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Optimizing Forest Monitoring: Using Marxan to Identify Priority Patrol Areas on Guadalcanal, Solomon Islands

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Abstract

Illegal logging causes deforestation, depleting government revenue and exacerbating natural disasters such as landslides and floods in developing countries. Timber exports in Solomon Islands exceed sustainable levels by a factor of seven, yet monitoring remains inadequate due to acute financial and human resource constraints. This study uses Marxan, a systematic conservation planning software, to identify priority ranger patrol areas in Guadalcanal, Solomon Islands. Although studies on forest patrols have mostly looked at pathfinding algorithms, these studies have not considered conservation goals that tools like Marxan support. Using watersheds as the primary planning units, four cost-based scenarios (A–D) were modeled to achieve a conservation target of protecting 50% of the forest above 400 m—a critical zone for biodiversity and regulatory protection. The scenarios evaluated cost substitutes, including watershed area, stream network density, annual precipitation, and downstream land-use impacts. Results indicate that Scenario B (cost—stream network density) is the most effective strategy by successfully meeting the 50% target and encompassed 42.1% of the total watershed. Conversely, Scenario B provided a more concentrated, connectivity-focused spatial plan. These findings suggest that integrating Marxan's systematic prioritization with hydrological data can transition forest management from random monitoring to data-driven, and efficient patrol routes.

Keywords: *deforestation, floods, illegal logging, management cost, ranger*

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Introduction

Illegal logging and the associated trade of illegally harvested timber products are major causes of deforestation and forest degradation in many developing countries. Illegal logging deprives cash-strapped governments of vital revenue, devastates the livelihoods of forest-dependent people, and fuels corruption and conflict (Lawson & MacFaul, 2010; Maican, 2022). While the exact amount of timber harvested illegally is unknown, globally illegal logging costs USD 30–100 billion annually, which is equivalent to 90% of the timber exports of some countries (Goncalves et al., 2012; World Bank, 2019). In Amazonian countries, such as Bolivia, Brazil, and Peru, with large forests, the countries lost USD 558–639 million annually due to illegal logging (Gutierrez-Velez & MacDicken, 2008). In Indonesia, which has experienced a significant decline in forest cover, illegal logging causes a loss of IDR30.42 trillion (USD1.9 billion) year^{-1} (Dekiawati, 2022). The study site at the Solomon Islands is no exception, and the rate of timber exports exceeds sustainable levels by a factor of 7 due to unauthorized logging (Katovai et al., 2015).

Illegal logging is a significant contributor to forest degradation in many developing countries, with the potential to trigger catastrophic events, such as landslides and floods (Clark, 1987; Bruijnzeel, 1990; Douglas et al., 1992; Bruijnzeel, 2004; Chethan et al., 2012; Tan-Soo et al., 2016). Excessive tree harvesting and the resulting landslides and floods have had profound effects on terrestrial and marine ecosystems, as well as forest biodiversity (Wenger et al., 2018; Noor et al., 2021). These upstream changes have significant downstream impacts on rivers. Floods are associated with high water discharge, high levels of inundation for long periods, disruption of social activities, and the transport of debris, including wood. Floods also affect the quality of clean water in a region. Almost all human activities on earth use water, including basic sanitation, washing, eating, and drinking (Sholihah et al., 2020; Anderson, 2023). The water sources most commonly used by people in the Solomon Islands are streams, springs, rivers, rainwater, and wells/groundwater (Pacific Islands Applied Geoscience and Technology, 2007; Food and Agriculture Organization, 2016). Therefore, reducing excessive illegal logging will lessen water pollution from flooding.

Ranger patrols have been suggested as a way to reduce illegal logging, as they send a clear message to illegal operations (Noor et al., 2021) and have shown some success (Jachmann, 2008; Wiafe & Amoah, 2012; Linkie et al., 2014; Dong et al., 2018; Gonedelé Bi et al., 2019). However, due to a lack of financial and human resources, the monitoring of logging activities is limited in many developing countries (Katovai et al., 2015; Dong et al., 2018). One way to address this is to enlist the help of locals, in addition to rangers

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employed by the government and other organizations (Dong et al., 2018; Gonedelé Bi et al., 2019). However, this may not include large forests. One of our ideas is to limit the priority monitoring areas. Marxan is the most widely used conservation planning software and is designed to solve complex conservation planning problems in landscapes and seascapes (Ball & Possingham, 2000). The principal advantage of employing decision-support tools, such as Marxan, is that they generate optimal spatial outcomes while minimizing the total costs incurred due to constraints defined by the user. For example, if the objective is to design a concentrated forest patrol and time and effort are identified as constraints, the algorithm will operate in selected areas with reduced time and effort while consistently striving to achieve pre-defined targets (Ball & Possingham, 2000). Therefore, we determined that Marxan would narrow down the priority patrol area, which was our objective in this study. Studies on forest patrols have mostly looked at pathfinding algorithms (Fang et al., 2016; Xu et al., 2016). However, these studies have not thought about the wider conservation goals that tools like Marxan support. This study adds to the existing research by combining Marxan's systematic prioritization with efficiency for patrols. By doing this, it goes beyond just deciding where to protect and can give a clear plan for how patrols can be carried out.

The purpose of this study was to narrow down priority ranger patrol areas in Guadalcanal, Solomon Islands, using Marxan to address limitations in monitoring logging activities resulting from financial and human resource constraints. In contrast to the common practice of random patrols or visits to "easily accessible" areas near roads, which is common in the Solomon Islands, our study can propose the development of designed routes that ensure the establishment of connectivity between protected forest fragments. This is very important for protecting the Solomon Islands' forests, which are full of rare plants and animals.

Methods

Study site The study site was Guadalcanal Island (S9°37, E160°11; Figure 1). Honiara, the capital city of the Solomon Islands, is located in the northern part of the island. The total area of Guadalcanal is 5,302 km^2 with the highest peak at 2,330 m. Guadalcanal Island is the largest island in the Solomon Islands (Wairiu, 2007). The average annual rainfall on Guadalcanal Island is 3,000–5,500 mm year^{-1} (Britannica, 2011; Solomon Islands Government, 2017) with a tropical climate. Forests cover more than 90% of the Solomon Islands. Therefore, it is highly dependent on logging for revenue (Gibson, 2018), with 50% of the foreign exchange and 17% of the government revenue from logging (URS Australia Pty Ltd, 2014). Most of the timber is exported to East Asia, including China (URS Australia Pty Ltd, 2014). *Vasa* (*Vitex cofassus*), rosewood (*Pterocarpus indicus*), *kwila* (*Instia bijuga*), and *akwa* (*Pometia pinnata*) are exported as sawn timbers (URS Australia Pty Ltd, 2014), and they are also a significant export sector in the Solomon Islands. Most of these trees are cut down illegally from natural forests. The forest exceeding 400 m above sea level is subject to rigorous regulation, and logging activities are only permitted after a logging permit is issued by the Commissioner of Forests. Nevertheless, this rule is not always followed. Excessive logging has been a big issue (Hughes et al., 2010; URS Australia Pty Ltd, 2014; Katovai et al., 2015). The government has not played an active role in forest management due to budgetary and human resource constraints. In addition, the planned use of the forests in this area is still in its infancy. Therefore, the lack of spatial forest planning fuels illegal logging.

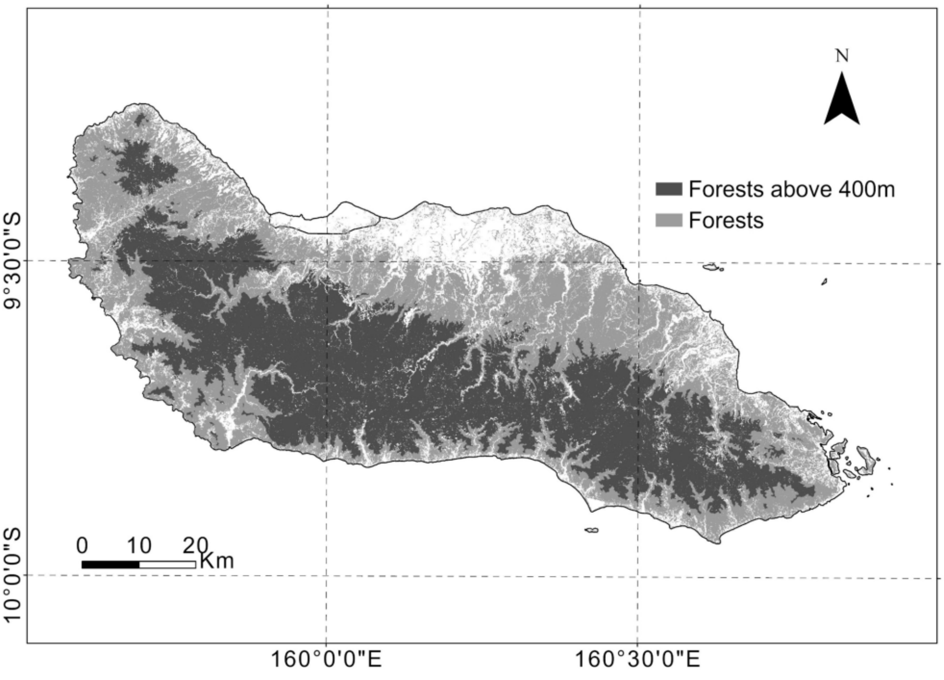

Figure 1 Study site at Guadalcanal, Solomon Islands.

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Data preparation As the country has not yet created a forest management unit, watersheds constituted the forest management unit of analysis in this study. Using the watershed as a unit has the advantage of being easily accessible and practical. Watersheds are defined by ridges and drainage divides, which line up with the natural barriers and corridors that rangers must navigate. When planning, rangers often follow paths that start at the highest point of a watershed and follow the river to the sea. This makes it so that you do not have to do a lot of difficult climbs across many ridges. Using watershed divides as the boundaries of a patrol sector provides "hard" natural borders. This makes it easier for rangers to know where they are without relying solely on GPS, as the drainage direction tells them exactly which sector they are in. Stream networks and the boundary to delineate the watershed were generated from digital elevation models (DEMs, Aster GDEM: 30-m spatial resolution) using the hydrology tools in QGIS 3.34.5 and ArcGIS Pro 3.2. The stream networks and watersheds were generated using flow directions and accumulation was calculated from the DEM. A threshold was set for the area of the slope into which the water flowed to determine the size of the stream network and watershed. In this study, we used 10,000 for the threshold and adjusted it to match the actual location of the rivers. The threshold was adjusted in an iterative manner to approximate the locations of valleys and ridges. After conducting a thorough visual inspection, the threshold was determined to have achieved the closest match at 10,000. Finally, 245 watersheds were generated (Figure 2). Land cover and use in 2019, such as built-up areas, cropland, forest, and wetland areas, were obtained from Global Land Analysis & Discovery (30-m spatial resolution, https://glad.umd.edu/). The wetland area was created by merging land cover types with the prefix wetlands, including wetland tree cover loss, wetland tree cover gain, wetland sparse vegetation, wetland open tree cover, wetland dense tree cover, and wetland dense short vegetation. Annual precipitation was obtained from the WorldClim database (30-m spatial resolution, version 2 climate data for 1970–2000, Fick & Hijmans, 2017) and was the average for 1970–2000 (Figure 2). We stored the area of all watersheds, the length of the stream networks, the area of the land cover, and the average annual precipitation within each watershed.

Scenarios Marxan software was employed to identify the priority watersheds for forest management operations, such as ranger patrols, to address the budgetary and human resource constraints within the government. Marxan's parameters essentially control how it balances the trade-off between minimizing cost and boundary length for clumping/compactness while meeting targets. The most critical parameters you need to set are *boundary length modifier* (*BLM*), *cost*, *status*, and *targets*. *BLM* is a weighting factor that determines the relative importance of minimizing the boundary length compared to minimizing the total cost. *Cost* is a function Marxan acts to minimize in its pursuit of achieving the targets. *Status* is this variable defines whether a planning unit (PU) is locked in or out of the initial and final selection systems. This is the key control for forcing Marxan to meet your targets. *Targets* are the minimum quantity or proportion of the feature in the planning region to be included in the solution (Serra et al., 2020).

The priority watershed areas for forest management operations, such as ranger patrols, were limited to four scenarios (A, B, C, and D in Table 1). Watersheds were used as PUs in this study. The priority watersheds identified in the

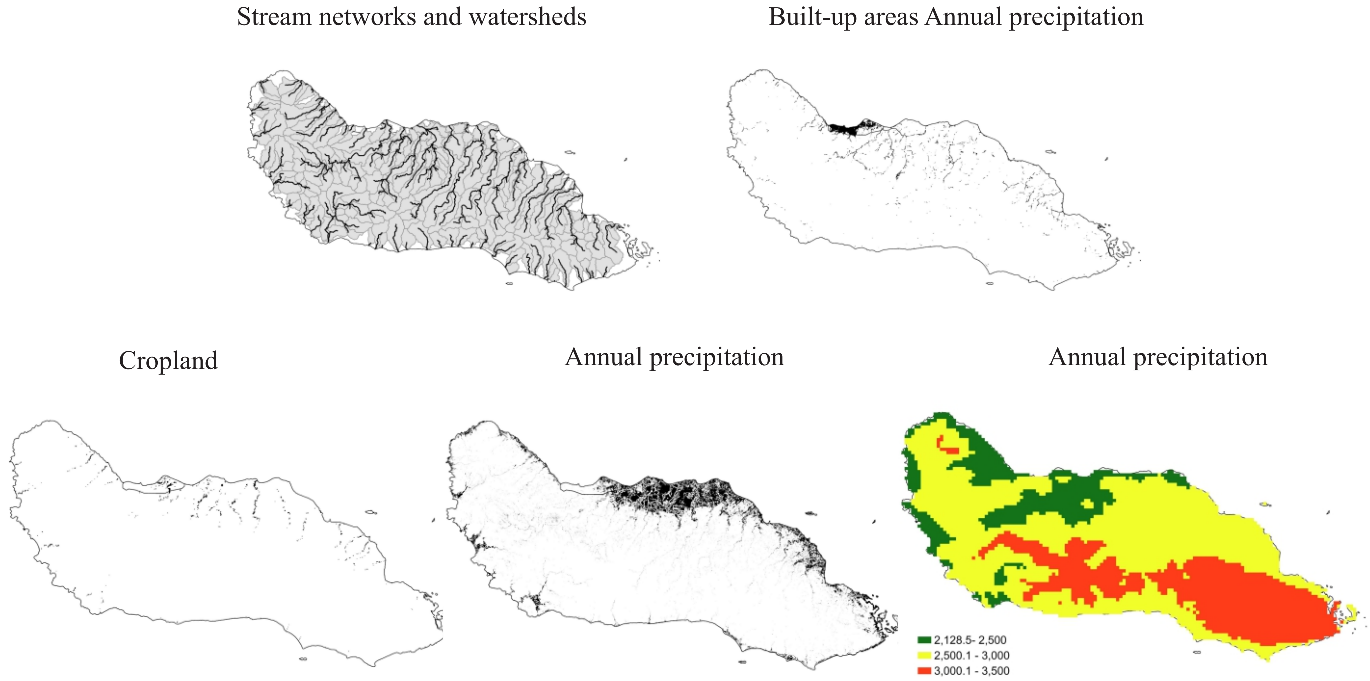

Figure 2 Planning units and geographical data used in the Marxan analysis.

scenarios were targeted to include 50% of the forest above 400 m above sea level (*target*). Forests exceeding 400 m above sea level are of such importance that they require a logging permit from the Commissioner of Forests; thus, those forests are strictly conserved, and forest management operations, such as patrols, must be particularly strengthened to prevent illegal logging in those areas. On the other hand, given the impracticality of foot patrolling the entirety of these forest areas, this study established a provisional objective of patrolling 50% of the forest. A total of 100 iterations were run to determine the optimal parameters for the Marxan analysis, with the unit selected as a priority patrol watershed if the score exceeded 90. The default settings (100 iterations) were used, as they have demonstrated a high degree of versatility across a diverse array of datasets (García-Barón et al., 2021; Akasaka et al., 2022; Zhang & Li, 2022) in this study. There was no difference in the number of selected watersheds around 90 as the threshold. In this study, the BLM was set to 1.0 as the default value. In addition to the BLM value, *status* was also set to a default value in Marxan, which is 0, meaning that the PU will be included in the initial selection system but may not be included in the final solution. *Costs* were set for each scenario. The QMarxan toolbox in QGIS was used for this analysis (based on Marxan version 2.4.3).

In the first scenario (A), the area of the watershed was defined as a cost substitute for time and labor. This was based on the idea that larger areas require more time and effort to complete forest management operations, such as ranger patrols. Thus, the objective was to create a spatial plan that would reduce time and labor. In the second scenario (B), the stream network density (*cost*) was also defined as a cost substitute for time and labor. This was predicated on the assumption that the stream network density would increase in corresponding areas surrounding the river that required forest management. In the Solomon Islands, logging is prohibited within a 25–50 m buffer zone around rivers (Solomon Islands Government, 2002; Solomon Islands Government & Secretariate of the Pacific Regional Environment Programme, 2021), because areas left unattended after logging are subject to erosion (Wenger et al., 2018; Tha et al., 2024) and water pollution (Wenger et al., 2018; Albert et al., 2021). However, illegal logging has continued (Albert et al., 2021; Chacha & Itaya, 2025). Therefore, these areas must be carefully monitored. However, if the area is larger, extra time and labor are required for careful monitoring. The objective of this study was to devise a spatial plan that would minimize the time and labor required for forest management operations, such as ranger patrols. In the third scenario (C), the inverse number of the annual precipitation (*cost*) was defined as a cost substitute for the risk of erosion in the logged areas or flooding in downstream areas after logging. We assumed that logging in areas with higher annual precipitation would produce erosion after logging (Schuller et al. 2013) or flooding in downstream areas (Bhuyan et al., 2024; Gentry & Lopez-Parodi, 1980; Tan-Soo et al., 2016). This approach was used to allow Marxan to prioritize watersheds with higher annual precipitation. Consequently, the objective was to devise a spatial plan that would prioritize watersheds with a higher risk of erosion in the logged areas and flooding in downstream areas after logging for forest management operations, such as ranger patrols. In the fourth scenario (D), the inverse of the area of important land cover and use in downstream areas (*cost*), such as built-up areas, cropland, and wetlands, was defined as a cost substitute for impacts to downstream areas, such as those associated with human livelihoods and ecologically or scientifically important sites. The downstream location of many residential areas in Guadalcanal, Solomon Islands, exposes them to flooding and water pollution. Mangrove forests, wetlands, and coral reefs are distributed near the mouths of the rivers, and flooding and water pollution have a major impact on these ecologically important areas (Solomon Islands Government & Secretariate of the Pacific Regional Environment Programme, 2021). We tried to ensure that logging would have as little impact on this land cover as possible by setting Marxan to prioritize watersheds with larger areas of land cover and use.

Results

Figure 3 and Table 2 show the priority watersheds that were narrowed down by each scenario. The selected priority watersheds for each of the scenarios A to D encompassed 46, 107, 21, and 14 of the 254 watersheds, representing 18.1%, 42.1%, 8.3%, and 5.5% of the total, respectively. The respective areas of these watersheds are 675,341,556 m², 2,084,169,547 m², 771,637,497 m², and 805,577,539 m². The

Table 1 Scenarios for the priority watersheds for forest management operations to address the budgetary and human resource constraints within the government

	Scenario A	Scenario B	Scenario C	Scenario D
Planning unit (PU)	Watersheds			
Status	0: PU will be included in the initial selection system but may not be included in the final solution			
Cost	The area of the watershed	The stream network density	The inverse number of the annual precipitation	The inverse of the area of important land cover and use in downstream areas
Target and proportion	Target: the forest above 400 m above sea level Proportion: 50%			

Note: Scenario A = Reduce time and labor; scenario B = Reduce time and labor; scenario C = The risk of erosion in the logged areas or flooding in downstream areas after logging; and scenario D = Impacts to downstream areas, such as those associated with human livelihoods and ecologically or scientifically important sites.

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forest area above 400 m in the priority watershed was 632,187,062.4 m², 1,070,820,262.0 m², 537,384,390.9 m², and 555,366,016.0 m², respectively. These values correspond to 29.5%, 49.9%, 25.0%, and 25.9% of the forest area in question. In scenario A, the selected areas were distributed in the mountains at elevations above 400 m, which are typically less accessible. In scenario B, the selected areas were distributed around the center of the island, including the capital city. In scenario C, the watersheds were distributed in the central and eastern parts of the island at high elevations. In scenario D, the selected areas were distributed across the entire island. In Scenario B, a greater number of watersheds were selected in comparison to Scenario D, where a smaller number were selected. Scenario B exhibited the greatest extent of forest areas situated above 400 m above sea level, constituting 50% of the total area encompassed by such forests. While Scenario B encompasses an area that might be too extensive to effectively patrol, the watersheds are concentrated. In scenarios C and D, the priority watersheds are characterized by dispersion. These distribution characteristics might have ramifications for patrol efficiency.

Discussion

The implementation of ranger patrols has been proposed as a strategy to mitigate illegal logging. These patrols are intended to communicate a clear message to illegal operators and have demonstrated a degree of success. For instance, research on poaching-related threats—a form of illegal resource extraction analogous to illegal logging—indicates that increasing the frequency of ranger patrols substantially increases the probability that threats disappear from a site where they were present (Critchlow et al., 2016; Noor et al., 2021). Law enforcement by rangers is regarded as a primary deterrent that facilitates the effectiveness of higher-level legal policies in the field (Critchlow et al., 2016). On the other hand, the limitations posed by resource scarcity

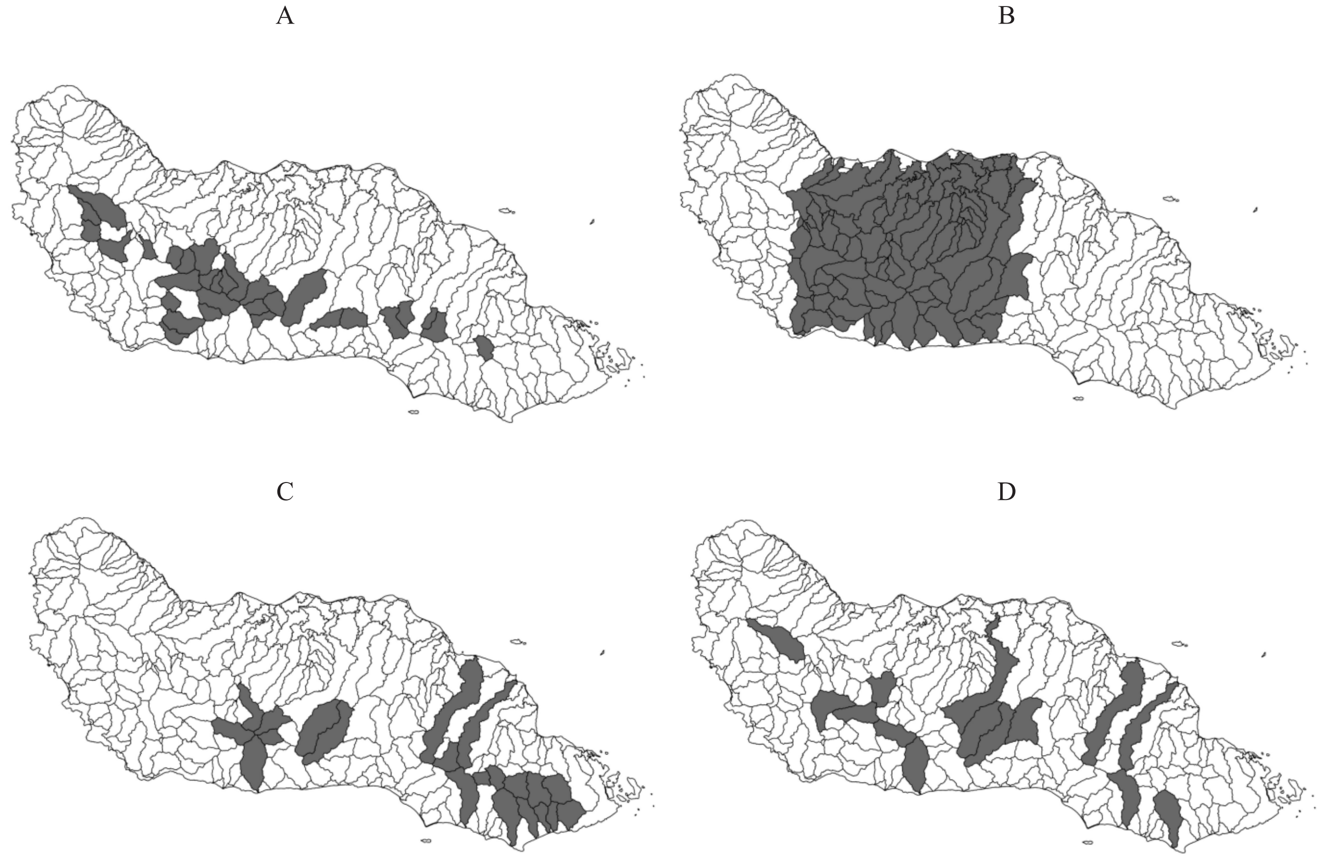

Figure 3 Priority watersheds are narrowed down based on scenarios A–D.

Table 2 Number of prioritized watersheds which narrowed down

Scenario	Number of priority watersheds	Total area of priority watersheds (m²)	Forests above 400 m above sea level (m²)
A	46 (18.1%)	675,341,556	632,187,062.4 (29.5%)
B	107 (42.1%)	2,084,169,547	1,070,820,262.0 (49.9%)
C	21 (8.3%)	771,637,497	537,384,390.9 (25.0%)
D	14 (5.5%)	805,577,539	555,366,016.0 (25.9%)

highlight the need for strategies that improve efficiency without requiring massive increases in funding. As an idea for a solution, optimizing patrol allocation—methods that use ranger-collected data and spatial crime mapping can help improve patrol efficiency by targeting high-risk areas (hotspots) for illegal activity (Critchlow et al., 2016; Dong et al., 2018; Mujetahid et al., 2023).

Katovai et al. (2015) suggested that illegal and excessive logging on the Solomon Islands may be caused by inadequate monitoring of logging activities due to a lack of financial and human resources. We narrowed down the monitoring areas using Marxan analysis to compensate for this based on several scenarios. Although the only difference between the scenarios was cost, the selected priority watersheds for forest management operations were very different in distribution and number. Because the watersheds selected in scenario A, which was the spatial plan that would reduce time and labor for forest management operations as much as possible based on the area of the watershed, were concentrated at high altitudes and far from human activity zones downstream, intensive ranger patrols would not be efficient given the time it would take to reach them, and it might not reduce the time and labor for forest management operations. However, scenario B would reduce time and labor for forest management operations based on the density of the stream networks. As the selected watersheds were continuous with human activity zones downstream to high-elevation ridges, they might be suitable for forest patrols. Moreover, the forests above 400 m above sea level, which must be strictly preserved, include 50% of the priority watersheds. However, only scenario B achieved this goal. Excluding scenario B, only a quarter of them were selected from the forests in each scenario. It seems probable that this outcome is the consequence of the prioritization of cost minimization by Marxan. Priority watersheds in scenarios C and D were dispersed. Scenario C prioritized the watersheds with a higher risk of erosion in the logged areas and flooding in downstream areas after logging, based on annual precipitation. Scenario D reduced the risk of erosion and flooding to downstream areas, based on the area of major land cover and use in downstream areas. These scenarios are very important ways to control flooding caused by excessive logging on the Solomon Islands. However, considering the efficiency of ranger patrols, it may be inefficient to distribute them in a dispersed manner. Moreover, except for the priority watersheds located east of the study area, most of the watersheds were included in the watershed area selected in scenario B. We suggest the priority watershed area using scenario B among the scenarios in this study. Conversely, we are concerned that the area selected in Scenario B is overly extensive. The implementation of effective patrolling strategies for such an expansive area necessitates further consultation with the pertinent parties. This process, involving the comparison of scenarios with government officials, experts, rangers, and other relevant parties, has the potential to foster collaboration and shared understanding in the realm of forest management.

The Solomon Islands are particularly vulnerable to natural disasters. The Solomon Islands are located south of the equator at the northern extremity of an area known for frequent tropical cyclones with damaging winds, rain, and storm surges between October and May. Devastating cyclones have repeatedly affected the islands in recent decades. Storms have caused massive landslides and flooding with severe damage (World Bank, 2015), and excessive illegal tree harvesting has not helped. Although logging in erosion-prone areas, such as steep slopes and riverbanks, is prohibited by the government (Solomon Island Government, 2002; Solomon Islands Government & Secretariat of the Pacific Regional Environment Programme, 2021), illegal logging continues (Albert et al., 2021; Chacha & Itaya, 2025). Although the effects of flooding of downstream areas were considered in scenarios C and D, we suggest the priority watershed area using scenario B in this study. Scenario B selected watersheds with reduced stream network density, as relating to cost, while consistently striving to achieve predefined targets of watersheds, including 50% of the forest above 400 m above sea level. This would minimize the time and labor required for ranger patrols. However, flooding, which is a major issue in the study area, was not considered. Most of the watersheds selected by scenarios C and D were included in the results of scenario B. In the end, the results of scenario B considered the impact on downstream areas.

While illegal and excessive logging can have serious effects on the ecosystem and forest biodiversity, rangers patrolling areas to protect them from poachers are effective in preventing illegal harvesting (Noor et al., 2021). Active forest monitoring is more likely to maintain a basal area, which is the area occupied by tree trunks and species diversity, than an unmonitored forest (Coleman, 2009). Gonedelé Bi et al. (2019) reported that ranger patrols of protected areas result in intact forests compared to unsupervised areas. Ranger patrols send out a clear message to illegal operations. Ranger patrols are conducted on foot with GPS recording (Dong et al., 2018; Gonedelé Bi et al., 2019), but a lack of financial and human resources often makes monitoring inadequate (The International Criminal Police Organization, 2013; Kalaba, 2016; Faisal, 2019; Noor et al., 2021). Moreover, the high-altitude areas with difficult terrain limit patrolling in those areas. Illegal logging operations are very difficult to monitor in remote areas (Schloenhardt, 2008; Katovai et al., 2015). Natural events, such as rainfall, also hinder forest patrols (Dong et al., 2018). The Solomon Islands is not exempt from this situation (Katovai et al., 2015). Therefore, we have no choice but to narrow down the priority area patrolled by rangers. The use of Marxan analysis based on multiple scenarios in this study facilitated efficient limitation of the ranger patrol areas. While numerous factors require consideration when establishing the scenarios, the results of this analysis will be beneficial for the Solomon Islands, which are experiencing significant challenges due to illegal and excessive logging practices, leading to adverse environmental consequences.

Conclusion

Priority areas for ranger patrols in Guadalcanal, Solomon Islands, were identified using Marxan spatial prioritization software to optimize monitoring efforts amidst significant financial and human resource constraints. Among the scenarios tested, Scenario B -weighted by stream network density—was selected as the most effective strategy. The area selected by Scenario B might be excessive. Therefore, further dialogue with pertinent agencies might be necessary to implement an effective patrol strategy in a vast area, such as zoning of the area and the number of rangers required. While these results provide a valuable framework for addressing illegal logging, certain limitations exist. There is a deficiency in accurate data regarding the current numbers of forest rangers. In order to combine this data and our results can be useful to properly understand how many forest rangers are required for the country to monitor the logging activities. The Ministry of Forestry updates its maps with active logging concessions, facilitating monitoring to prevent illegal logging. Despite these factors, this analysis offers a data-driven foundation to improve forest monitoring and resource allocation in a region facing severe environmental threats from excessive logging.

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References

Akasaka, T., Mori, T., Ishiyama, N., Takekawa, Y., Kawamoto, T., Inoue, M., Mitsuhashi, H., Kawaguchi, Y., Ichiyanagi, H., Onikura, N., Miyake, Y., Katano, I., Akasaka, M., & Nakamura, F. (2022). Reconciling biodiversity conservation and flood risk reduction: The new strategy for freshwater protected areas. *Diversity and Distributions*, *28*(6), 1191–1201. https://doi.org/10.1111/ddi.13517

Albert, S., Deering, N., Tongi, S., Nandy, A., Kisi, A., Sirikolo, M., Maehaka, M., Hutley, N., Kies-Ryan, S., & Grinham, A. (2021). Water quality challenges associated with industrial logging of a karst landscape: Guadalcanal, Solomon Islands. *Marine Pollution Bulletin*, *169*, Article 112506. https://doi.org/10.1016/j.marpolbul.2021.112506

Anderson, B. (2023, August 3). The costs of logging in Solomon Islands. *Devpolicyblog*. Retrieved from https://devpolicy.org/the-costs-of-logging-in-solomon-islands-20230803/

Ball, I. R., & Possingham, H. P. (2000). Marxan (V1.8.2): Marine reserve design using spatially explicit annealing, A manual. Retrieved from https://courses.washington.edu/cfr590/software/Marxan1810/marxan_manual_1_8_2

Bhuyan, N., Sajjad, H., Saha, T. K., Roshani., Sharma, Y., Masroor, Md., Rahaman, Md. H., & Ahmed, R. (2024). Assessing landscape ecological vulnerability to riverbank erosion in the Middle Brahmaputra floodplains of Assam, India using machine learning algorithms. *CATENA*, *234*, Article 107581. https://doi.org/10.1016/j.catena.2023.107581

Britannica. (2011). The editors of encyclopedia: "Guadalcanal Island". *Encyclopedia Britannica*. Retrieved from https://www.britannica.com/place/Guadalcanal-Island

Bruijnzeel, L. A. (1990). *Hydrology of moist tropical forest and effects of conversion: A state of knowledge review*. UNESCO International Hydrological Programme.

Bruijnzeel, L. A. (2004). Hydrological functions of tropical forests. *Agriculture Ecosystem Environment*, *104*, 185–228. https://doi.org/10.1016/j.agee.2004.01.015

Chacha, T., & Itaya, A. (2025). Forest cover changes in the Lungga River Basin of Guadalcanal, Solomon Islands. *Journal of Forest Planning*, *31*, 38–43. https://doi.org/10.20659/jfp.2024.003

Chethan, K. P., Srinivasan, J., Kriti, K., & Sivaji, K. (2012). Sustainable forest management techniques. In P. Moutinho (Ed.), *Deforestation around the world*. IntechOpen, London. https://doi.org/10.5772/35823

Clark, C. (1987). Deforestation and floods. *Environmental Conservation*, *14*(1), 67–69. https://doi.org/10.1017/S0376892900011127

Coleman, E. A. (2009). Institutional factors affecting biophysical outcomes in forest management. *Journal of Policy Analysis and Management*, *28*(1), 122–146. https://doi.org/10.1002/pam.20405

Critchlow, R., Plumtre, A. J., Alidria, B., Nsubuga, M., Driciru, M., Rwetsiba, A., Wanyama, F., & Beale, C. M. (2016). Improving law-enforcement effectiveness and efficiency in protected areas using ranger-collected monitoring data. *Conservation Letters*. *10*(5), 572–580. https://doi.org/10.1111/conl.12288

Dekiawati, E. S. (2022). Law enforcement on illegal logging in Indonesia: Problems and challenges in present and the future. *Indonesian Journal of Environmental Law and Sustainable Development*, *1*(1), 47–68. https://doi.org/10.15294/ijel.v1i1.21822

Dong, L. K., Sinutok, S., Hoa, A. X., Anh, N. T., Thinh, N. V., Hai, L. V., Manop, P., & Techato, K. (2018). Overview of improving patrolling efforts: a case study of forest station in Pu Hu Nature Reserve, Vietnam. *Applied Ecology and Environmental Research*, *16*(3).

2845–2859. https://doi.org/10.15666/aeer/1603_28452859

Douglas, I., Spencer, T., Greer, T., Sinun, W., & Wong, W. M. (1992). The impact of selective commercial logging on stream hydrology, chemistry and sediment loads in the Ulu Segama rainforest, Sabah, Malaysia. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *335*(1275), 397–406. https://doi.org/10.1098/rstb.1992.0031

Faisal, F. (2019). Effectiveness of forestry police in preventing illegal logging activity in North Halmahera Regency. *Papua Law Journal*, *3*(2), 71–85. https://doi.org/10.31957/plj.v3i2.785

Fang, F., Nguyen, T. H., Pickles, R., Lam, W. Y., Clements, G. R., An, B., Singh, A., Tambe, M., & Lemieux, A. (2016). Deploying PAWS: Field optimization of the protection assistant for wildlife security. *Proceedings of the AAAI Conference on Artificial Intelligence*, *30*(2), 3966–3973. https://doi.org/10.1609/aaai.v30i2.19070

Fick, S. E., & Hijmans R. J. (2017). WorldClim 2: New 1 km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, *37*(12), 4302–4315. https://doi.org/10.1002/joc.5086

Food and Agriculture Organization. (2016). *AQUASTAT country profile–Solomon Islands*. Rome: FAO. Retrieved from https://openknowledge.fao.org/server/api/core/bitstreams/7f1c03c8-73cb-4b84-9971-1f3abce708c8/content

Gentry, A. H., & Lopez-Parodi, J. (1980). Deforestation and increased flooding of the upper Amazon. *Science*, *210*(4476), 1354–1356. https://doi.org/10.1126/science.210.4476.1354

Gibson, J. (2018). Forest loss and economic inequality in the solomon islands: Using small- area estimation to link environmental change to welfare outcomes. *Ecological Economics*, *148*, 66–76. https://doi.org/10.1016/j.ecolecon.2018.02.012

Goncalves, M. P., Panjer, M., Greenberg, T. S., & Magrath, W. B. (2012). *Justice for forests: Improving criminal justice efforts to combat illegal logging*. Washington, D.C.: the World Bank. Retrieved from http://www.unece.lsu.edu/responsible_trade/documents/2013Mar/rt13_19

Gonedelé Bi, S., Bitty, E. A., Yao, A. K., & McGraw, W. S. (2019). Foot patrols enhance conservation efforts in threatened forest reserves of coastal côte d'Ivoire. *Tropical Conservation Science*, *12*(6). https://doi.org/10.1177/1940082919872637

García-Barón, I., Giakoumi, S., Santos, M. B., Granado, I., & Louzao, M. (2021). The value of time-series data for conservation planning. *Journal of Applied Ecology*, *58*(3), 608–619. https://doi.org/10.1111/1365-2664.13790

Gutierrez-Velez, V. H., & MacDicken, K. (2008). Quantifying the direct social and governmental costs of illegal logging in the Bolivian, Brazilian, and Peruvian Amazon. *Forest Policy and Economics*, *10*(4), 248–256. https://doi.org/10.1016/j.forpol.2007.10.007

Hughes, T., Crawford, P., Sutch, H., & Tacconi, L. (2010). Solomon Islands forest management Project II (FMP2): Independent completion report (ICR). Retrieved from https://www.dfat.gov.au/sites/default/files/solomon-islands-forestry-icr.pdf

Jachmann, H. (2008). Monitoring law-enforcement performance in nine protected areas in Ghana. *Biological Conservation*, *141*(1), 89–99. https://doi.org/10.1016/j.biocon.2007.09.012

Kalaba, F. K. (2016). Barriers to policy implementation and implications for Zambia's forest ecosystems. *Forest Policy and Economics*, *69*, 40–44. https://doi.org/10.1016/j.forpol.2016.04.004

Katovai, E., Edwards, W., & Laurance, W. (2015). Dynamics of logging in Solomon Islands: the need for restoration and conservation alternatives. *Tropical Conservation Science*, *8*(3), 718–731. https://doi.org/10.1177/194008291500800309

Lawson, S., & MacFaul, L. (2010). *Illegal logging and related trade: Indicators of the global response*. London: Chatham House. Retrieved from https://www.chathamhouse.org/sites/default/files/public/Research/Energy%2C%20Environment%20and%20Development/0710pr_illegallogging.pdf

Linkie, M., Sloan, S., Kasia, R., Kiswayadi, D., & Azmi, W. (2014). Breaking the vicious circle of illegal logging in Indonesia. *Conservation Biology*, *28*(4), 1023–1033. https://doi.org/10.1111/cobi.12255

Maican, O. (2022). Regulations regarding illegal logging. *Perspectives of Law and Public*, *11*(2), 333–342.

Mujetahid, A., Nursaputra, M., & Soma, A. S. (2023). Monitoring illegal logging logging using Google Earth Engine in Sulawesi Selatan tropical forest, Indonesia. *Forests*, *14*(3), Article 652. https://doi.org/10.3390/f14030652

Noor, M. N. H. M., Kadir, R., & Muhamad, S. (2021). Issues of forest enforcement against illegal logging and forest offences in peninsular Malaysia. *Journal of Sustainability Science and Management*, *16*(7), 260–272. http://doi.org/10.46754/jssm.2021.10.019

Pacific Islands Applied Geoscience and Technology. (2007). *National integrated water resource management diagnostic report: Solomon Islands*. Suva, Fiji: Applied Geoscience and Technology Division.

Retrieved from https://library.sprep.org/content/national-integrated-water-resource-management-diagnostic-report-solomon-islands-sustainable

Serra, N., Kockel, A., Game, E. T., Grantham, H., Possingham, H. P., & McGowan, J. (2020). Marxan user manual: for marxan version 2.43 and above. The Nature Conservancy (TNC), Arlington, Virginia, United States and Pacific Marine Analysis and Research Association (PacMARA), Victoria, British Columbia, Canada. Retrieved from https://marxansolutions.org/wp-content/uploads/2021/02/Marxan-User-Manual_2021.pdf

Schloenhardt, A. (2008). *The illegal trade in timber and timber products in the Asia-Pacific region*. Research and Public Policy Series No. 89, Australian Institute of Criminology. Retrieved from https://core.ac.uk/download/pdf/30687625.pdf

Schuller, P., Walling, D. E., Iroume, A., Quilodran, C., Castillo, A., & Navas, A. (2013). Using 137Cs and 210Pbex and other sediment source fingerprints to document suspended sediment sources in small forested catchments in south-central Chile. *Journal of Environmental Radioactivity*, *124*, 147–159. https://doi.org/10.1016/j.jenvrad.2013.05.002

Sholihah, Q., Kuncoro, W., Wahyuni, S., Suwandi, S. P., & Feditasari, E. D. (2020). The analysis of the causes of flood disasters and their impacts in the perspective of environmental law. *IOP Conference Series: Earth and Environmental Science*, *437*(1), Article 012056. https://doi.org/10.1088/1755-1315/437/1/012056

Solomon Islands Government. (2002). *The revised Solomon Islands code of logging practice*. Ministry of Forests, Environment and Conservation. Retrieved from http://macbio-pacific.info/wp-content/uploads/2017/08/Code_of_Logging_Practice.pdf

Solomon Islands Government. (2017). *Solomon Islands second national communication*. Ministry of environment, climate change, disaster management and meteorology (MECDM). Retrieved from https://unfccc.int/sites/default/files/resource/SI%20SNC%20FINAL_1-1.pdf

Solomon Islands Government, & Secretariate of the Pacific Regional Environment Programme. (2021). Helping communities with best practice for logging in the Solomon Islands: A summary of the code of logging practice. Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM). Retrieved from https://solomonislands-data.sprep.org/resource/solomon-islands-logging-code

Tan-Soo, J., Adnan, N., Ahmad, I., Pattanayak, S. K., & Vincent, J. R. (2016). Econometric evidence on forest ecosystem services: Deforestation and flooding in Malaysia. *Environmental and Resource Economics*, *63*, 25–44. https://doi.org/10.1007/s10640-014-9834-4

Tha, T., Piman, T., Kittipongvises, S., & Ruangrassamee, P. (2024). Riverbank erosion vulnerability assessment and coping strategies: A case study of the riparian communities in the Mekong River Basin in Cambodia. *Heliyon*, *10*(3), Article e25418. https://doi.org/10.1016/j.heliyon.2024.e25418

The International Criminal Police Organization. (2013). *Assessment of law enforcement capacity needs to tackle forest crime*. Lyon: Interpol Environmental Crime Programme.

URS Australia Pty Ltd. (2014). *Market study for Solomon Islands timber exports: A report for the Pacific Horticultural and Agricultural Market Access Program* (*PHAMA*). Retrieved from https://phamaplus.com.au/wp-content/uploads/2024/07/TR-60-SOLS18-Market-Study-for-Solomon-Islands-Timber-Exports-v1.0-FINAL.pdf

Wairiu, M. (2007). History of the forestry industry in Solomon Islands: the case of Guadalcanal. *The Journal of Pacific History*, *42*(2), 233–246. https://doi.org/10.1080/00223340701461684

Wenger, A. S., Atkinson, S., Santini, T., Falinski, K., Hutley, N., Albert, S., Horning, N., Watson, J. E. M., Mumby, P. J., & Jupiter, S. D. (2018). Predicting the impact of logging activities on soil erosion and water quality in steep, forested tropical islands. *Environmental Research. Letters*, *13*, Article 044035. https://doi.org/10.1088/1748-9326/aab9eb

Wiafe, E. D., & Amoah, M. (2012). The use of field patrol in monitoring of forest primates and illegal hunting activities in Kakum Conservation Area, Ghana. *African Primate*, *7*(2), 238–246.

World Bank. (2015). *Solomon Islands*. Washington, D.C.: Wordl Bank. Retrieved from https://documents1.worldbank.org/curated/pt/640541468100735571/pdf/949830WP0P13240Note0Solomon0Islands.pdf

World Bank (2019). Illegal logging, fishing, and wildlife trade: the costs and how to combat it. Washington, D.C.: World Bank. Retrieved from http://hdl.handle.net/10986/32806

Xu, H., Ford, B., Fang, F., Dilkina, B., Plumptre, A., Tambe, M., & Mabonga, J. (2017). Optimal patrol planning for green security games with black-box attackers. In S. Rass, B. An, C. Kiekintveld, F. Fang, & S. Schauer (Eds.), *Decision and game theory for security* (pp. 458–477). GameSec 2017. Springer, Champ. https://doi.org/10.1007/978-3-319-68711-7_24

Zhang, L., & Li, J. (2022). Identifying priority areas for biodiversity conservation based on Marxan and InVEST model. *Landscape Ecology*, *37*(12), 3043–3058. https://doi.org/10.1007/s10980-022-01547-0