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Mapping hotspots of human-wildlife conflict involving porcupines, long-tailed macaques, and humans in the Karst Region of Wonogiri, Indonesia

DIVA GALEH AININDYA[1], MUHAMMAD IRFAN RAHMADANA[1], FARAH MEILANI[1], DISTAYANA ALDA GESTAN[1], ANGGUN DERISTANI[2], AHMAD DWI SETYAWAN[1,3,♥]

[1]Department of Environmental Science, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia. Tel./fax.: +62-271-663375, ♥email: volatileoils@gmail.com

[2]Department of Environmental Science, Faculty of Graduate School, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia

[3]Biodiversity Research Group, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia

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Abstract. *Ainindya DG, Rahmadana MI, Meilani F, Gestan DA, Deristani A, Setyawan AD. 2025. Mapping hotspots of human-wildlife conflict involving porcupines, long-tailed macaques, and humans in the Karst Region of Wonogiri, Indonesia. Intl J Trop Drylands 9: 65-73.* The Wonogiri Karst Area in Indonesia is dominated by forests/shrubs that provide space for wildlife to thrive. However, the presence of species such as Javan porcupines (*Hystrix javanica*) and long-tailed macaques (*Macaca fascicularis*) can lead to conflicts with humans. This study aims to map conflict-prone areas between humans and wildlife by utilizing buffer tools in spatial analysis to gain a deeper understanding of these conflicts and develop sustainable solutions in Songbledeg, Paranggupito, and Gunturharjo Villages, located in Paranggupito Sub-district, Wonogiri District, Central Java. The research was conducted in October 2024. The methodology used includes buffer analysis using ArcGIS software. Data collection points are obtained through field surveys supported by the Avenza Map application, interviews, and equipped with spatial data. The results indicate that human wildlife, such as Java porcupines and long-tailed macaques, conflicts in the three villages occur near water sources such as rivers and coastal areas. In Gunturharjo and Songbledeg, conflicts were found in areas with elevations of 300-600 meters above sea level (masl), particularly in rice fields and drylands. Meanwhile, in Paranggupito, conflicts occurred not only at the same elevation range but also in residential areas. These conflicts highlight the need for the involvement of all stakeholders to mitigate the factors contributing to conflicts between porcupines, macaques, and humans. Efforts to reduce the occurrence of such conflicts include law enforcement and monitoring through joint patrols in the affected areas.

Keywords: Human-wildlife conflict, karst area, spatial analysis, wildlife management

INTRODUCTION

The clash between humans and natural life poses a danger that can result in the reduction of some natural life populations (Bahari et al. 2022). These clashes as often as possible happen around the world due to expanding human populace development, land-use changes, territory misfortune, and framework improvement (Sahu et al. 2021). Such conflicts involve competition for limited resources between humans and wildlife in a particular area, resulting in losses for one of the parties. However, it's important to note that some wild animal species provide positive impacts (benefits), and with the right conservation efforts, these benefits can be enhanced. On the other hand, others are perceived as causing negative impacts, leading to human-wildlife conflicts (Khawarizmi et al. 2024). Increased encroachment activities by communities can affect the ecological dynamics of monkeys (Hambali et al. 2012). Exploitative forest clearing leads to degradation, fragmentation, and even the loss of natural wildlife habitats (Ekarini et al. 2022).

This situation forces various animal species out of their natural habitats, leading to unwanted direct interactions with humans. When forests and natural lands are converted into plantations or residential areas, wild animals lose their habitats and natural food sources. This pushes some wildlife species to venture into human settlements and agricultural lands. Human-wildlife conflict has increasingly become a concern for environmental conservationists (Somu and Palanisamy 2022). In Indonesia, conflicts between humans and animals, such as with elephants or tigers, are quite common. Indonesia has the highest rate of elephant conflicts in Asia, at approximately 1.2% of incidents, compared to 0.4% in Thailand and 0.2% in Vietnam (Bahari et al. 2022).

The karst region of Wonogiri, Central Java, Indonesia, is an area with high biodiversity, featuring a unique and fragile ecosystem. This region serves as a habitat for various fauna species, including porcupines (*Hystrix* sp.) and long-tailed macaques (*Macaca* sp.), which play crucial roles in maintaining ecosystem balance. The most common conflicts occur between humans and porcupines or long-tailed macaques. Porcupine habitats are found in rocky and mountainous forests, which these animals use for foraging

and resting (Awak et al. 2015). Conflicts between humans and long-tailed macaques frequently occur due to their proximity to human environments, which are directly adjacent to their natural habitats (Fauziah et al. 2023).

The agricultural region of Wonogiri is known for its intercropping farming system. Long-tailed macaques and porcupines venture into human settlements due to the depletion of resources in their natural habitats, causing them to forage in areas close to their original environments (Makmur et al. 2020). Long-tailed macaques and porcupines foraging or entering plantations result in damage (Rittem et al. 2023). This circumstance specifically impacts farmers vocations and nearby nourishment security (Paripurno et al. 2024). Clashes between people and monkeys are habitually detailed in different considers, primarily due to covering ranges or spatial domains (Sulistiyowati et al. 2024). Research by Tandi et al. (2023) states that monkey conflicts arise due to limited food resources caused by habitat destruction, such as deforestation and agricultural areas bordering long-tailed macaques habitats. The presence of these wild animals causes significant economic losses to local communities that rely on agricultural produce (Riska et al. 2023).

In addressing human-wildlife conflicts, understanding species habitats and distributions is crucial. Remote sensing imagery, particularly from Landsat satellites, is widely used to estimate wildlife distribution and habitat suitability due to its free access and broad spatial coverage (Giefer and An 2022). Geographic Information Systems (GIS) have various applications, including natural resource inventory, land suitability evaluation for activities such as agriculture, plantations, and forestry, land-use planning, disaster-prone area analysis, and the management of conservation areas for flora and fauna (Utami et al. 2022).

Remote sensing and GIS technologies are increasingly applied in wildlife conflict studies, although spatial analyses focusing on identifying Human-Wildlife Conflict (HWC) risk zones still need to be expanded. Research also utilizes Sentinel-2 satellite imagery for Land Use and Land Cover (LULC) classification and MODIS satellite data to monitor vegetation changes (Gunawansa et al. 2023). Assessing physical and social factors, such as NDVI, LULC, proximity to rivers and roads, conflict risk zones, settlements, slope gradients, and other aspects through geospatial techniques, helps identify suitable locations to understand human-wildlife conflicts (Badhe and Jayabhaye 2021). The difference between this study and other studies is in the research method; in the study by Toiyo et al. (2024), the method used was to use the community perspective from the results of interview data, observations, and focus group discussions, while this study was supplemented with data processing via GIS. This study aims to map conflict-prone areas between humans and wildlife using buffer tools in spatial analysis to gain a deeper understanding of these conflicts and develop sustainable solutions.

MATERIALS AND METHODS

Study area

This research was conducted in October 2024 in three villages: Songbledeg, Paranggupito, and Gunturharjo, located in Paranggupito Sub-district, Wonogiri District, Central Java, Indonesia (Figure 1). Karst landscapes characterize the study area. Karst regions harbor biodiversity, including endemic species that are threatened by human activities (Stanković 2023). The presence of long-tailed macaques and porcupines entering agricultural areas in the 3 villages can trigger changes in the diet and behavior of these animals. On the other hand, long-tailed macaques and porcupines play a crucial role in maintaining the balance of the karst ecosystem.

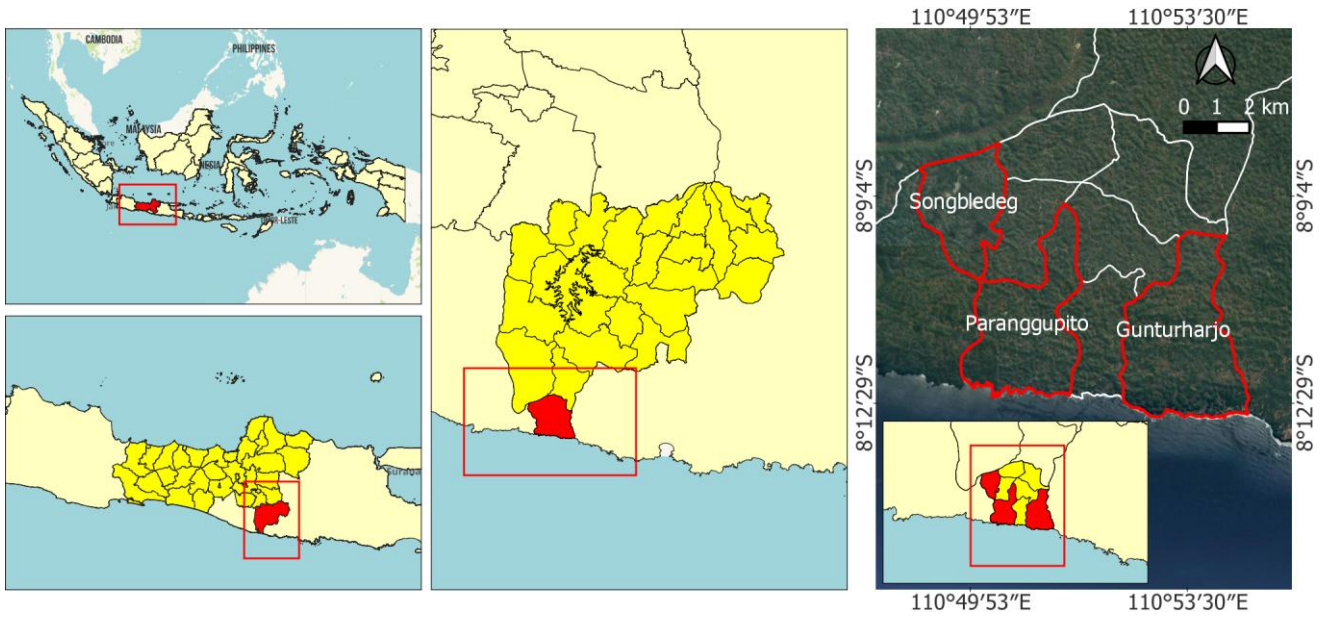

Figure 1. The research location is in Paranggupito Sub-district, Wonogiri District, Central Java, Indonesia

The determination of these three villages as investigative targets was based on their nearness to the coast and their broad woodland ranges. In addition, the area of agricultural land in the 3 villages is larger when compared to other villages in Paranggupito Sub-district. These components, too, contribute to potential clashes between people and natural life. Besides, agribusiness in Paranggupito, Songbledeg, and Gunturharjo is considered more beneficial, drawing in natural life to scavenge in neighborhood rural areas. These villages are also directly adjacent to the coastline, which serves as a habitat for long-tailed macaques. According to Hadi et al. (2019), long-tailed monkeys can thrive in various habitats, such as coastal areas, mountain forests, humid forests, and areas surrounded by human settlements, including sacred cemeteries, temples, tourist parks, and village forests.

Based on Figure 1, Paranggupito and Gunturharjo Villages are directly adjacent to the Indian Ocean. This makes it prone to conflicts in both villages. This is because the habitat of wildlife, especially monkeys, which are generally located along the coast, has undergone land use changes and caused food shortages. In addition, Paranggupito Sub-district is one of the sub-districts in Wonogiri District that has characteristics as a karst area. This rocky area provides a habitat unit for wildlife such as hedgehogs and long-tailed monkeys. The three villages are also dominated by tropical forests and shrubs used by wildlife to shelter and forage for food.

Data collection

The instruments used in this study include computers, Geographic Information System (GIS) software such as ArcGIS 10.8, Avenza Map, and Global Positioning System (GPS) to assist in the creation of conflict risk maps and land use maps, as well as contour maps. Data on human-wildlife conflicts were collected from primary sources, including field research, and secondary sources from published and unpublished literature, such as in-depth interviews with village heads to obtain data related to conflicts. In-depth interviews were conducted with 3 people who were key informants in each village, these informants were village heads who had an age range of 30-50 years. The spatial data used includes administrative boundaries, road and river networks, land use, and topography, which support the analysis.

The initial map of conflict-prone areas between long-tailed macaques, porcupines, and humans was created by collecting data on conflict points involving wildlife. The point data were obtained through field surveys using the Avenza Maps application at three research locations. After the point data and spatial data were collected, they were processed using ArcGIS through buffer analysis. Buffer analysis is a method of processing vector data with GIS software to generate the outermost polygon boundaries. These boundaries are based on the input used, either in the form of lines or points. The buffer tool generates a polygon surrounding the points or areas with a specified distance. In this study, the buffer radius used was 200 meters and 400 meters from the wildlife location points. This buffer distance was chosen to represent the area of direct interaction between wildlife and humans that could potentially lead to conflict. The general categories of land cover are differentiated into several types, such as forest, plantation, settlement, shrubs, grasslands with finer textures, open land, and water bodies represented in blue. Slope analysis, similar to the creation of elevation maps, is conducted through the slope process. Distance measurement involves objects in the form of point, line, area, or grid shapefiles. Buffer creation is carried out to generate distance-based shapefiles.

Data analysis

Data analysis was conducted descriptively by analyzing the spatial distribution of conflicts between wildlife and humans using maps with high incident frequencies. Spatial analysis was also required to examine the relationship between the research areas and the conflict occurrences in relation to environmental factors such as land use, elevation, slope, and terrain. Land use maps, contour slopes, rivers, and roads for each village were created to analyze the vulnerability of wildlife-human conflicts. The examination of arrival utilization, especially the move from thick woodlands and shrublands to rural areas, rice paddies, and settlements, essentially contributes to an increment in wildlife-human struggle occurrences, driving to more powerless and high-risk strife zones (Nad et al. 2022). Buffer creation is carried out to generate distance-based shapefiles. Applying buffering in mapping can enhance spatial analysis related to human-wildlife conflicts by defining areas of influence and allowing for dynamic adjustments based on environmental factors (Xu et al. 2021). This analysis can lead to more accurate decision-making and support ecological sustainability through tailored spatial assessments.

RESULTS AND DISCUSSION

The location points for observing conflict-prone areas between porcupines, long-tailed macaques, and humans were taken in three villages: Gunturharjo, Paranggupito, and Songbledeg. These villages were selected because they are considered to be the largest agricultural producers. Factors influencing the occurrence of conflicts include the elevation of the location, slope, distance from rivers, distance from roads, and land cover conditions. The three observation locations, Gunturharjo, Paranggupito, and Songbledeg, are villages with relatively abundant agricultural production. Gunturharjo also has dense natural vegetation, such as forests and gardens. Songbledeg, on the other hand, has varied landscapes, including agricultural lands, but relatively dense forest areas. Paranggupito is the closest village to the coast, making it more prone to conflicts between long-tailed macaques and humans. Meanwhile, Gunturharjo and Songbledeg are farther from the coast, so the conflicts that occur there are more frequent between porcupines and humans.

Distribution of animal conflict sites by slope

Based on Figure 2, we know that the three research locations, namely Gunturharjo, Paranggupito, and Songbledeg Villages, are located in areas with flat terrain, with slopes

ranging from flat until very steep. Meanwhile, in Paranggupito Village, conflict points are spread across several slope classes, including slope sloping class with 1 point, slope rather steep class and slope very steep class. The conflict points in Songbledeg Village are spread across slope classes flat until steep. This observation point was taken from the slopes of class flat until steep because most people cultivate plants on land that ranges from flat to steep.

Distribution of animal conflict sites by altitude

Based on Figure 3, we know that the three research locations are located at an altitude of 300-600 masl. The observation of conflict locations is divided into four points to identify the areas with the highest conflict intensity. The selection of four observation points in Paranggupito Village is divided between the outskirts of the village, where long-tailed macaques roam, and the center of the village, which serves as a habitat for porcupines. The three locations also have consistent heights and locations that can facilitate conflicts to spread to various parts of the village. Consistent elevations and similar locations across villages contribute to conflicts involving hedgehogs and long-tailed macaques in different parts of the village. In addition, altitude also affects conflicts between hedgehogs and humans, as hedgehogs are generally found in karst-hilly areas at higher altitudes. This is also due to the fact that areas at an altitude of 300-600 masl constitute a transition zone between lowlands and plateaus, which affects vegetation, temperature, food availability, and humidity. As a result, most of the people at the research site use the land for agriculture, plantations, and even housing and tourism development. As development increases, competition between humans, long-tailed apes, and hedgehogs for limited natural resources has led to increased conflicts.

Distribution of animal conflict sites by distance from river

Based on Figure 4, the conflict in Gunturharjo Village occurred in an area with a radius of less than 400 meters from a small river. Then, Paranggupito Village has a conflict area located in the agricultural area of the community near the river. Observations were made at four points, namely 2 points within a radius of <400 meters from the river, 1 point within a radius of 400-800 meters, and 1 point within a radius of 800-1.200 meters. Meanwhile, Songbledeg Village did not find a radius of conflict with the river because no image of the river area was found during the buffer process. The proximity of agricultural land to the river affects the occurrence of conflicts between wildlife and humans. Conflict-prone areas that are near water sources, such as rivers, attract animals to forage at that location. In addition, the area is also highland close to the habitat of porcupines, which usually live in cavities in the karst area.

Distribution of animal conflict sites by distance from the road

The buffer creation aims to determine the proximity of the conflict location to the roads in the three research locations. The entire research area is located at the same distance, less than 1.000 meters from the village road. The location of this research is quite close to road access (Figure 5). The proximity of the conflict location to the road is due to the fact that hedgehog-man conflicts also occur in residential areas that are very close to the road. The closest conflict location to the road in Gunturharjo Village is within 1.000 meters of the two points, while the two farthest locations are between 1.001 and 2.000 meters from the road. The location of the conflict farther away from road access is due to the pressure on hedgehogs and long-tailed macaques, causing them to move away from areas near the road. Importantly, transportation activities and housing development encouraged hedgehogs to move from this area and to other areas in search of food. Meanwhile, Paranggupito Village, which is known as a tourist village, has led to the development of many roads to beach tourist destinations in the area. The conflict that occurred near the road access was caused by the pressure on the hedgehog and long-tailed macaques, forcing them to stay in the area but venture into residential areas in search of food. In Songbledeg Village, most of the karst cliffs are located near the road, so conflicts often occur because porcupines often forage in residential and agricultural areas. In addition, land clearing puts pressure on hedgehogs and long-tailed macaques, forcing them to stay in the area but travel to residential areas in search of food.

Distribution of animal conflict sites by land cover

The conflict observation locations are in several areas that indicate the presence of porcupines and long-tailed macaques (Figure 6). The observation sites in Gunturharjo Village are divided into four areas: shrubland, dry farmland, mixed dry farmland and shrubland, and rice fields, with each area having one observation point. These land cover areas are where porcupines predominantly roam, causing conflicts with humans. Additionally, these areas are located near porcupine habitats, making them the most vulnerable locations for human-porcupine conflicts. Porcupine and long-tailed macaque conflicts often occur in land areas and rarely in residential areas. This is because porcupines and long-tailed macaques predominantly search for food in areas with lots of food sources, one of which is land close to the beach area. Beach areas are richer in food resources, so animals prefer to look for food in beach areas rather than in housing areas. The observation site in Paranggupito Village is divided into two areas: mixed dry farmland and shrubs and rice fields, with two observation points in each area. This land-use area is where hedgehogs and long-tailed macaques mostly roam, causing conflicts with humans. The area is also close to hedgehog habitats, making it the most vulnerable location for human-hedgehog conflicts. The Paranggupito Region, near the coast, is the area with the highest likelihood of conflict between long-tailed macaques and humans. Meanwhile, the observation location in Songbledeg Village is divided into three areas: mixed dry agricultural land and shrubs with 1 point, rice fields with 2 points, and residential areas with 1 point (Figure 6). This land-use area is where hedgehogs and long-tailed macaques mostly roam, causing conflicts with humans.

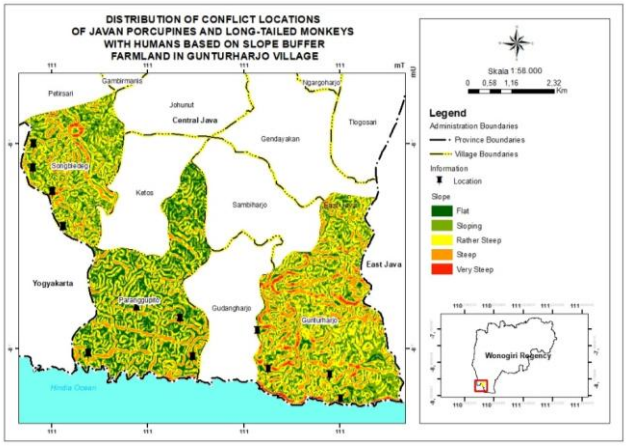

Figure 2. Distribution of animal conflict sites by slope in village

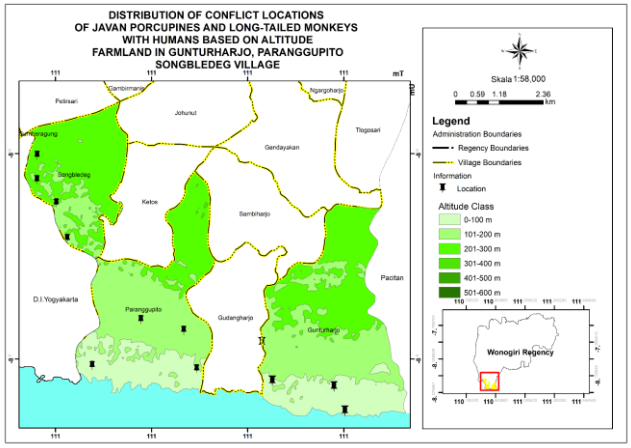

Figure 3. Distribution of animal conflict sites by altitude in village

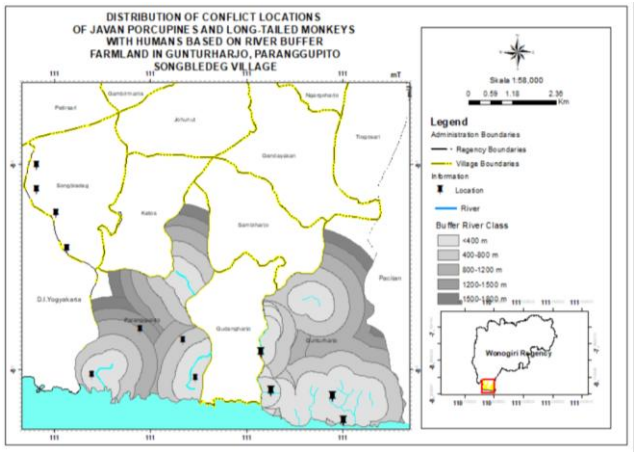

Figure 4. Distribution of animal conflict sites by distance from river in village

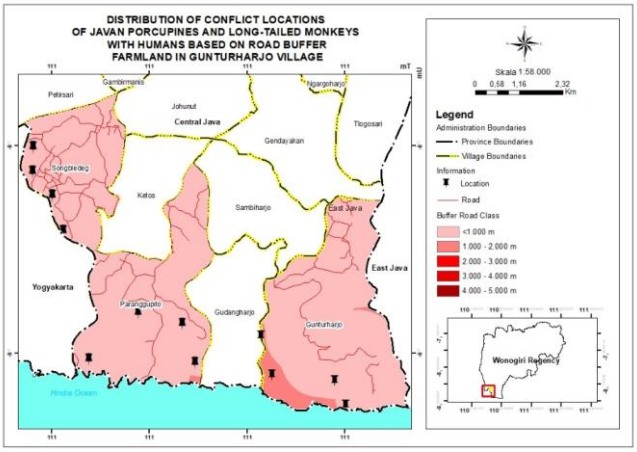

Figure 5. Distribution of animal conflict sites by distance from road in village

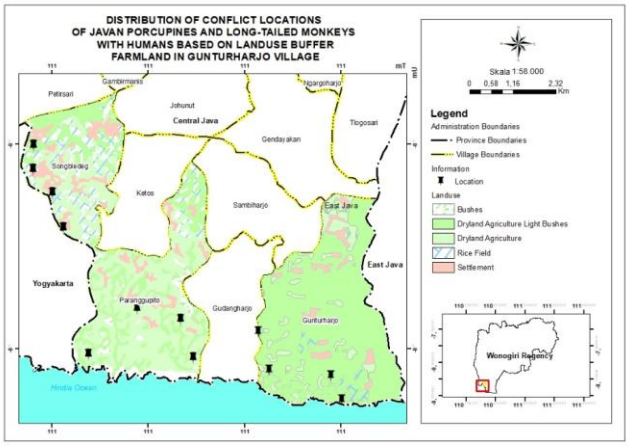

Figure 6. Distribution of animal conflict sites by land cover in village

Discussion

In general, porcupines live in habitats with dense vegetation, such as lowland forests or mountainous areas. Conflict-prone regions within the three towns are found at rises 300-600 meters over ocean level. More extreme slants regularly have denser vegetation, giving protect for porcupines. Regions with tender slants are more appealing for farming or settlement, expanding the probability of intelligence with natural life (Achmadi et al. 2023). Crops planted by people, such as corn, cassava, or tubers, frequently pull in long-tailed macaques and porcupines. When humans clear land in these areas for agriculture, porcupines may lose their habitat and be forced to forage in fields or plantations, leading to conflicts.

Monkeys are more flexible in their habitat and are often found in areas with varying slopes. This is in line with research conducted by Supriyatna and Ramadhan (2016), which states that long-tailed macaques habitats can range from lowlands to mountainous areas with elevations between 600-800 meters above sea level. However, on steep slopes that are difficult for humans to access, long-tailed macaques tend to be safer. When areas with gentle slopes are cleared for settlements or plantations, long-tailed macaques can more easily access crops, leading to conflicts. Figure 6 shows two points of high conflict between humans and wildlife. On the other hand, areas with steep slopes are less utilized by humans due to the difficulty in farming or establishing settlements, which results in fewer conflicts in slopes greater (Tiempo et al. 2023)

The presence of porcupines in the three villages is found at elevations of 300-600 masl, which is considered a transitional zone. These conditions can include habitats with shrubs, small caves, or protected burrows. Lowland areas are generally used by humans for agriculture, which provides the preferred food for porcupines, leading to more frequent conflicts. Animals like long-tailed macaques and porcupines forage in agricultural areas due to reduced access to their natural habitats. Long-tailed macaques, on the other hand, are more commonly found in forested areas at various elevations, depending on the species. In lowland areas, long-tailed macaques have access to a variety of natural foods. When forests are cleared for settlements or plantations, long-tailed macaques approach human areas, resulting in more frequent conflicts.

The absence of potential conflicts between humans and wildlife at elevations above 600 masl is due to the lack of productive agricultural land in these areas. Additionally, long-tailed macaques are rarely found at elevations between 1.000 and 2.000 meters, so there are fewer conflicts in these regions. These areas are often used for secondary forest agriculture, such as teak and acacia plantations. Due to the availability of food from human-planted crops, conflicts with wildlife, particularly long-tailed macaques, are more intense compared to lowland areas. This is consistent with research by Azwir et al. (2021), which found that at higher elevations, long-tailed macaque species are often encountered in secondary growth areas or areas with local plantations.

Conflicts between humans and wildlife are predominantly found in areas near rivers, within a distance of less than 400 meters, as shown in Figure 4. Long-tailed macaques often use areas near rivers as habitats because water is a vital resource (Otani et al. 2020). The large trees along the riverbanks also provide shelter, food (fruits, leaves), and natural movement corridors. Conflicts occur in areas farther from the river, up to 1.200 meters. This may be because porcupines are not directly dependent on rivers, but they are often found in areas with dense vegetation that thrive around rivers. These habitats offer protection and access to food sources, such as roots and tubers. However, when humans clear land near the river for agriculture, porcupines may forage in fields or plantations, leading to increased conflicts.

Areas near rivers are often used for farming, such as growing rice, corn, or tubers, or for irrigation purposes. These activities can attract porcupines and long-tailed macaques, as these crops are often a source of food for them. Even if humans clear land for agriculture around the river, species behavior can change. Porcupines may move away from the river to forage for food, while long-tailed macaques tend to follow the vegetation corridors along the river, showcasing intriguing changes in their behavior (Putri et al. 2024).

In both Paranggupito and Songbledeg villages, all conflicts occur in areas near roads, with the distance between the conflict-prone areas and wildlife being less than 1.000 meters. Areas that are close to roads or greater than 1.000 meters are often used for agriculture, settlements, or areas with high human activity, increasing the likelihood of conflict. Porcupines are more likely to approach human fields or plantations if their natural habitat is disturbed by road construction. Conflicts tend to be fewer because porcupines have more access to relatively undisturbed natural habitats. On the other hand, long-tailed macaques often use roads as movement corridors, especially if the roads are near their natural habitats. Vegetation along the roads can also serve as an additional food source. Long-tailed macaques are more likely to approach human areas because roads provide direct access to fields, plantations, or settlements.

Figure 5 shows that conflict-prone areas are located at distances from roads exceeding 2.000 meters. Long-tailed macaques are less likely to access human areas as the distance from their natural habitats increases. At distances greater than 1.000 meters, human activity decreases, but habitat fragmentation caused by roads can still affect wildlife. Conflicts may occur, especially if fields or plantations are located near the edges of wildlife habitats.

Root crops (such as cassava, sweet potatoes, or potatoes) that are widely cultivated in agricultural land are very attractive to porcupines. Clearing agricultural land near forests or natural porcupine habitats often increases conflict because porcupines lose their natural food sources and approach human fields. Fruit plantations, corn, or rice are highly attractive to long-tailed macaques as they provide easily available food. Long-tailed macaques tend to attack agricultural land located at the edges of forests or in transitional areas between natural habitats and agricultural land.

If forest areas are preserved, conflicts with porcupines are minimal because they have access to their natural habitats and sufficient food. Intact forests tend to reduce conflicts, but disturbed forests (e.g., due to logging or conversion into industrial tree plantations) can drive long-tailed macaques out to forage for food in human fields. Conflicts are less common in residential areas compared to agricultural land, but if settlements are near natural habitats, porcupines may dig into yards to search for food. Settlements near forest habitats often face issues with long-tailed macaques stealing food from kitchens and trash cans or even attacking people to find food. As settlements become more densely populated and closer to forests, conflicts are likely to increase.

Comparison with other studies

This study differs from previous research in terms of the types of conflicts and the species involved in human-wildlife conflicts. In this study, the main species involved in conflicts at the research location were Javan porcupines (*Hystrix javanica* (F.Cuvier, 1823)) and long-tailed macaques (*Macaca fascicularis* (Raffles, 1821)). Meanwhile, in the study by Tandi et al. (2023), conflicts in the Duasudara Nature Reserve and Batuputih Nature Tourism Park in Bitung City, North Sulawesi, Indonesia, involved yaki monkeys (*Macaca nigra* (Desmarest, 1822)) and humans. Differences in the species involved in human-wildlife conflicts in various regions may be influenced by factors such as endemic species variation, species distribution, ecosystem types, land availability, land use patterns, interaction intensity, shifts in species distribution, and seasonal pattern changes in each area.

Several examples of human-wildlife conflict cases in Indonesia illustrate the interconnectedness of human and wildlife habitats. One notable example is the conflict in Sumatra, Indonesia, where the Sumatran tiger (*Panthera tigris* subsp. *sumatrae* Pocock, 1929) comes into conflict with humans due to land conversion into oil palm plantations (Ronitua 2020). Similarly, in Sumatra, conflicts involving Sumatran orangutans (*Pongo abelii* Lesson, 1827) arise due to habitat loss caused by land conversion into plantations. These studies, while highlighting different species and conflict situations, all point to the same underlying cause: the loss or degradation of wildlife habitat caused by human activities, emphasizing our shared responsibility in preserving these habitats.

Enforcement and monitoring by stakeholders

The success of relief procedures in dealing with human-wildlife clashes depends on organization, implementation, change, and inspection. Reducing disputes between humans and wildlife can be achieved through a multifaceted approach, including legal requirements and inspections carried out by partners. This multifaceted approach coordinates biological, social, and financial techniques. Biological processes that can be implemented include land use regulation, where the movement of species from agricultural land to normal land will increase resources that increase biodiversity and provide help to maintain environmental adaptation, ultimately contributing to the health of nature. This aligns with the findings of (Kamande et al. 2023), who stated that agricultural land often attracts wildlife due to the presence of food resources. Therefore, effective land-use planning can reduce conflicts between wildlife and humans.

Spatial analysis and mapping of conflict areas are among the recommendations to reduce the larger impacts of conflicts that occur. Environmental communication is also considered one of the successful recommendations for mitigating wildlife-human conflict incidents. Developing environmental communication with local communities about the importance of conservation efforts can include training for officers, communities, and even volunteers to identify wildlife and conflict mitigation techniques for various dominant wildlife species in the area. Involving local communities in conservation-related communication fosters a sense of ownership and responsibility for managing environmental resources (Berkes 2004).

Based on field visits, there have yet to be any outreach or training programs related to managing wildlife-human conflicts at the research site. Therefore, coordination and collaboration between the government, local communities, organizations, and academics to improve capacity and understanding of human resources is important and is one of the suggestions to implement in mitigating the issues in the study area. On the other hand, legal requirements must also be linked and strengthened by carrying out an open awareness campaign regarding the enforcement of guarantees of natural life. Strict punishments for violators ought to moreover be upheld, with participation between the BKSDA (Nature Preservation Office), the police, and the prosecutor's office in in handling violation cases.

A methodology for requirement and observing can be created by taking strict lawful activity against wrongdoers, such as those included within the unlawful chasing of secured natural life and living space devastation. Socialization and education are too pivotal to extending open information and mindfulness around the significance of natural life preservation and keeping up the adjust of the karst biological system to decrease human-wildlife clashes. Checking, such as joint watches by BKSDA, the police, and nearby communities, can be an exertion to watch and avoid infringement within the karst zone. A few arrangements can also be connected, such as expanding the budget designated for preservation exercises, including volunteers, and utilizing the most recent and more effective innovations. This ought to be complemented by serious and continuous socialization endeavors, including community pioneers and giving motivation to their members. The final solution is to establish and develop sustainable alternative livelihoods, such as through the promotion of ecotourism.

Future challenges

Major challenges are arising from the ongoing conflicts between wildlife and humans, which are expected to persist in the future. These challenges include resource competition, where the growing human population threatens to shift wildlife habitats, leading to increased competition for land and resources (Burudi et al. 2023). This issue has already been observed in the study area, where wildlife has started consuming crops in agricultural fields due to a decrease in

their natural food sources, which have either dwindled or vanished since land-use changes from woodlands to settlements and farmland. Future challenges may escalate as human expansion into rural and wild areas increasingly fragments wildlife habitats, forcing animals to adapt to human-dominated environments (Nyhus 2016).

The lack of community involvement in wildlife conflict management often undermines the success of conservation programs (Treves and Karanth 2003). Besides, clashes between natural life and people display extra challenges closely connected to past ones, such as financial misfortunes. With the consumption of common assets, natural life tends to look for nourishment from neighborhood areas. As noted by (Alam and Nayak 2024) in their research, conflicts between wildlife and humans can create new economic challenges, often resulting in financial losses for local communities due to crop damage in agricultural fields.

These losses pose a challenge, as fields intended to meet the local community's food needs are damaged or even depleted by wildlife. The losses faced by local communities can range from partial crop failure to total crop loss caused by wildlife attacks. The challenges are wider than this, as there are also challenges in the cultural and social dynamics, where humans prioritize economic needs over conservation goals. Another emerging challenge is that, as noted by Shofiyah (2019) in her research, despite the fact that the Javan porcupine is a protected species, illegal hunting of porcupines still occurs in Indonesia. The rampant illegal hunting remains a challenge that complicates management and conservation efforts. According to Wisnu et al. (2024), poaching is a complex phenomenon that requires a holistic approach, where all stakeholders play an active role in addressing it for sustainability, making it another challenge in itself.

Inadequate mitigation strategies can exacerbate human-wildlife conflicts, potentially resulting in injuries, fatalities, and loss of property (Chakuya et al. 2024). Despite the existing challenges, many studies aim to develop innovative solutions to address them. However, the complexity of wildlife-human conflicts often requires a specialized approach and identification of specific challenges and issues that arise (Sillero-Zubiri et al. 2023). Although some mitigation efforts have been implemented in the study area, such as installing fences and using pesticides, challenges remain, such as insufficient funding for pesticide purchases, local community participation in alternative livelihoods, and public awareness programs emphasizing the importance of integrating economics with conservation.

Conclusion, based on the research findings from the mapping process, we have identified that human-wildlife conflicts occur in areas close to water sources, such as rivers and coastal regions. These conflicts take place at elevations of 300-600 masl. The conflicts occur in dry agricultural land, mixed dry agricultural land with shrubs, rice fields, and residential areas. However, we are not just identifying the problem, but we are actively working on solutions. Our efforts to reduce the occurrence of conflict include robust law enforcement and supervision through joint patrols in disaster areas, providing a sense of reassurance about our mitigation efforts.

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