Cibodas, konservasi tumbuhan, tumbuhan invasif

INTRODUCTION

Cestrum aurantiacum Lindl. is an exotic species found in native remnant forest of the Gede Pangrango National Park forest which is located inside the Cibodas Botanic Garden (CBG). *C. aurantiacum* native to Central America (Zhi-yun et al., 1994; Benitez and D'Arcy, 1998) and is known as an escape species from CBG living collection and has an invasive potential in all remnant forest area of CBG and also could spread further to native forest of GPNP. *C. aurantiacum* had been identified as a wide-spread and well established invasive species in totally five hectares remnant forest area located inside CBG. These remnants forest area are part of the main forest ecosystem of Gede Pangrango National Park (GPNP), Botanic Gardens stated as one of the contributed factor to the spread of invasive species (Virtue et al., 2008; Coghlan, 2011; Hulme, 2011).

There are at least two major adverse effects of the existence of an invasive species in a native ecosystem. First, invasive plant can change native ecosystem processes such as nutrient cycle or hydrology and contribute significant role on the decrease of native species abundance (Mack et al. 2000; Gurevitch and Padilla, 2004). *C. aurantiacum* was identified as an exotic invasive plants causing several adverse impact including displace native plants from their habitat in Malawi and South Africa (McDonald et al., 2003; Henderson, 2007). Second, *C. aurantiacum* is toxic to animal and possibly has similar effect on human (McLennan and Kelly, 1984; McDonald et al., 2003).

The main concern on the effect of *C. aurantiacum* as invasive species is the possible risk caused by the species invasion to invaded remnant forest of CBG and potentially invaded GPNP as the main forest ecosystem. There are at least two reasons underpin the importance of remnant forest area of CBG and main native ecosystem of GPNP. First, GPNP and adjacent remnant forest is a high priority site for global conservation (Olson and Dinerstein, 2002). *C. aurantiacum* invasion can potentially effecting the biodiversity and plant community of GPNP native forest which is a significant site in global conservation priority. Second, native remnant forest of CBG and GPNP maintain native ecosystem services including hydrological balance and provide habitat and food for native animals.

General understanding and theory of invasion process could be used to conceptualize the process of the invasion (Richardson et al.,2000; Theoharides and Dukes, 2007). Biological invasion of an exotic species could be considered as a series of processes or steps.

Theoretically, management options for invasive plants (such as *C. aurantiacum* in remnant forest inside CBG) are depends on the invasiveness stages. First, eradication is an appropriate option for exotic species which is not well established yet as common invasive species in an area. Second, containment is a management option for exotic species when full eradication is not feasible to conduct or will potentially causing unwanted side effects. Third, special treatment such as bio-control is an option for established and dispersed exotic species which are needed to be eradicated because already causing adverse effect and become invasive (Radosevich, 2007). Moreover, long-term time frame assumed as appropriate time frame for management implementation. The time frame of the management assumed as long as 50 years.

Furthermore, there is another management option for *C. aurantiacum* in remnant forest of CBG. Hewage et al. (1997) stated that this species is a potential raw material for bio-insecticide. Therefore, the last management option is harvesting *C. aurantiacum* for producing bio-insecticide. Harvesting will be implemented by gradually harvest the *C. aurantiacum* until all propagule eradicated for certain time. The timeframe for harvesting will be shorter than containment and longer than eradication.

The evaluation criteria of the assessment consists of several considerations. First, cost is the most obvious criteria for the assessment. Achieving balance between cost allocation and protecting the environment is important due to the uncertainty of the consequences of the decision (Olson 2006). The order of management option from the most expensive to the lowest cost subjective assumption respectively: bio-control, containment, eradication, harvesting and do nothing.

Second, the ecological impact of the management option is another important factor to be considered. Ecological impact in this context defined as possible impact from *C. aurantiacum* as invader and possible impact from *C. aurantiacum* management implications to native ecosystem including remnant forest and main native GPNP forest. The rate of these impacts could be subjectively assumed from the rate of biodiversity degradation or from the total area occupied by invasive *C. aurantiacum*. Third, public acceptance also important due to the great concern of society to the nature conservation of GPNP forest ecosystem including remnant forest CBG (Olson and Dinerstein, 2002). The hierarchical model of the problem formulation presented in Figure 1.

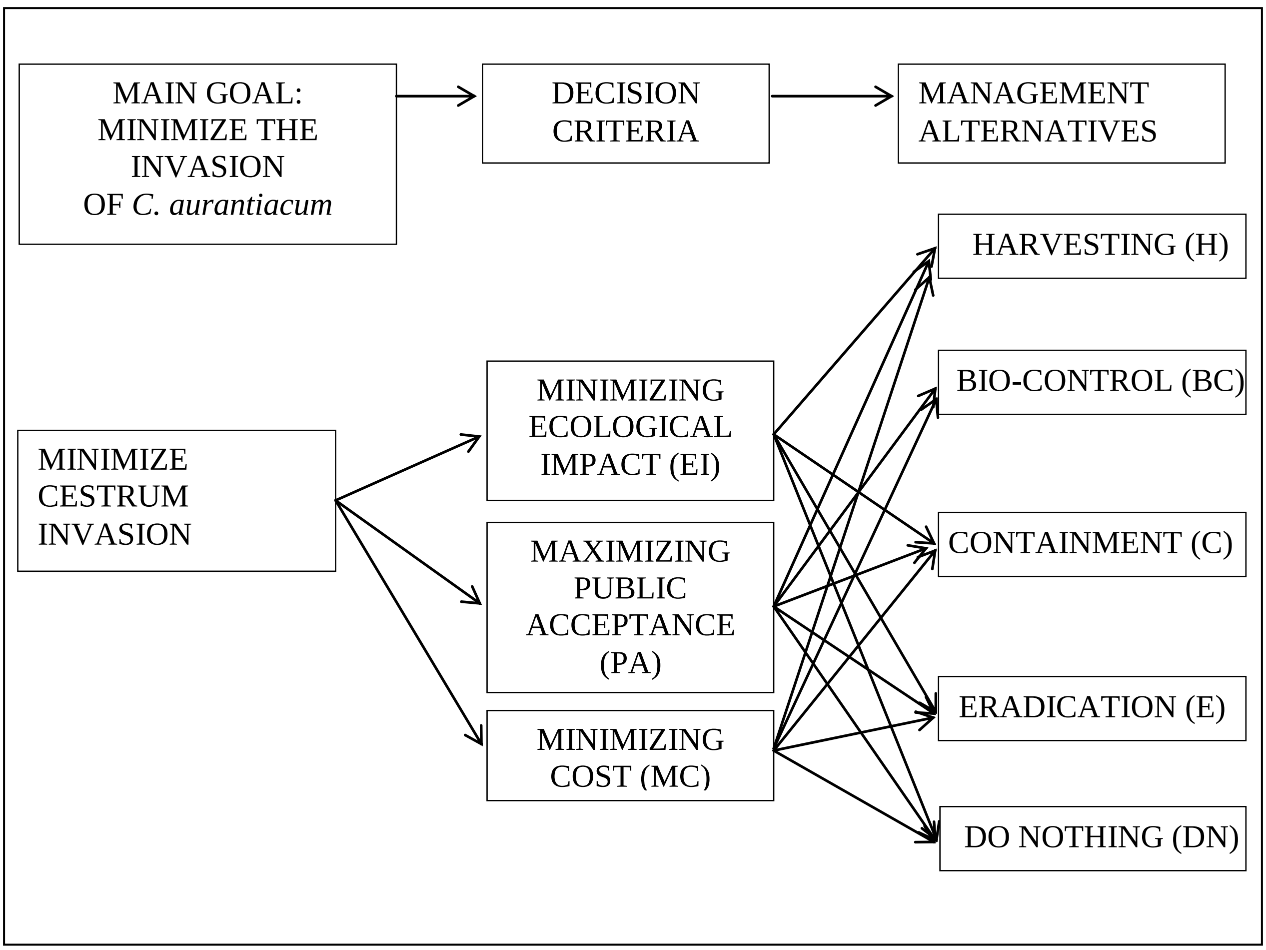

Figure 1. Hierarchy model of Multi Criteria Decision Analysis of minimizing invasion of *Cestrum aurantiacum* in remnant forest of Cibodas Botanic Gardens (CBG). Time did not included in the pairwise table (Table 2) due to the assumption of the management time: 50 years.

This study will discuss the risk assessment of invasive *C. aurantiacum* in remnant forest of CBG using Multi-criteria Decision Analysis (MCDA) method. This study will also give recommendation of appropriate management option to minimize the invasion of *C. aurantiacum* in native remnant forest of CBG based on the consideration of minimizing cost, minimizing ecological impact, and maximizing public acceptance.

METHODS

Multi Criteria Decision Analysis (MCDA) performs evaluation on decision or scenario relative to multiple decision alternatives. MCDA is a tool to evaluate decision consequences or decision scenario and alternatives by constructing and ordering these multiple decision options based on value of people who are affected by the decision (Burgman, 2005). MCDA is a good method due to multiple objectives fulfillment. MCDA could be used for finding decision alternatives and opportunities, defining decision which is reflecting social aspiration or constructing understanding amongst stakeholders (Burgman, 2005).

The main management goal is to minimize the invasion of *C. aurantiacum* in remnant forest CBG. The management options are: do nothing (DN), eradication (E), containment (C), bio-control (BC) and harvesting (H). The management goal criteria are minimizing cost (MC), minimizing ecological impact (EI), and maximizing public acceptance (PA). MC refers to minimizing the amount of the cost used on the management option implementation. PA refers to maximizing society acceptance due to the management option implementation. EI refers to minimizing ecological impact on the native forest ecosystem due to the management option implementation and minimizing the impact of *C. aurantiacum* as invasive species to native ecosystem.

Recommendation of best management option of *C. aurantiacum* in remnant forest CBG defined by using MCDA from several possible management options on CRITERIUM DECISION PLUS® software. Analytical Hierarchy Process (AHP) methods with weight option on the hierarchy model were used on the calculation analysis. AHP accommodate subjective judgment of relative importance in to a set of weight for rating processes (Guitouni and Martel, 1998). The full pairwise method used for sub-criteria rating method. Full pairwise method rate the sub-criteria by giving subjective rate on all possible pairwise combination of sub-criteria. For example, based on Figure 1, the rate sub-criteria of minimize invasive *C. aurantiacum* consists of pairwise of all possible sub-criteria combination between EI, PA and MC. These pairwise combinations are EI vs PA, EI vs MC and PA vs MC. Then, we subjectively select better option between two options in a pairwise and subjectively rate the magnitude of the ‘betterness’. These processes also implemented to every sub criteria of EI, PA and MC which is consists of five management options (DN, E, C, BC and H). The score of ‘betterness’ used on the analysis process based on software setting presented in Table 1.

Table 1. The magnitude of ‘betterness’ for subjective rating in full pairwise method on Analytical hierarchy process (AHP) based on setting of CRITERIUM DECISION PLUS® software.

‘Betterness’	Weight Value
Equal	1
Barely better	2
Weakly better	3
Moderately better	4
Definitely better	5
Strongly better	6
Very strongly better	7
Critically better	8
Absolutely better	9

The importance rate (reflected by ‘betterness’ on pairwise) of decision criteria from the most important to the least are EI, MC and PA respectively. EI is very important because study show that without careful plan and appropriate management, management effort on invasive plant can lead to negative feedback such as stimulate further invasion through immediate new forest gap (Alpert et al.,2000; With, 2002; 2004). MC is important because every management plan will have to deal with limited resources. Moreover, PA considered has lower weight compared to two previous criteria due to low direct impact to human activities.

Due to the maximum contribution of decision criteria, three different management options have highest contribution of decision criteria. DN is the best option for MC due to the minimum management cost. C is the best option for EI because this option implemented carefully and gradually to minimize ecological impact. H is the best option for PA due to the positive impression on the offsetting management cost from producing bio-insecticide. Moreover, the negative feedback from synthetic insecticide industries could reduce public acceptance. However, this negative feedback subjectively assumed as minor. The full subjective rate on full pairwise method on AHP process between all decision criteria (MC, EI and PA) and all management options (DN, E, C, BC and H) presented in Table 2.

Table 2. Subjective rate on full pairwise method on AHP process of all management options

Management options	Decision Criteria														
	MC					EI					PA				
	DN’	E’	C’	BC’	H’	DN’	E’	C’	BC’	H’	DN’	E’	C’	BC’	H’
DN		4	3	3											
E						5					6				
C		3				7	3				6	1			
BC		3	2			5	2	2			5	2	3		1
H	1	4	4	5		5	3	1	2		7	5	3		

Note: DN=do nothing, E=eradication, C=containment, BC=bio-control and H=harvesting of all decision criteria (MC=minimizing cost, EI=minimizing ecological impact and PA=maximizing public acceptance). Numbers in a row represent how better is a corresponding management option compared to other options for all decision criteria (e.g. BC is better than C’ for minimising cost and BC is better than H’ for public acceptance). Numbers in a column represent how bad a corresponding management option is compared to other options (e.g. E’ is worse than DN for minimising cost and DN’ is worse than E for public acceptance). The score values of ‘betterness’, which are numbers on the table, weighted based on table 1 discrete scale.

Table 2 recapitulates the full pairwise method on every possible combination of management options for every decision criteria (e.g. DN vs BC’, C vs H’). The numbers in the table represent the rate (weight) of ‘betterness’ of corresponding better management option on every pairwise (DN, E, C, BC and H versus DN’, E’, C’, BC’ and H’). Numbers in a row represent how better is a corresponding management option compared to other options for all decision criteria. Numbers in a column represent how bad a corresponding management option is compared to other options.

RESULTS

Decision value reflects the priority selection between management options. From MCDA calculation, the priority of management option from the best option to the least respectively are: harvesting (decision value: 0.364), bio-control (decision value: 0.243), containment (decision value: 0.169), eradication (decision value: 0.113) and do nothing (decision value: 0.111). Decision rank based on the decision value presented in Figure 2.

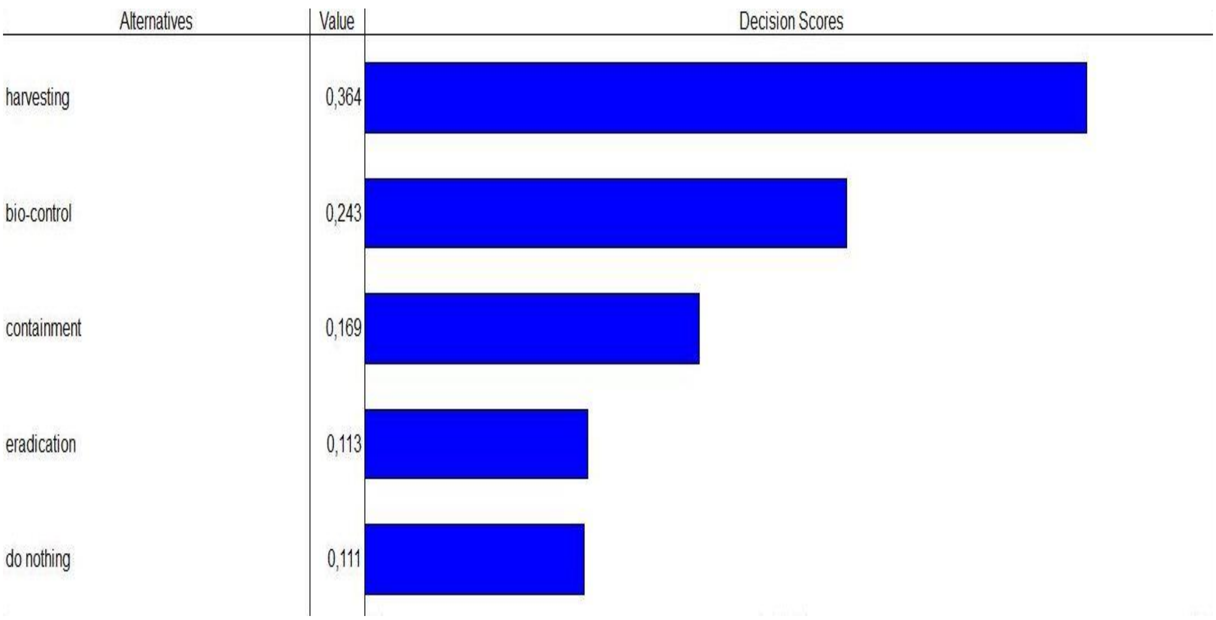

Figure 2. Decision score value of Multi Criteria Decision Analysis of minimizing invasion of Cestrum aurantiacum in remnant forest of Cibodas Botanic Gardens (CBG). The management alternavites are consists of: harvesting, containment, eradication, bio-control and do nothing.

Decision value rank reflecting the best management alternatives rank. For example, harvesting is the best management alternatives because it has highest decision value (0.364). Do nothing and eradication is not appropriate option because the decision score of these optionsare the lowest amongst other option (0.113 for eradication and 0.111 for do nothing).

MCDA can identify the contribution of each decision criteria to decision value on every management option. These contributions presented in Figure 3.

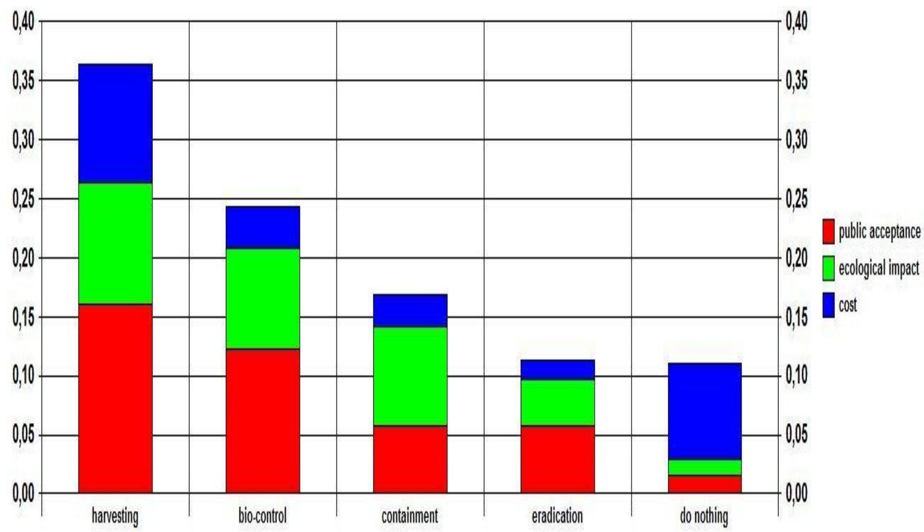

Figure 3. Contribution of decision value of all management options (harvesting, containment, eradication, bio-control and do nothing) from all decision criteria on minimizing invasion of *Cestrum aurantiacum* in remnant forest of Cibodas Botanic Gardens (CBG).

The sensitivity analysis of all decision criteria on all management options presented on Figure 4. These sensitivity analysis convey the inconsistency priority along different value judgment of the importance of decision criteria to main management goal (minimize invasive C. aurantiacum).

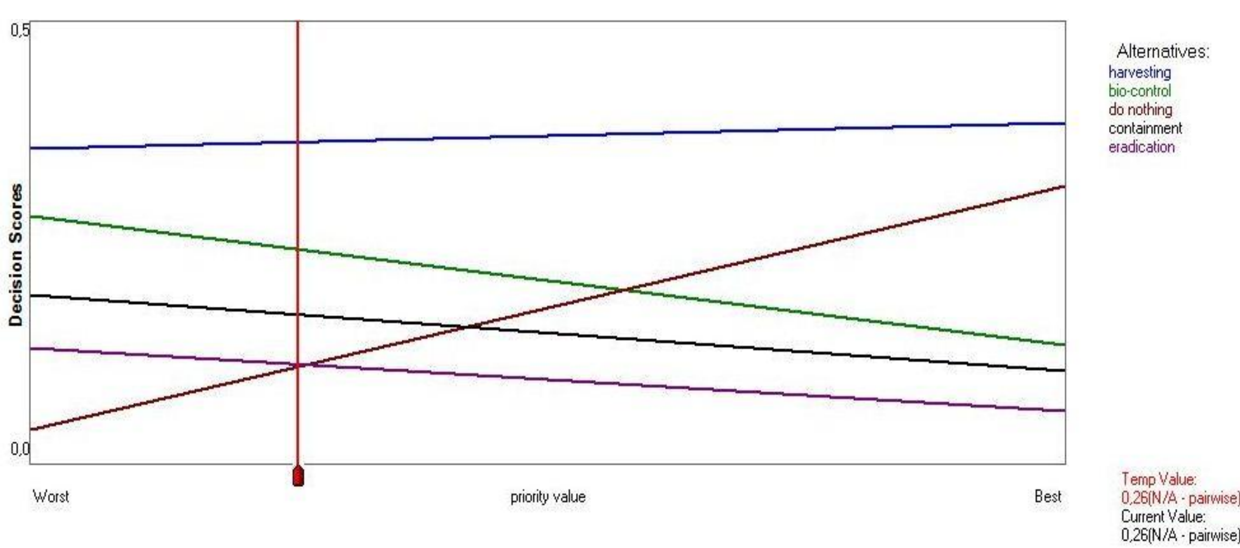

Figure 4a. Sensitivity analysis of decision criteria of minimizes cost (MC) on all management options.

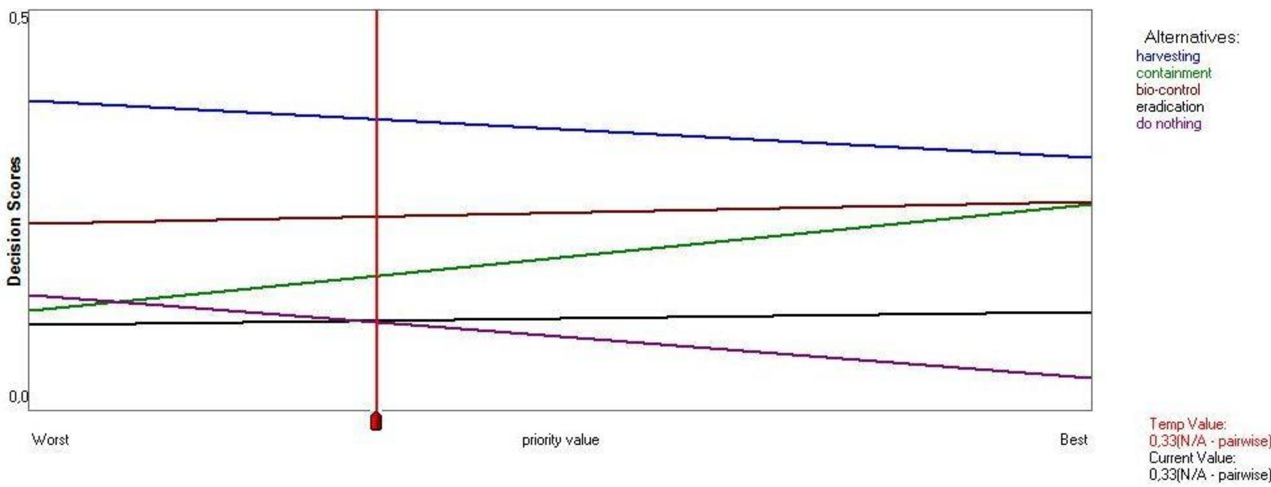

Figure 4b. Sensitivity analysis of decision criteria of minimizes ecological impact (EI) on all management options.

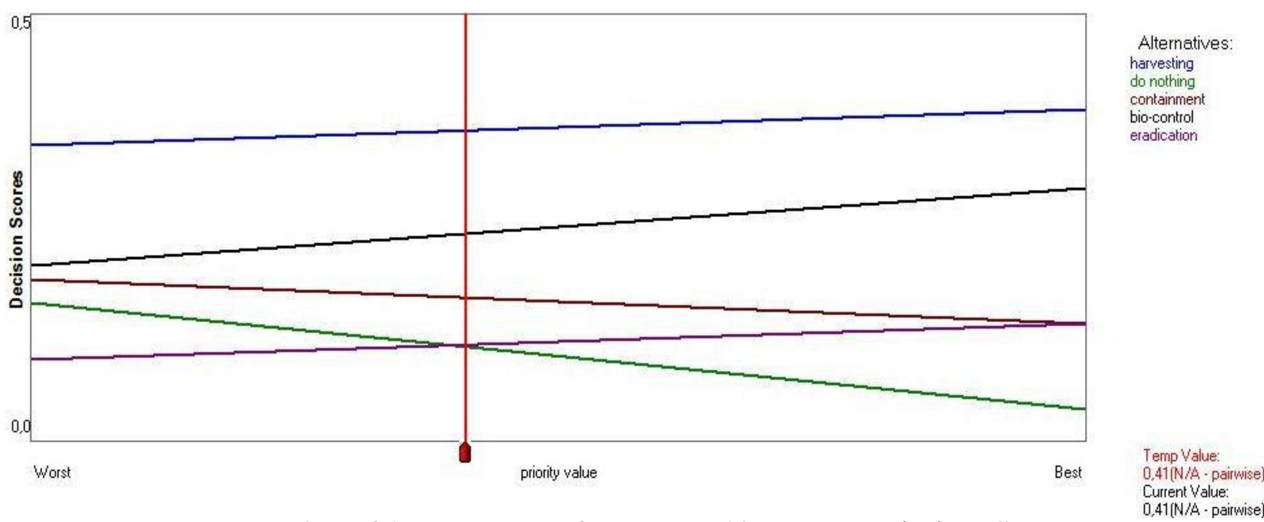

Figure 4c. Sensitivity analysis of decision criteria of maximize public acceptance (PA) on all management options.

DISCUSSION

The possible three best management options for *C. aurantiacum* are containment, bio-control and harvesting. First, containment of *C. aurantiacum* from remnant forest of CBG could be sustainably maintained if there is enough funding availability. Containment also minimize the most important decision criteria: ecological impact. The main limitation of containment is the requirement of huge amount of resources and time. Containment will require consistency and dedicated efforts for long time and will not solve the problem completely in short time. Second, bio-control of *C. aurantiacum* is a possible solution if there is a specific biological agent available. However, the weakness of this option is the big amount of fund needed to conduct biological control to *C. aurantiacum.* These expensive cost associated with the importation of the biological agent and the test needed to make sure there is no side effect from this biological agent to native ecosystem.

Third, gradual eradication by harvesting is another management option for *C. aurantiacum.* This option conducted by implementing gradually increased intensity of containment and utilize the propagule to produce benefit for CBG (insecticide from *C. aurantiacum*) to offset the management cost itself. Though, the benefit from harvesting and utilizing *C. aurantiacum* will not offset all the management cost. Moreover, the fixed quantification of how much money produced from the use of the *C. aurantiacum* extract as insecticide/pesticide is still a prediction and not based on real example. However, this benefit potentially contributes to the minimizing cost criteria (Figure 3). The other weakness of this harvesting as a decision is the resistence (minimizing public acceptance) from community especially from agro-chemical industries.

Eradication and do nothing are the option with the lowest decision scores. Therefore, these two options did not recommended as suitable management decision for *C. aurantiacum* in CBG remnant forest. Eradication might be maximize public acceptance, but at the same time the cost is high and the negative ecological impact might be significant because eradication will change the ecosystem drastically. Do nothing is obviously the worst management option for invasive species. It is true that by do nothing there will be no cost, but the ecological impact, negative public acceptance and future cost for the possible impact significantly reduce the decision score.

Sensitivity analysis of the developed AHP model reflects several interesting results (Figure 4a, 4b, and 4c). Firstly, MC criterion is sensitive to do nothing, eradication, containment, and bio-control. Do nothing considered as the second best option if we put MC on highly extreme priority value while harvesting considered as best option if we put MC as lowest priority. Moreover, harvesting is the best option for all range of priority of MC (Figure 4a). Secondly, EI criterion is sensitive to do nothing, containment and eradication. Harvesting is the best option for allpriority rangeon EI. For low priority of EI criterion, eradication is the worst option while at high priority of EI, do nothing is the worst option (Figure 4b). Thirdly, PA is relatively robust (insensitive) to most of the management option except for sensitivity on do nothing and eradication. Eradication is the worst option for low PA priority and do nothing is the worst option for high PA priority. All of these sensitivities for all three decision criteria could be reflecting the real tendency due to interdependencies between all criteria and management options. On the other hand, these sensitivities could also reflect bias of analyst judgment on giving rating score on the AHP pair-wise process. Moreover, this is should be noted as the limitation of MCDA by using AHP pair-wise due to the subjectivity judgment (Guitoni and Martel, 1998).

Furthermore, the common paradigm of invasive risk assessment considers the risk as adverse impact. However, the adverse impact source can be viewed as part of solution in certain context. The context of *C. aurantiacum* is an example for this “bless in disguise”. *C. aurantiacum* is give adverse impact when this species is escaped from CBG to adjacent remnant forest and native forest of GPNP. On the other hand, *C. aurantiacum* has potency as raw material for bio-pesticide (Hewage et al., 1997). The fact that *C. aurantiacum* have beneficial prospects lead to a different paradigm of management options. The eradication/ minimizing risks activity is not only require certain cost but also create prospects of benefit. These benefits could be used as the source of resource to offset the management cost at certain level. These principles are underpinning the management option of gradual eradication by harvesting.

CONCLUSION

In conclusion, harvesting considered as the most recommended management option to minimize the invasion of *C. aurantiacumin* remnant forest CBG. This management option is not only create environment/ ecosystem remediation but also provide source of fund topartially offsetting the cost requirements for corresponding management implementation.

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