

Invasive Alien Plant Species on Hiking Trails in Mount Prau, Indonesia

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Abstract. Hiking tourism activities create habitats that support the introduction of non-native (alien) plant species and encourage their further spread in mountainous areas. Consequently, this will change the species composition of mountain plant communities. This research aims to investigate the richness of plant species and examine alien plant species that have the potential to be invasive on one of the mountains that is popular as a tourist destination, namely Mount Prau, Indonesia. Plant data collection was carried out using exploration methods according to hiking routes. PAST statistical software was used to carry out cluster analysis based on the composition of the plant community species and the composition of invasive alien species. The results of exploration on several hiking routes on Mount Prau found 192 species of plants. A total of 22 species are known to be invasive alien plants dominated by the Asteraceae family. Traditional hiking routes have a higher species richness value than commercial hiking routes for nature tourism. The research results also strengthen predictions that hiking routes for tourism activities have potentially increased the presence of invasive alien species of plants in mountainous areas.

1 Introduction

Hiking tourism activities in mountainous areas are now increasing massively. The increasing preference for mountain hiking causes negative impacts such as garbage, devastation of vegetation, rare plant picking, soil erosion, and destruction of wildlife habitats [1, 2] in mountainous areas. Additionally, the activities of hikers also create habitats that support introducing non-native plants and encourage their distribution in mountainous areas. It could happen because of the possibility that hikers from outside the original area accidentally brought plant seeds from other places during the hiking. In addition, replanting activities in

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mountain forest areas by hikers or base camp management often introduce non-native species to the mountain habitat.

Non-native plant richness varies with the degree of anthropogenic disturbance. In particular, more non-native species are found along hiking trails and camping areas, which are generally subject to intense human activity [3]. For example, the non-native plant *Clidemia hirta* was only found along roads and paths, but no individuals were located on the forest floor only five meters from the pathway [4].

One of the mountains that is popular as a tourist destination is Mount Prau. This mountain is located at coordinates 7°11'13"S 109°55'22"E. Administratively, Mount Prau is located in several regencies, namely Batang, Kendal, Temanggung, Wonosobo, and Banjarnegara Regency, Central Java province, Indonesia. Mount Prau has the highest peak of 2,590 meters above sea level in the Dieng Plateau area. Information regarding floristic data and the originality of plant species on the Mount Prau hiking trails is currently not available; therefore, more detailed exploration needs to be carried out to be used as a recommendation for reforestation or replanting activities in the Mount Prau forest in the future. The study of the originality of plant species and the potential for invasive alien plants along the Mount Prau tourist corridor needs immediate attention so that the negative impacts do not become more widespread. This research aimed to investigate the species richness of plants and analyze the diversity of potentially invasive alien plant species on the Mount Prau hiking routes in Central Java, Indonesia.

2 Materials and methods

This research was conducted in July - August 2023 in the Mount Prau area, including the Regency of Batang, Kendal, Temanggung, Wonosobo, and Banjarnegara, Central Java Province. Data was collected in the forest of several villages surrounding Mount Prau, which have hiking trails to the top of Mount Prau. The research location of Mount Prau has a peak with an altitude of 2590 m above sea level and has good tropical rainforest vegetation. However, in several areas, especially those in the Temanggung and Wonosobo Regencies, the forest has begun to be damaged by converting land to agricultural land. The forest vegetation is still quite good on the north slope, included in the Kendal and Batang Regencies, even though it is already under threat.

Six villages were selected as research sampling locations (Fig. 1) based on the following categories: first, villages with traditional or non-commercial routes, namely Ngelak Bawang village, Batang Regency; Genting Gunung and Purwosari village, Kendal Regency. Second, Villages with official routes that have long been operating for hiking tourism, namely Wates and Igrimranak villages, Temanggung regency, and Dwarawati village, Banjarnegara regency).

The diversity of plants in the Prau mountain tourism corridor was studied based on species richness and the potential for invasive alien species (IAS). Plant inventory data (presence or absence of species) was collected using the exploration method according to the hiking route. Identification of invasive plants used literature guides [5-7]. The PAST statistical program [8] was used to carry out cluster analysis based on the composition of plant species on hiking routes to determine the level of similarity of plant communities and IAS plants among hiking routes.

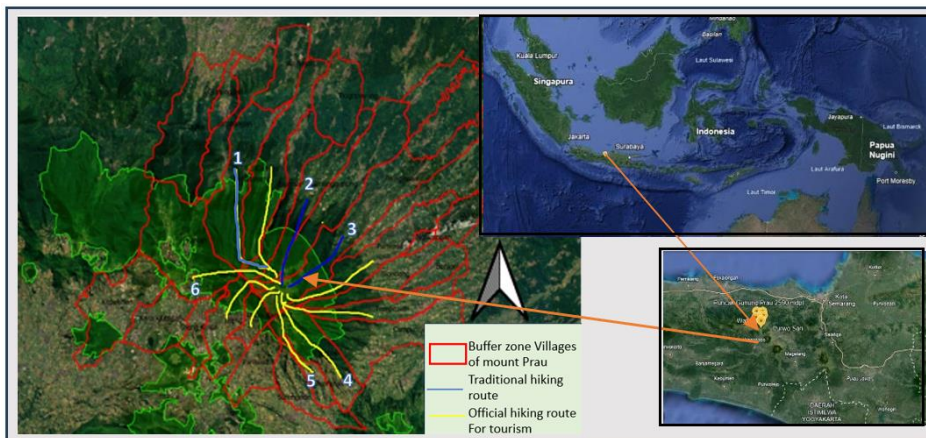


Fig. 1. Sampling location in six villages; (1) Ngelak Bawang, (2) Genteng Gunung, (3) Purwosari, (4) Wates, (5) Igrimranak, and (6) Dwarawati village, Indonesia

3 Results and discussion

An exploration has been carried out to obtain plant species along the hiking trails of Mount Prau. Results showed that 192 plant species in total have been found along the Prau mountain hiking routes, with 22 species categorized as IAS of plants. Traditional hiking routes (Bawang, Genteng Gunung, and Purwosari) have a higher plant species composition compared to commercial routes (Wates, Dwarawati, and Igrimranak) for hiking tourism on Mount Prau, Fig. 2). The highest number of species was found in the Bawang (161 species), while the least was in Igrimranak, which numbered less than 50. On the other hand, the number of invasive alien species is found less frequently on traditional routes than on tourist hiking routes.

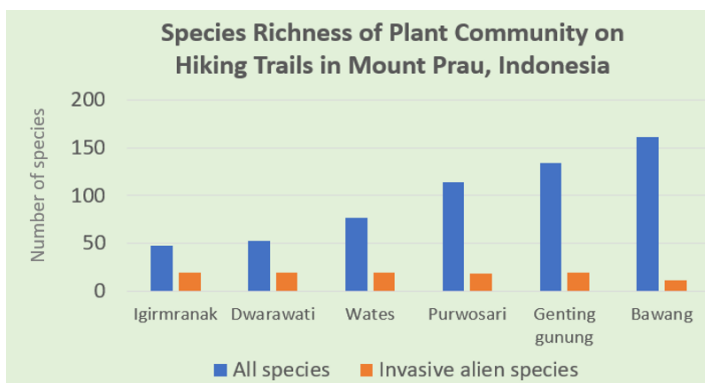


Fig. 2. Species richness of plant community and invasive alien plant species on hiking trails in Mount Prau, Indonesia

Hiking trails that have long been used for tourism have lower biodiversity than new hiking trails [9]. The level of human activity disturbance contributes to the decline in biodiversity. However, at the same time, the activities of hiking tourists increase the number of invasive alien species along the hiking route. Based on the literature which was used to study exotic and invasive plant species, there are 22 plant species found on the Mount Prau hiking route, categorized as alien and invasive plants. Table 1 provides a list of these plant species.

Table 1. List of invasive alien plant species that present (V) and absent (X) for each hiking trail in Mount Prau, Indonesia

No	Species name	Familia	Habitus	Bawang	Genting gunung	Wates	Igirmra nak	Dwara wati	Purwo sari
1	<i>Acacia decurens</i>	Fabaceae	Tree	X	V	V	V	V	V
2	<i>Ageratina riparia</i>	Asteraceae	Herb	V	V	V	V	V	V
3	<i>Ageratum conyzoides</i>	Asteraceae	Herb	X	V	V	V	V	X
4	<i>Austro eupatorium inulifolium</i>	Asteraceae	Shrub	V	V	V	V	V	V
5	<i>Bidens pilosa</i>	Asteraceae	Herb	V	V	V	V	V	V
6	<i>Brugmansia suaveolens</i>	Solanaceae	Shrub	X	V	V	V	V	V
7	<i>Calliandra calothyrsus</i>	Fabaceae	Shrub	X	X	V	V	V	V
8	<i>Centella asiatica</i>	Apiaceae	Herb	V	V	V	V	V	V
9	<i>Cinchona pubescens</i>	Rubiaceae	Tree	X	V	X	X	V	V
10	<i>Cleome rutidosperma</i>	Cappareaceae	Herb	X	X	V	V	V	X
11	<i>Clidemia hirta</i>	Melastomata ceae	Shrub	V	V	V	V	V	V
12	<i>Crassocephalum crepidiodes</i>	Asteraceae	Herb	X	X	V	V	V	V
13	<i>Eryngium foetidum</i>	Apiaceae	Shrub	V	V	V	X	X	V
14	<i>Etilingera coccinea</i>	Zingiberaceae	Herb	V	V	X	X	X	X
15	<i>Eupatorium odoratum</i>	Asteraceae	Shurb	V	V	V	V	V	V
16	<i>Imperata cylindrica</i>	Poaceae	Herb	V	V	V	V	V	V
17	<i>Lantana camara</i>	Verbenaceae	Shrub	V	V	V	V	V	V
18	<i>Ludwigia peruviana</i>	Onagraceae	Shrub	X	V	X	V	X	X
19	<i>Melastoma malabathricum</i>	Melastomata ceae	Shrub	V	V	V	V	V	V
20	<i>Sphagneticola trilobata</i>	Asteraceae	Herb	X	V	V	V	V	V
21	<i>Stachytarpheta urticifolia</i>	Verbenaceae	Herb	X	V	V	V	V	V
22	<i>Tithonia diversifolia</i>	Asteraceae	Shrub	X	V	V	V	V	V

Based on Fig. 3, it is known that the IAS found came from 11 families, most of which are shrubs and herbs (each 45%) and trees only 10%. Asteraceae has the most IAS on the Mount Prau hiking route. The morphology of the fruit and seeds of Asteraceae, some of which have wings and spines, enable them to be easily dispersed by the wind or carried by hiking tourists or animals that use hiking routes as corridors. *Acacia decurens* and *Cinchona pubescens* are IAS trees often found on the Prau mountain hiking route. *Acacia decurens* grow in clusters in areas where land fires have occurred. Fire is essential in breaking the dormancy of hard seeds and producing seedlings of several *Acacia* species [10]. Apart from that, the abundance of *Acacia decurens* trees on Mount Prau is also since the seedlings of this tree were chosen for forest replanting activities by the hiking basecamp management. This species was chosen because it can proliferate and adapt quickly. Public knowledge about invasive alien species is probably still deficient. Interestingly, this species is not found in the Ngelak Bawang route, Batang district. This route is still relatively natural, with limited forest encroachment and forest conversion into agricultural land. *Acacia decurrens* was also reported to be found on Mount Merapi [11-13] and on Mount Merbabu [14].

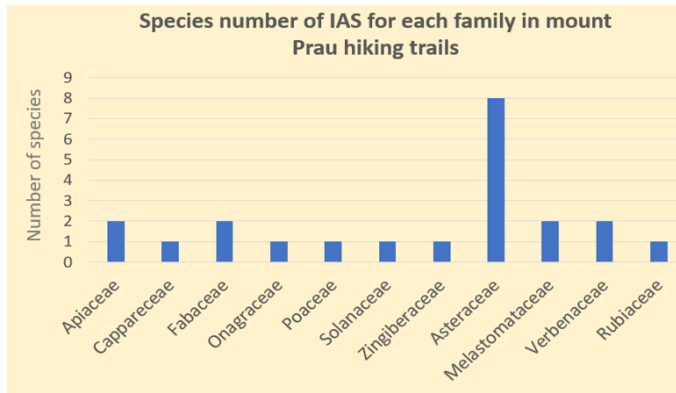


Fig. 3. Species number of invasive alien plant species for each family

Several decades ago, government programs for harvesting non-timber forest products may have caused the abundance of invasive alien plants. For example, the *Cinchona pubescens* species was initially introduced in mountain forest areas as an anti-malarial drug. In fact, according to the Invasive Species Specialist Group (ISSG), *Cinchona pubescens*, *Imperata cylindrica*, *Clidemia hirta*, and *Lantana camara* are recorded as the worst invasive alien species [15]. These four species can be found on all hiking routes on Mount Prau. Nine IAS plants are commonly found on all Mount Prau hiking routes (Table 1 in bold text). *Clidemia hirta* and *Melastoma malabatricum*, both shrubs from the Melastomataceae family, can be found in all habitat species and at various altitudes, up to close to the peak area.

Cluster analysis was used to examine the similarity of plant diversity on Mount Prau hiking routes based on the composition of plant community and alien invasive species (Fig. 4). The Jaccard similarity index for the presence and absence data was chosen in the cluster analysis. The resulting dendrogram shows two large groups; the official commercial routes for hiking tourism are combined in one group, while the traditional hiking routes are combined in another group. This follows what is predicted as one of the impacts of land conversion and the opening of hiking routes for tourism.

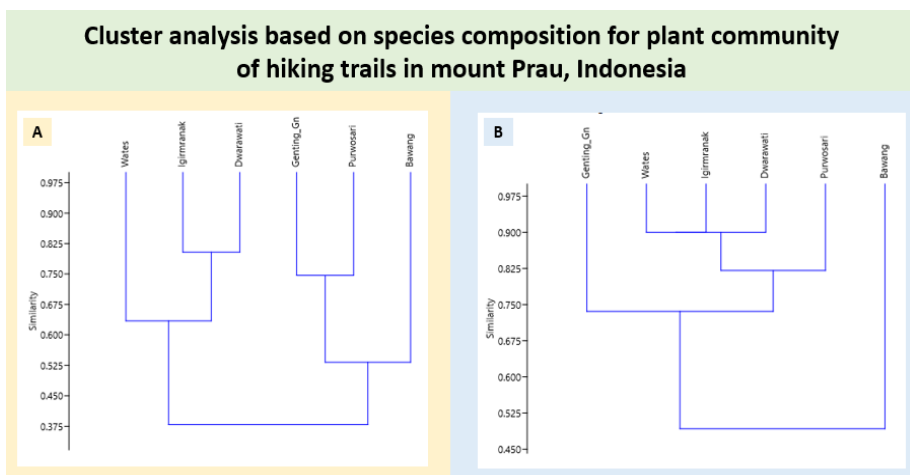


Fig. 4. Cluster analysis based on species composition for plant community of hiking trails in Mount Prau, Indonesia; (A) all species, (B) IAS only

Meanwhile, the resulting dendrogram is slightly different based on the composition of invasive alien plant species. The Ngelak Bawang route is separate from the other groups of routes since fewer IAS are found on this route, which is relatively different from other hiking routes. The Purwosari route is grouped with the three commercial hiking routes with a similarity index of 80%. This is probably because, on the Purwosari route, forest replanting activities are often carried out using non-native plant species. The Wates, Igrimranak, and Dwarawati routes have about 90% similarity based on IAS type composition. Since the three routes are commercial hiking tourist routes that are geographically close to each other, the routes allowed the distribution of IAS species naturally and with the help of humans or animals to be more accessible.

4 Conclusion

This research has investigated the richness of species that comprise plant communities of several hiking routes on Mount Prau, Central Java, Indonesia. It is known that traditional hiking routes have a higher species richness value compared to commercial hiking routes for nature-based tourism. This research also showed that hiking routes for tourism activities can increase the presence of invasive alien species of plants in mountainous areas.

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