Risk Assessment and Management Recommendations of Invasive Species in Papandayan Mountain Nature Reserve, West Java

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Abstract

Natural disasters and anthropogenic disturbances have caused several locations in the Papandayan Mountain Nature Reserve to be more vulnerable and exposed further triggering the presence of invasive species. This presence impacts the environment, the economy, and the health of humans and animals. This research aims to assess the risks of these invasive species, followed by various recommendation strategies towards their species management. Data on species diversity was collected by vegetation analysis, using the quadratic method by purposively sampling plots. Results showed the existence of six invasive species in Papandayan i.e. *Ageratina riparia* (Regel) R.M.King & H.Rob., *Ageratina adenophora* (Spreng.) R.M.King & H.Rob., *Austroeupatorium inulaefolium* (Kunth) R.M.King & H.Rob., *Imperata cylindrica* (L.) Raeusch., *Rubus moluccanus* L., and *Ageratum conyzoides* (L.) L.. The assessment of invasive species was assessed through two indices; Risk Index and Feasibility Index. Each of them was calculated based on the Risk Assessment Protocol to determine their strategy of control. Based on the Risk and Feasibility Indices, several recommendation strategies to manage invasive species are proposed.

Keywords: *Ageratina riparia*, invasive risk assessment, invasive species, Papandayan Mountain Nature Reserve

1. Introduction

Papandayan Mountain Nature Reserve is a region that often experiences various natural disasters, such as volcanic eruptions and anthropogenic disturbances in the form of forest encroachment, opening up the environment to be more vulnerable [1]. These exposed conditions and scars of disturbance prove to be a suitable environment for the growth of invasive species [2]. Invasive species are native or non-native species that grow uncontrollably, have an effective way of seed dispersal and rapid reproduction, with their presence resulting on the disturbance of native species. [3]. In natural ecosystems, the presence of invasive species frequently results in negative impacts towards the environment, economy, and health of humans and animals [3, 4]. In Baluran National Park, East Java, *Acacia nilotica* has invaded almost 6,000 ha out of the 10,000 hectares of the savanna. The area has been converted into shrubs, causing a decrease in grass productivity for animal feed, and thus consequently threatening the lives of wildlife such as bull, buffalo, and deer [5]. In the United States, the impact of invasive species is expected to reach USD 167.9 billion [6]. Also, invasive species can cause health problems, for example, *Ambrosia artemisiifolia*, native in Central America, can cause sunburn on direct contact with humans [7].

The control of invasive species needs to be planned seriously to prevent the distribution of invasive species, especially to the natural ecosystems [8]. Several efforts in controlling invasive species have been implemented: mechanically, through felling or burning; chemical controls through the usage of natural herbicides; or, through biological controls, by bringing natural enemies. However, the results of these methods have been deemed ineffective, with staggeringly expensive costs [8]. The study of preventing the arrival of invasive foreign species is the most effective strategy compared to eradication [9]. Risk analysis is an effort to predict the chances of risk, distribution impacts, and threats to the preservation of natural resources due to the presence of invasive alien species [10]. Therefore, in this paper, conducting a review through risk assessments of invasiveness and management feasibility of invasive species is established as the basis for more effective and efficient management [10]. A risk assessment is needed to determine the risk of each invasive species, before being able to propose recommendations for appropriate invasive species management in Papandayan Nature Reserve.

2. Methods

2.1. Study Area and Sampling Time

The research was carried out in March until October 2019 in the Papandayan Mountain Nature Reserve, Garut, West Java. The research location is divided into three types of land cover, i.e. grassland (Pondok Salada and Tegal Alun), Tepi Kawah, and Cisupabeureum (Fig. 1).

2.2. Vegetation Analysis

The research was carried out in March until October 2019 in the Papandayan Mountain Nature Reserve, Garut, West Java. The research location is divided into three types of land cover, i.e. grassland (Pondok Salada and Tegal Alun), Tepi Kawah, and Cisupabeureum (Fig. 1).

Vegetation analysis was conducted to determine the invasive species, using the quadratic method. This was done by purposively sampling plots on three types of land cover, i.e. grassland, crater rim, and mixed forest. There were 18 plot of 5 x 5 m for the shrubs and 36 plots of 2 x 2 m for the herb. The composition of the invasive species in Papandayan was determined by the Index of Important Values (IV). The calculation of IV for herbs and shrubs were obtained by summing the relative density values and the frequency relative values, by using the following equation [11]:

$$\text{Density (D)} = \frac{\text{Number of individuals in the sample}}{\text{Total area of the sample}}$$

$$\text{Relative Density (RD)} = \frac{\text{Density of one species in the sample}}{\text{Total density of all species in the sample}} \times 100\%$$

$$\text{Frequency (F)} = \frac{\text{Number of sub−plots in which a species occurs}}{\text{Total number of sub−plots in sample}}$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species in sample}} \times 100\%$$

The Important Value index (IV) of shrubs and herbs $= RD + RF$

2.3. The identification of Invasive Species

The specimens were identified based on Flora of Java book volume I-III [12-14]. Specimens not available in the book were identified based on local name references from Papandayan Mountain Nature Reserve officials and other

references. Invasive species were classified by checking into online databases such as *Invasive Species Specialist Group* (ISSG), *Convention of Biological Diversity* (CBD), *Center* *for Agriculture Biosciences International* (CABI), *Guide Book to Invasive Species in Indonesia*, dan *Forest in Southeast Asia-Indonesia Program* (FORIS-INDONESIA).
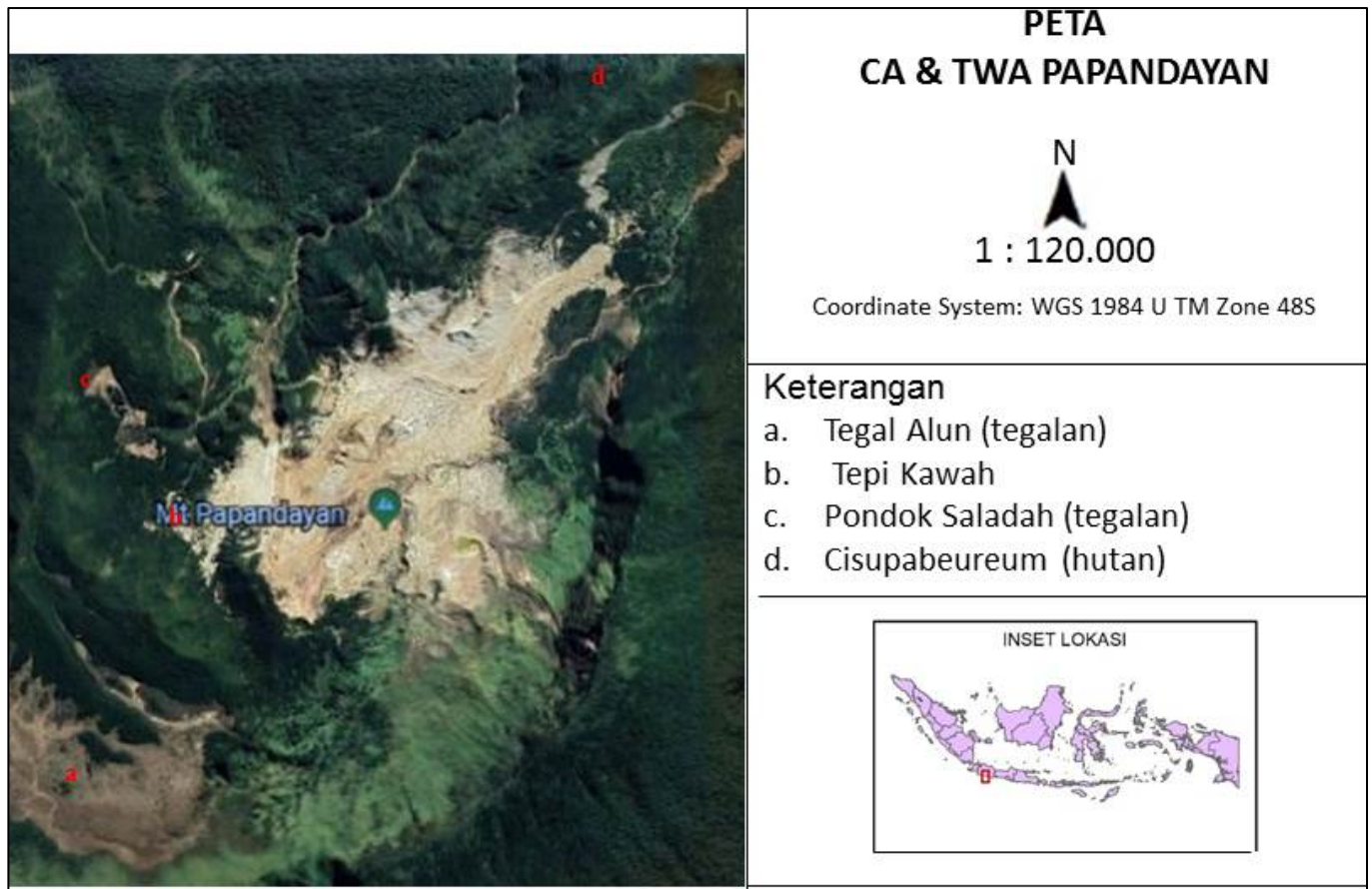

Figure 1 Research Site of Study (a) Tegal Alun (grassland), (b) Tepi Kawah (crater rim), (c) Pondok Saladah (grassland), (d) Cisupabeureum (mixed forest)

2.4. Risk Assessment

The research was carried out in March until October 2019 in the Papandayan Mountain Nature Reserve, Garut, West Java. The research location is divided into three types of land cover, i.e grassland (Pondok Salada and Tegal Alun), Tepi Kawah, and Cisupabeureum (Fig. 1).

A risk assessment of invasive species was analysed using The Invasive Species Risk Management System Protocol [15] modified by [10]. It was further adapted to suit the conditions of the Indonesian habitat. The risk assessment was further determined by three components, i.e. Risk Index, Feasibility Index, and Management Recommendation.

Risk index (R) was obtained after all questions from three related parameters were answered. The scores from each parameter were processed by the equation as follows [10]:

The risk index = I × Ip × DP [10]. Invasiveness (I), the total score is divided by 15 and multiplied by 10; Impact (Ip), the total score is divided by 19 and multiplied by 10; Distribution potential (DP), total score.

One of the parameters to obtain F (feasibility index) is the actual distribution (AD) of invasive species. The AD value was determined in percentage units using the following formula [16]:

$$\text{Percentage of AD} = \frac{\sum_j^i F_i A_j}{A\,PNR} \times 100\%$$

with,   Fi = Frequency of species,
          iAj = Area of ecosystem where species found (ha)
          A PNR = Area of Papandayan Mountain Nature Reserve.

F was obtained after answering all questions from three related parameters using formula as follows [10]: **The feasibility index = C × IPD × P**. Control Cost (C), the total score is divided by 15 multiplied by 10; Actual Distribution (AD), the total score is divided by 12 multiplied by 10; Persistence (P), the total score is divided 11 multiplied by 10. Risk Index and Feasibility index categorized as showed in Table 1 [10].

The R and F score obtained were classified into the following categories [10]: The higher the value of R showed a higher risk of invasive species, while the higher the value of F showed lower feasibility to manage invasive species. The recommended strategy of invasive species management was determined based on the matrix of score and category of R and F, as shown in Table 2 [10].

3. Results and discussion

3.1. Invasive Species in Papandayan Nature Reserve

There were six invasive species belong to three families of Asteraceae, Poaceae, and Rosaceae grow in Papandayan Nature Reserve (Table 3). The invasive species mostly grew in an open area of the grassland, but none in the vegetation at the edge of crater. The grassland area has been disturbed in the form of forest fires and has open vegetation cover so that 6 invasive alien species can be found in this area because invasive alien species are relatively easy to grow in the open and experience disturbance [3] The type of soil conditions in the edges of the dry craters was considered not suitable for invasive species to grow [10, 17]. One of the factors that prevent invasive alien species from growing and spreading is unsuitable abiotic conditions [17]. In Cisupabeureum forest area, only two invasive species, i.e. *A. riparia* and *A. adenophora* had grown because of the coverage of vegetation is difficult to make other species grow [3].

3.2. Invasive Species Risk Assessment

Based on the calculation of Risk Index, the invasive species in Papandayan was categorized as low risk (*A. conyzoides*) (4.18), to high risk (*A. riparia* (Regel) R.M.King & H.Rob.*)* (154.22) (Table 4). *A. riparia* has the highest Risk index, which means that its ability to invade a new habitat is considerably high. *A. riparia,* a shade-tolerant plant, can also appear on disturbed forest habitats [18, 19]. The species is also a prolific seeder and grows very fast compared to other invasive species [20-22]. Additionally, *A. riparia* can suppress the growth of other species due to its rapid and high-density growth, dominating ground covers among the locations [23]. In our research, *A. riparia* grew in a large area, and based on an estimated calculation, its potential distribution resulted in more than 50% of study area. The species was tolerant of shade. The branches of each individual *A. riparia* plants intertwined with each other, producing a blanket effect with 100% ground covers. This means that the seeds of other forest species may not be able to reach the soil to initiate germination [23]. Other invasive species that are not tolerant of shade require open land and high light intensity to grow such as *A. adenophora* can be established in open areas, forest areas, forest edges, and clearing disturbed areas [24].

The feasibility control of invasive species in Papandayan varied from the low to the high. The Feasibility Index of *A.riparia* was found to have the highest score (226.90), compared to other invasive species (Table 5). This indicates that the feasibility of management *A. riparia* in Papandayan is low, or substantially difficult to implement. This is could be related to *A. riparia* widespread distribution. In another study, the widespread growth species of *Dioscorea centruroides* had low management feasibility [16].

A. riparia was considered to spread widely in Papandayan. In our study, the species grew in three locations of sampling area, i.e Tegal Alun, Pondok Salada and Cisupabeureum. In contrast, other invasive species was usually only found in one or two sampling areas. Based on our research, the percentage distribution of *A. riparia* was predicted to be amounting to 50-60% of study area. Further *A. riparia* was found to produce an allelopathy compound i.e. phenolic *O-Coumaric acid (2-hydroxycoumaric),* which can inhibit the growth of other species [25, 26]. *A. adenophora* invaded 30-40% of land, mostly in open areas in grassland (Pondok Salada) and *A. inulaefolium* invaded 19% of the land. The number was only scattered in grassland areas *A. conyzoides* (1%), *I cylindrical* (9%) and *R. mollucanus* (24%) were found to be localized only in Pondok Salada. Control costs are not too high because the distribution is not too broad.

The traditional management of invasive species in Papandayan can be considered a solution. This is usually done through a mechanical control method, by slashing or cutting using a simple local equipment called *parang*. The predicted cost can amount to Rp 600,000,- per day. The costs were calculated based on the wages of labors at Rp. 100.000/day, multiplied by the number of workers, at six people.

Based on the matrix of recommendation management, Risk Index, and Feasibility Index, there are four recommendations for managing invasive species in Papandayan; managing its invasive species, managing the location of the growing place, performing limited action to the location of the growing invasive species; and lastly, monitoring (Table 6).

Table 1 Classification of risk and feasibility indices [10]

Risk Score	Category	Feasibility Score	Category
>192	Very high	>113	Very low
101 – 192	High	56 – 112	Low
39 – 100	Hose	31 – 55	Medium
13 – 38	Low	14 – 30	High
< 13	Very low	<14	Very High

Table 2 Matrix of Invasive Species Recommendations of Management [10]

Risk Index	Feasibility Index				
	Very low >113	Low 56-112	Medium 31-55	High 14-30	Very high <14
Very low <14	Limited action	Limited action	Limited action	Limited action	Monitoring
Low 15-38	Limited action	Limited action	Limited action	Monitoring	Monitoring
Medium 39-101	Manage location	Manage location	Manage location	Protect location	Contain spread
High 102-192	Manage species	Manage species	Protect location	Contain spread	Destroy infestation
Very high >192	Manage species	Protec location and manage species	Contain spread	Destroy infestation	Eradicate

Table 3 Index Value (IV) of Invasive Species in Papandayan Nature Reserve

Species	Family	IV (%)		
		Grassland	Crater side	Forest
Ageratina riparia (Regel) R.M.King & H.Rob.	Asteraceae	56.50	-	58.40
Ageratina adenophora (Spreng.) R.M.King & H.Rob.	Asteraceae	51.71	-	43.20
Rubus moluccanus L.	Rosaceae	22.92	-	-
Austroeupatorium inulaefolium (Kunth) R.M.King & H.Rob.	Asteraceae	19.70	-	-
Imperata cylindrica (L.) Raeusch	Poaceae	16.70	-	-
Ageratum conyzoides (L.) L.	Asteraceae	1.33	-	-

Table 4 Risk Index and Category of Invasive Species in Papandayan Nature Reserve

Species	Parameters			Risk Index	Risk Category
	Invasiveness	Impact	Potential Distribution		
A. riparia	7.33	2.63	8	154.22	High
A. adenophora	6	2.63	4	63.12	Medium
I. cylindrical	5.33	2.63	1	14.01	Very low
R. mollucanus	5.33	1.05	2	11.19	Very low
A. inulaefolium	5.33	1.05	2	11.19	Very low
A. conyzoides	5.33	1.57	0.5	4.18	Very low

Table 5 Feasibility Index and Category of Invasive Species in Papandayan Nature Reserve

Species	Parameters			Feasibility Index	Feasibility Category
	Control Cost	Distribution	Persistence		
A. riparia	6	6.66	4.54	182.21	Very low
A. adenophora	4.67	5	5.45	127.25	Very low
R. mollucanus	3.33	3.33	4.54	50.34	Medium
I. cylindrica	4	1.67	4.54	30.32	High
A. inulaefolium	4	0.83	4.54	15.07	High
A. conyzoides	3.33	0.41	3.63	4.95	Very high

Table 6 Recommendation of Invasive Species Management in Papandayan Nature Reserve

Species name	Risk Category	Feasibility Category	Recommendation of Management
A. conyzoides	Very low	Very high	Monitoring
I. cylindrical	Very low	High	Limited action
R. mollucanus	Very low	High	Limited action
A. inulaefolium	Very low	High	Limited action
A. riparia	High	Very low	Manage species
A. adenophora	Medium	Low	Manage location

Management recommendation to manage invasive species for *A. riparia* is aimed to reduce the environmental, economic, and social impacts of invasive species. This particular management approach is recommended by [10] especially for invasive species with high risk categories. The control feasibility of *A. riparia* is considered significantly low, due to its already-expanding distribution, thus causing considerable difficulties to control. Mapping of priority management locations can serve as a solution. This is done by modelling the distribution of species to configure the main environmental factors which affects the invasive species distribution [27, 28]. Another way is through mechanical controls, such as physically uprooting small plants and disposing them either by before the flowering of *A. riparia*. Cultivation, grubbing, hoeing, burning, replanting competitive pastures, or replacing *A. riparia* with native species can also prevent re-infestations [29]. Another management effort is to regularly monitor the cleaned areas every month [10].

Management location is recommended for *A. adenophora* aim to maintain environmental conditions of the conservation area [10]. This recommendation focuses more on location management, due to the lower potential distribution of *A. adenophora*. Mapping out the distribution of *A. adenophora* in Papandayan can be implemented [10, 15]. Management can also be done by slashing the seeds and flowers as they emerge, as well as clearing of colonization areas [22]. Utilization of biological control agents can be implemented by using the *Procecidocares utilis* flies and the *Eupatorii cercospora* mushrooms, considered as natural enemies to

inhibit the growth of *A. adenophora* [30,31]. Limiting the invaded locations of *A. adenopora* from human access is also needed. This reduces the potential of *A. adenophora* being carried by human clothing and footwear to other places [23].

The recommended management of *I. cylindrica, A. inulaefolium,* and *R. mollucanus* is to perform limited actions aimed at reducing potential distribution invasive species to all research locations. This can be done by collecting the species bio-ecological data and analyze its response to management, to determine the best time for control [27]. Another method is by periodically monitoring the distribution of three species in Papandayan [10,15].

The monitoring recommendation for *A. conyzoides* is to detect changes in the risk of invasive species [10]. Generally, monitoring applies to species that have high management feasibility but with a low risk, therefore it does not necessarily need to be eradicated. Monitoring efforts can be implemented by making a permanent sample plot to monitor the spread of *A. conyzoides* [25], or by reviewing the invasiveness changes of *A. conyzoides* through a risk assessment within a certain period [32].

The recommendations above require continual monitoring efforts to detect threats of invasive species at the earliest possible time and evaluate any action that has been taken. These recommendations can become the foundational effort to control invasive species in Papandayan. This will further protect conservation areas in West Java. The role, support, and awareness of the threat of invasive species from various parties are needed. Therefore, dissemination, information exchange, and transfer of knowledge about invasive species

are significantly important efforts in preventing the spread of invasive species in Papandayan Nature Reserve.

4. Conclusion

There are six invasive species within the area of the Papandayan moor i.e *Ageratina riparia Ageratina adenophora, Austroeupatorium inulaefolium, Imperata cylindrica, Rubus mollucanus* and *Ageratum conyzoides.* Recommendations towards the management of invasive species in Papandayan Nature Reserve depends on the character of each species. *A. riparia* is managed by managing the invasiveness of the species. *A. adenophora* is managed through the location its growing location. The management of *I. cylindrica, R. mollucanus* and*, A inulaefolium* is focused on limited actions. Finally, *A. conyzoides* can be managed effectively by periodical monitoring. *A. riparia* will need to be managed in the highest priority in Papandayan Nature Reserve, due to the highest risk of invasiveness (154.22), with low feasibility of control (182.21).

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