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Turning the invasive alien species challenges into local opportunities: a case study of the enclave villages in Bromo Tengger Semeru National Park

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Abstract

Apart from its adverse impact on biodiversity in an ecosystem, the presence of Invasive Alien Species (IAS) can be a blessing in disguise for local communities. Its daily utilization, including for traditional medicine needs, is a crucial factor in how the existence of Invasive Alien Species can be a game changer for the local community. This research took place in a national park, Bromo-Tengger-Semeru, Indonesia, and focuses on an enclave village inhabited by the indigenous Tengger people. It aimed to evaluate how the presence of Invasive Alien Species, specifically fennel (*Foeniculum vulgare*) and slimmer weed or kirinyuh (*Chromolaena odorata*), has adverse impacts on the natural environment but potentially has positive impacts on the community's socio-economy. The research was conducted through a literature study referring to a semi-structural literature review based on the Scopus database and descriptive analysis based on the interviews with various key informants, which included the national park management, local government at the village and sub-district levels, NGO representatives, and community group who understand and directly utilize IAS plants. The results showed that based on the literature review, research on IAS, especially Fennel and slam weed, is still very limited. Those two species have embedded connections with the locals. In addition to its economic potential, utilizing IAS plants for traditional medicine and ritual completeness for local communities is a critical factor that makes its existence need to be better managed. At this point, a more integrative alternative management of the area was proposed as the way forward.

Keywords: Bromo-Tengger-Semeru National Park, *Chromolaena odorata, Foeniculum vulgare,* Invasive Alien Species, Tengger Community

1. Introduction

Invasive Alien Species (IAS) or Alien Invasive Species (AIS) are species whose presence and distribution affect and threaten aspects of biodiversity in an ecosystem [1]. These IAS or AIS can be plants or animals [2–4].The presence of IAS in an ecosystem often becomes a "disease" that disrupts the existence of endemic or native species. The magnitude and significance of adverse effects of IAS on native species vary and depend on the characteristics of the landscape, ecosystem, and human response to their presence.

IAS plants include climbers, trees, shrubs, and herbs [5] or aquatic species [6]; due to their massive distribution, they can displace endemic species and threaten the biodiversity of an area. For instance, IAS plants are "becoming a threat to the native flora" [5,7]. Even worse, IAS plant species can be considered a deadly disease or "green cancer" in the region, such as the species *Miconia calvescens* (velvet tree or bush currant) in Brazil [8]. Meanwhile, the presence of IAS animals affects endemic animals, one of which is due to the aspect of daily consumption/diet; for example, the following *Didelphis aurita* (Big-eared opossum) was disturbed by the presence of *Sus scrofa* (wild boar) [3,4], or the presence of *Canis familiaris* (domestic dog) that disturbs *Chrysocyon brachyurus* s(maned wolf) [3].

The presence and spread of IAS arise due to natural factors, but can also be intentional. For instance, because an IAS species has a high economic value, it is cultivated, even into large-

scale plantations, such as cacao, coffee, black paper, cloves, and teak wood in Tanzania [9], Eucalyptus di Western Ghats of India [10], or Albacia wood and cinnamon in Western Indian Ocean Islands [11]. In this situation, the IAS issue requires consideration of a wiser solution regarding how the trade-off between biodiversity goals can accommodate aspects of the economic potential generated by IAS, especially for local communities.

Given the limited knowledge of this issue, this research highlights the above issue. Current studies on IAS are still limited, primarily aiming to understand invasive alien species' distribution and abundance pattern*s* [2,12,13], which is generally helpful for strategic management or future planning [4,13]. There is not too much research that discusses how the initial response to the existence of IAS., including what the profit calculation is like in the process of utilizing IAS, especially if it appears in a protected area, which certainly has special provisions related to efforts to maintain the continuity and balance of natural/native ecosystems.

This research aims to (1) Record issues regarding research on IAS in protected areas, with a focus on Indonesia; (2) Identify the characteristics of IAS in Bromo Tengger Semeru National Park, especially in research areas, Ngadas and Ranupani Villages; (3) Assess the potential handling of IAS that refers to local-livelihood characteristics.

2. Materials and Methods

This research employs three approaches to answer research questions. First, a secondary data analysis approach using the Scopus research database provided an overview of research issues regarding IAS in Indonesia. Second, to find out the characteristics of IAS, a field survey was conducted at the research location, and interviews were conducted with the key interviewees. The third step was formulating a strategy for handling IAS, mainly by interviewing relevant interviewees.

Surveys and interviews were conducted over two months (May-June 2022), focusing on the research area's natural-environmental, social, and economic aspects. Interview segments included local communities, national park managers, external actors from the government, practitioners including NGOs, and academics from local universities. The interview material focused on the fundamental aspects of the region, protected area management issues, and specific questions related to IAS. This step is intended so that the IAS issue can be addressed more comprehensively, and the solutions raised can be more balanced.

Beyond the interview sessions, research information was also obtained through public speaking events organized by the national park management and online discussions with the key interviewees. Attending events allows us to interact directly with many parties. In contrast, continuous communication through online media such as Facebook allows researchers to be current regarding the latest developments of the issues discussed. Information gathered through this alternative scheme was collected until January 2024.

3. Results and Discussion

3.1. Result

3.1.1. IAS research in tropical protected areas around the globe

There has been quite a lot of research on IAS worldwide, but on the contrary, it has not been viral in Indonesia. Referring to the Scopus database analysis using the combination of term or key word/s of IAS AND Indonesia, we found a total of 75 documents consisting of journal articles, book chapters, and conference articles indexed by Scopus. Of these, with the combination of the terms IAS AND Indonesia AND protected area, we only found eight documents. This result proves that many spaces and subjects related to IAS in Indonesia can still be researched.

Further related to the focus of IAS raised in this research, the discussion of specific IAS species found diverse findings from the Scopus database, although with similar patterns. For instance, using the terms IAS AND *Verbena brasiliensis*, we only found 1 document article

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that uses the case in Turkey. For another IAS species, namely, with the combination of IAS. AND *Chromolaena odorata*, we could identify 105 documents, with five documents of scientific articles, using case studies in Indonesia. Furthermore, using the terms IAS AND *Salvinia molesta*, we found 21 documents, but only 1 document was used for a case in Indonesia. Subsequently, for the term species *pinnata*, we only found two documents, none addressing Indonesian cases. Based on the above findings, it can be concluded that the species *Chromolaena odorata* is the most popularly researched, followed by the species *Salvinia molesta*. However, there are still minimal cases in Indonesia. The IAS species *Verbena brasiliensis* and *Azolla pinnata* are still less discussed in Indonesia and globally.

3.1.2. IAS in the Bromo Tengger Semeru National Park: Biodiversity Problems with Advantages Offered for the Surrounding Traditional Communities

Bromo Tengger Semeru National Park is one of 55 protected areas in Indonesia (https://jasling.menlhk.go.id/). The park protects several rare and endangered species, such as the Javan eagle (*Nisaetus bartelsi*), javan leopard (*Panthera pardus melas*), and several endemic orchid species, such as *Malaxis purpureonervosa*, *Habenaria tosariensis*, and *Macodes petola* explicitly. The national park is in East Java Province, covering four districts (Malang, Lumajang, Pasuruan, and Probolinggo) with a total area of 50,276.3 ha. The BTS National Park Administrator manages the area under the Ministry of Environment and Forestry [14,15], which has recently gained popularity as one of the priority destinations of the 10 New Bali program [16].

Mount Semeru is the mountain with the highest peak in Java (3,676 meters asl.), and Ranupani Village is the last village and the starting point of the climb. Mount Semeru mountaineering is another alternative that is no less attractive, primarily supported by free promotion through some popular movies [17]. However, the attraction is because this area is inhabited by the Tengger tribe, which has various unique traditions that appeal to tourists [18,19].

The Tengger people have a solid attachment to their natural environment, including the natural resources in the national park forest [20]. In addition to daily needs, such as building materials and firewood, they exploit various natural resources for consumption, ritual purposes, and traditional medicine [20,21]. Some endemic plants and animals are used explicitly for this purpose. For instance, Edelweiss, putihan and others are used for Karo or Kasada ceremonies/ rituals [22,23]. At the same time, many kinds of plants can be used for traditional medicine [24–26]. In the past, when this location was isolated, the Tengger people relied much more on traditional medicine and herbs than on medical treatment, which was very difficult and limited [25].

Due to the increasing severity of the problem, national park managers have recently paid close attention to the issue of IAS. The following section explains several types of IAS, their distribution, and the problems they cause.

1. Settlement environment

Some of the IAS plants can be found easily in the settlement area. The most dominant ones, however, are fennel and kirinyuh. These two plants have slightly different characteristics and distribution patterns. Fennel is categorized as an IAS but is less recognized by the local community because it is so long and tied to the use of this plant in the Tengger community. Even the village's name, Ngadas, was inspired by this plant's existence. Fennel distribution is massive and generally located along the main road from Jemplang to the Mount Bromo area, both through Malang and Lumajang as seen at Figure 1(a). Fennel, generally known in the Javanese cultural repertoire as adas pulowaras/ pulosari, has long been known as a medicinal source for various purposes, including coughing, bloating, and colds. This material has also been around for a long time. This ingredient has also long been used in modern medicine mixtures, such as telon oil, produced industrially by various high-tech national herbal industries.

The community and the national park management have distinct perspectives on this plant. The Tengger people consider this plant ordinary, especially its various traditional medicinal

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benefits. On the other hand, national park management is concerned about the massive spread of this species, which dominates the area's landscape around Jemplang Block.

Kirinyu*h* plant distribution, on the other hand, is more massive than Fennel. It is not just along the road but also into forest areas, including in the traditional zone, utilization zone, buffer zone, and even in parts of the core zone of BTS National Park as seen at Figure 1(b). Massive deforestation in the past, especially post-1999 reforms, has made tall-standing trees rare in this area [20].[1] As a result, in addition to cultivated crops, kirinyuh dominates the landscape. Its presence dramatically pressures several endemic plants in the Solanaceae, Rubiaceae, Verbenaceae, and Zingiberaceae families (see: https://bromotenggersemeru.org/page-static/flora).

Figure 1. Fennel plant distribution in a cultural object of the Tengger community (a), simultaneous distribution of fennel and *Kirinyuh* plants around the Jemplang Block (b).

Instead of its potential utilization as a traditional medicinal ingredient, the population has limited utilization due to limited knowledge [24]. They have little idea that this plant has medicinal functions that benefit them. However, in the end, traditional healers with knowledge and processing skills constantly utilize these potentials [23,24]. At this point, Knowledge (shamans vs. ordinary people) becomes the distinction. Knowledge becomes power, and this is also what has happened on-site. Specifically, various modern pharmaceutical factories request the existence of traditional medicinal plants. As a result, many forest encroachers search for these medicinal plants in the BTS National Park forest area. Most of them come from outside the village.[2] This situation happens for two reasons: firstly, related to customary rules that are (more) binding on residents of enclave areas, and secondly, in general, enclave villagers are already quite busy with their agricultural activities, and the addition of the tourism sector has recently emerged.[3]

To eradicate this, the BTS NP manager accommodates this effort in the Conservation Partnership policy [27].[4] The policy, which is based on the Regulation of the Director General of Natural Resources and Ecosystem Conservation Number P.6/KSDAE/S.E.T./Kum.1/6/2018 concerning Technical Guidelines for Conservation Partnerships in Nature Reserve Areas and Nature Conservation Areas, is in the form of granting permits for the utilization of non-timber natural resources (NTFP) in traditional zones or blocks or utilization in the BTS NP area from the NP manager to local community groups.[5] One management point is replacing kirinyuh plants with endemic Mountain Spruce plants. Furthermore, these kirinyuh plants are converted into charcoal briquets, which add functional, economic, and ecological value.[6] Functional, because the local community traditionally needs it as a substitute for firewood, economical, and because the demand for charcoal briquettes is also relatively high, it has the potential to be sold. Charcoal briquettes also have an ecological function because this policy concept is very strategic in answering the problem of pressure on protected areas due to the massive kirinyuh as IAS and reducing the local community's need for heating materials for

[1] Interview with R2, 2022
[2] Interview with L3, 2022
[3] Interview with L1, 2022 [20]
[4] Interview with A1, P1, 2022
[5] Interview with A2, 2022
[6] Interview with A6, M4, 2022

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themselves and their homes that were previously taken by the community from firewood taken from the national park forest area.

2. Area of the Mt. Bromo's slope

The location of this area is in the form of a savanna, with one of the famous tourist attractions being Teletubbies Hill or Watangan Hill in the local toponymy [28,29]. The most dominant IAS in this area is *Acacia decurrens*.[7] The appearance of this native Australian plant is quite distinctive in terms of colour and height. It tends to be taller and dark green than savanna areas, generally shrubs with brighter / lighter colours as shown in Figure 2.(a) and (b). Generally, local people secretly use it as firewood, even though customary rules do not allow it.[8] Nevertheless, in principle, the manager is more supportive of the eradicalization of this plant in the landscape.[9] However, due to limited understanding, the management never openly recommends that residents do so. Local people's lack of understanding of the distinction between one plant and another can trigger worse deforestation because local people can mindlessly cut down any tree for their daily firewood needs. This fact is consistent with an interview with one of the managers: "We have to be careful when giving directions to local people; we (managers) might talk to one of the local people to allow him to cut down an acacia tree (*Acacia decurrens*); and as a result, 100 different people cut down and exploit all the trees on a hill, because of their lack of understanding" (Interview with A3, 2022).

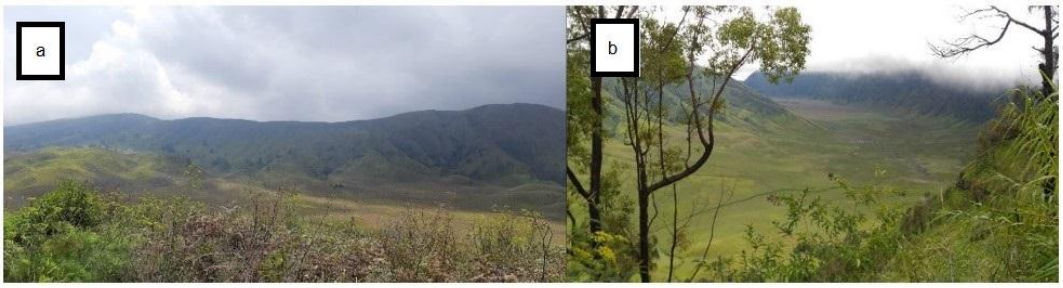

Figure 2. The slopes of Mount Bromo (a) and the Savannah landscape are dotted with several *Acacia decurrens* IAS spots (b).

Verbena brasiliensis vell is a plant that, on the one hand, is very invasive in its distribution but tends to be attractive in its physical appearance. Many hikers enjoy the beauty of its appearance, especially on the Oro-oro Ombo Savannah hiking trail as shown at Figure 3.(a). However, the national park management has a different idea, considering how aggressively this plant dominates the landscape, inhibiting endemic plants' existence and growth of endemic plants. Its massive spread covers an area of 20 hectares, significantly impacting the overall ecosystem balance.

Over the last five years, policies have been implemented to eradicate them. For example, mass movements from various parties can uproot these plants by their roots as shown at **Figure 3**.(b). It has also begun to promote active participation schemes to climbers instead of the Edelweiss that had been targeted. This appeal allows climbers to participate in solving the biodiversity threat in this protected area. Participation is achieved by uprooting and bringing down the AIS plants from the slopes of Mount Semeru. Something exciting, considering the appearance of the AIS *Verbena brasiliensis* is outstanding, similar to lavender. Picking flowers of this plant is like allowing hikers to get souvenirs of flowers for lovers waiting downtown. Although the contribution may not be maximal, at least this promotion can bring awareness to climbers and local communities about the IAS issue, as stated by one of the interviewees: "Mount Semeru climbers also have a responsibility to the environment around the area, and their contribution in reducing IAS plants is becoming one of the best alternatives." (Interview with A4, 2022).

[7] Interview with L1, 2022
[8] Interview with C5, C9, 2022
[9] Interview with A7, 2022

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Figure 3. Figure 3. Oro-oro Ombo Savannah Landscape with *Verbena brasiliensis* distribution (a) and Eradication of this plant by national park rangers (b). (https://nasional.tempo.co/ and https://ksdae.menlhk.go.id/, 2018)

3. Lake Area

Ranu Pane Lake has long been a reference for Semeru hikers to take a moment to unwind before the main climbing event [30]. The lake has also long been the primary water source for the Ranupani villagers (which shares its name with the lake) [31,32]. Unfortunately, in the last two decades, Ranu Pane Lake has experienced siltation problems, one of which is caused by the presence of IAS, *Salvinia molesta* or giant salvinia as seen at Figure 4.(a). This IAS, originally from south-eastern Brazil, proliferates uncontrollably, which in turn implies not only silting up the lake surface but also narrowing its area,[10] reducing the supply of clean water for residents' needs, and worst of all, triggering and aggravating flash floods in the highest village on Java Island, including on January 25 and October 8, 2022. Besides S. *molesta*, the lake also has another AIS, *Azolla pinnata*, which is smaller. However, the destructive power of *Azolla pinnata* is no less than that of *Salvinia molesta*. Under certain conditions, the extreme population of both AIS can even inhibit the growth of fish species in the lake, which has also become an alternative source of protein for the villagers. Of course, this is increasingly detrimental to the environment and the community's economy.

Figure 4. Lake Ranu Pane silting up (a) and mass Salvinia molesta eradication process (b).

As a commitment to eradicating weeds, the park manager's website reports that some cleaning activities were carried out jointly by involving many actors, including the BTS Park manager, representatives of the army and local police, NGOs, academia, various communities, tourism and environmental activists, and local villager with a total of 200 participants as shown at Figure 4.(b). The extremity of this issue has even attracted JICA (Japan International Cooperation Agency) to participate and contribute to solving this problem [33]. Through an activity called Restoration of Ecosystem in Conservation Areas (RECA) and collaboration with the BTS Park manager, this organization involves local actors in finding solutions to existing problems. Unfortunately, there has been no follow-up or formulation of long-term solutions.

[10] Based on BTS Park Manager information (2022), an extreme reduction in the size of Ranu Pane Lake, from 7 Ha (2015) to only about 3.5 Ha (2022).

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3.1.3. The potentials: AIS for supporting a more local, sustainable livelihood

IAS plants can interfere with naturalized plants, but some are noxious [5]. This fact means that in one situation, they tend to be detrimental (e.g., to ecosystems and other plants), but in other situations, they can be helpful, have value, and be used for something positive. This fact also applies to the various IAS plants present at the site.

The above description clearly illustrates how the various IAS discussed have harmful, extremely expansive properties that disrupt native plants or other species and the area's ecosystem. However, these IAS have actual (potential) economic value. Some of these potentials have been realized through special program assistance from the Ministry of Environment and Forestry through the BTS National Park manager. In contrast, others still require detailed studies to be explored realistically. The following are some discussions and calculations that can be presented in the efforts of the IAS plants above.

Charcoal briquettes from kirinyuh plants are a product that is not only environmentally friendly but also has a decent economic value. Although the process is rather complicated, if supported by various parties consistently, it will undoubtedly be able to obtain adequate economic value. As an illustration, the price of kirinyuh charcoal briquettes is IDR 6,000-8,000/kg. The total value obtained can be immense, with abundant raw materials from more than 30 hectares of land. It all depends on the production and marketing performance. The existence of the Bromo area as a tourist location with cold temperatures and the highly developed online buying and selling system is undoubtedly a significant supporting potential. Not to mention that Kirinyuh also has medical functions, where theoretically, kirinyuh leaves contain flavonoids, alkaloids, terpenoids, and polyphenols. The above compounds have anti-cancer, anti-inflammatory, and antioxidant benefits, accelerating wound healing [34]. Of course, this is an additional potential that residents must maximize. As an illustration, kirinyuh leaves are sold at the online market at IDR 10,000-15,000/ Kg in wet conditions and dry form, the price can even reach IDR 75,000-90,000/kg. From here, we can imagine how great the economic potential of kirinyuh would be if the local community could maximize it.

The same pattern also applies to Fennel, which has antifungal, antibacterial, antioxidant, antithrombotic and hepatoprotective benefits [35]. This plant has an advantage in terms of appearance and aroma. Physically, this plant can be sold as an attractive ornamental plant. Moreover, it is supported by an aromatic characteristic that fits as therapy. This advantage is undoubtedly an additional opportunity besides making it for the supply of the large traditional medicine industry. Residents may be able to sell it directly in the fresh plant form or by processing it into powder first. As an illustration, the price of fresh fennel plants in online marketplaces is IDR 7,500-15,000 per plant. Meanwhile, the added value is much higher in powder form, at IDR 50,000-80,000/kg.

Slightly different conditions apply to *Acacia decurrens* and *Verbena brasiliensis*. Despite their potential physical appearance, there are difficulties in exploiting their development. At least three reasons that hinder their optimization are related to the position and composition of IAS plants in the overall landscape and the short-lived nature of the plants. *Acacia decurrens* has a profile that is useful not only in supporting physical appearance, but also on Teletubbies Hill. The charm of this hill is even more perfect when there are spots of this plant.

For this reason, its radicalization requires more careful consideration, both from a technical perspective and from aspects of landscape design considerations. The challenge of utilizing *Verbena brasiliensis* is more in the position of the Oro-oro Ombo Savannah location, which is quite far away. The running process of this scenario is more about how to make the process exciting and profitable for climbers. This voluntary participation scheme is rather challenging to implement, given the high likelihood that the *Verbena brasiliensis* flowers from Oro-oro Ombo will have withered when they arrive at Ranupani Village. There is also a risk of the seeds being accidentally scattered in other locations, making the spread even more uncontrollable. We need to think about the best way to materialize these goals so that the biodiversity interests related to IAS plants can synergize with the interests of climbers.

Salvinia molesta and *Azolla pinnata* have different characteristics as aquatic plants. These IAS plants can use specific techniques to support agriculture, fisheries, and livestock activities. Their high protein content allows the plant to be used and converted into a fertilizer that

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adds nutrients [36]. In addition, these plants can also be converted into a food substance, both for fish and livestock [37]. If this scenario works, it will create synergy between sub-sectors, benefiting many parties, especially local communities.

Agriculture dominates the occupation of the population in these two village locations [18,19]. The community is familiar with various plant-related activities, including possibly utilizing these IAS plants. The potential suitability of these activities must be facilitated and mediated by competent parties, mainly to provide awareness of these potentials and guidance, assistance, and technical training on these matters. The constraints are twofold: direct benefits and mental attitude. The agricultural sector, which relies on potatoes and horticultural products, is already very prosperous for local communities [14,15]. This situation complicates efforts to get local communities to shift slightly to maximize the potential offered by something that also happens with the tourism sector's offerings [14,19]. Residents tend to be satisfied (to be precise enough) with the current conditions. Continuous promotion supported by in-depth technical assistance, direction, and mentoring is needed to raise people's awareness of more environmentally friendly, sustainable, and future-oriented livelihood alternatives.

3.2. Discussion

3.2.1. Research on IAS plant: seeing from a different perspective to fill the gap

Research linking the presence of IAS with indigenous peoples is limited. Indonesia is a highly biodiverse country whose database needs to be improved in terms of its characteristics and uses [38,39], including, in this case, its value to society. On the other hand, Indonesia also has indigenous/traditional communities that utilize and are attached to various traditional plants, some categorized as IAS. This situation means that efforts to continue learning more about the benefits of IAS, especially for traditional communities, are strategic for affirming the existence of indigenous peoples.

Not only that, but this knowledge can also be an alternative to locally based livelihoods, which is synergistic with efforts to remove dependence and the adverse effects of externalities on indigenous peoples. Exploration of research themes relevant to this should be supported and, at the same time, involve other relevant actors more broadly. Universities must collaborate with various parties in their operation to prevent the further marginalization of the position of Indigenous peoples due to the narrowing and limitation of their livelihood alternatives.

Exploring as much research as possible on the use of IAS plants for indigenous peoples can also be seen as a process of transition and adaptation of these communities to modernization. This process is crucial to prevent the culture shock that they would likely experience if they were to move from a society that is highly dependent on nature to a modern society that tends to be consumptive, instantaneous, and detached from nature.

3.2.2. To be centered or dispersed?

The discussion on the distribution of IAS plants in the landscape always ends on the criteria of IAS itself, namely 1a) species that should be eradicated/combated, (1b) species that should be controlled/destroyed, (2) species that need permits for its use, and (3) species that can exist in specific locations only, prohibited to be extended. Based on these criteria, this consideration becomes important concerning the technical management of its utilization. Each IAS plant discussed tends to have multiple functions, both from a cultural and economic perspective. However, it has in common that it is detrimental from an environmental perspective, referring to its invasive nature.

This article aims to show the potential economic value that plants can offer in a protected area landscape with different typologies. Referring to this, criteria (2) and (3) are the most likely categories. However, consideration of the habitat suitability of a species is also influenced [2].

Referring to the discussion above, routine monitoring by a designated party is the keyword. Routine means that it has a fixed/constant dimension according to the nature of the growth of each plant in its habitat. It could be daily to weekly. The appointed party can be a combination of cooperation between representatives of the park manager and residents, if

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they have knowledge and expertise related to the characteristics of plants and patterns of use from the side of residents. This provision will allow plants to be placed in an optimum position, meaning plants will always be available when residents use them. However, their distribution and growth are constantly monitored / not excessive. If it is deemed that the growth is excessive, then control measures can be taken that can guarantee or minimize the potential disturbance of these IAS plants for the ecosystem.

3.2.3. IAS potentials as an alternative livelihood for the local indigenous: how?

IAS plants, such as kirinyuh and fennel, are a daily necessity for the Tengger Indigenous people. These plants have important functions, mainly related to traditional medicine and ceremonial equipment. The opening of potential economic opportunities could reinforce the importance of these plants. The most important challenge now is to determine the appropriate utilization pattern so that the different uses do not overlook the fact that these plants are IAS. For this reason, the zoning and block system established and developed by the national park could be replicated on a more detailed scale.

Not only that, but the above strategy must also be combined with the choice of tourism strategy that is currently also intensively developed in the two villages. However, sometimes, this strategy choice is also problematic [40]. These plants are not just ornamental [41] but can be utilized, such as fennel and kirinyuh.

Using community-based development-based village tourism (42), it is possible to market the finished or semi-finished products from the processed IAS plants directly to tourists. In addition to shortening the distribution system, shortening the market distance, and eliminating marketing costs, this option can also be an alternative to creating and strengthening the image of the tourism village. For example, Ngadas, which already has the trademark of a traditional-based tourism village, will undoubtedly have a stronger image if it is equipped and presents processed products that can be processed for traditional medicine consumption. On the other hand, in Ranupani, the utilization of kirinyuh as a basic material for charcoal making is undoubtedly very interesting as it provides added value both from an economic perspective for the local community, as well as an ecological perspective for the overall environment of the national park [42,43]. The same scheme, of course, with different details based on aquatic habitat, applies to giant salvinia. Several studies have discussed the use of these or similar plants for handicraft products that support tourism programmes in the form of souvenirs [44]. The existence of souvenirs can be maximized to strengthen the identity of the local community.

In the case of *Verbena brasiliensis*, some previous studies have similar characteristics to hiking trails [45,46]. Unfortunately, these two references do not discuss the most appropriate follow-up to this condition. This situation means that the strategic choices made by BTS National Park managers are relatively advanced. We agree with this strategy choice, but evaluating its effectiveness is also necessary. Two considerations are relevant to this situation: (1) The strategy to rely on the participation of climbers to eradicate these plants faces obstacles related to the uncertainty of opening hiking trails due to the high volcanic activity of Mount Semeru itself. (2) The primary challenge is related to the supervision aspect, given the limited human resources of the BTS National Park manager staff. In early 2025, there was a proposal regarding the obligation for (prospective) climbers of Mount Semeru to be accompanied by personnel (staff/residents) appointed by the manager. Unfortunately, this policy was deemed unsuitable due to the overly burdensome cost for climbers, which is IDR 300,000/day.

Note that this implementation strategy must first be consistently trialled. Key success and failure factors will be identified from these trials, which can be improved. Indeed, there will be no guarantee of instant success. However, this strategy option can be a middle ground accommodating many interests: important for socio-cultural aspects, safe for ecological Interests, attractive for economic interests and local livelihood.

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4. Conclusions

The study area within the Bromo-Tengger-Semeru National Park has a wide distribution of IAS plants that disturb the existence of native species and the balance of the ecosystem. Still, this negative impact is less recognized by local communities. Certain plants have important traditional functions for the community to complete traditional ceremonies and traditional medicine. This gap needs to be answered with strategic research that can help mediate and reveal various alternative solutions that connect the two. This connection is needed to position IAS plants as livelihood alternatives that are important for the survival of indigenous peoples, not only in terms of economic and cultural identity. Management of the distribution and utilization of these various plants must still adjust the characteristics of plant life, combined with the conception of CBD-based tourism. Online marketing can be combined with onsite marketing in tourist villages, which can simultaneously diversify products and strengthen the image of the tourist village. Integration with a zoning and block-based governance system from the park administrator is essential to keep the management scheme comprehensive and has a high chance of sustainability.

Author Contributions

EBS: Conceptualization, Methodology, Writing and Editing; **NS**: Conceptualization, Data collection, Review and Editing.

Conflicts of interest

There are no conflicts to declare.

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