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Original Article

Application tool of the Global Positioning System as the first stage of patrol skills to support protected areas

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Abstract

Protected areas have been continually challenged among the special-use forests. An example is the Hon Can forest station, Xuan Lien Nature Reserve, Vietnam. This paper describes the patrol routes and the responsibility of a patrol ranger to record harm to the forest using the Geographic Information System. The Global Positioning System tracks the areas with the highest potential for illegal activities which had drastic negative effects on biodiversity conservation established along the patrol routes. The results illustrated six common patrol routes with 61 coordinate points and 14 types of illegal activity encounters. Interestingly, the illegal activity was not statistically significant among the patrol routes. Furthermore, the patrol distance had a higher efficiency than patrol time in each patrol route. Locally, it requires further planning of such patrols in the foreseeable future. Furthermore, the number of illegal activities regularly changed if the patrol personnel focused on recording only the long-term period.

Keywords: biodiversity conservation, forest, illegal activities, nature reserve, patrol route

1. Introduction

In theory, typical nature reserves reduce the risk of extinction because of the sizeable populations of endangered species of flora and fauna. Protected areas play a significant role in biodiversity conservation on our planet (Patarka lashvili, 2016; Stoll-Kleemann, 2010;). The key to conservation and protection of species and their natural habitat is to identify human activities in the refuge areas (Forester & Machlist, 1996; Mendenhall *et al.*, 2012; Sandifer *et al.*, 2015) and eliminate all illegal activities if possible. In practice, however, most poor and developing countries have limited resources to protect huge areas and prevent financial profit from illicit exploitation (Leader-Williams & Albon, 1988). Also, there are the critical issues of efficiency of forest protection (Wang *et al.*, 2015) and severe anthropic pressure due to agricultural, mining, tourism, and high urban expansion (Laurindo *et al.*, 2017).

In Vietnam, special-use forests, including nature reserves and national parks, are crucial for biodiversity and conservation, and improved protection requires the involve-

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ment of many stakeholders, such as local communities, government authorities, and international organizations (Thi, Krott, & Böcher, 2017). Moreover, a great variety of laws and regulations were put in place which aimed to enhance protection and guide sustainable use of the natural recourses. But non-compliance with the rules is the reality and illegal activities continue (Arias, 2015). Usually several stakeholders surround protected areas with conflicting interests on how to manage and plan for forest management. It should be noted, however, that residents normally gather fuelwood and timber illegally, as well as other non-timber forest products (NTFPs) (Allendorf, Smith, & Anderson, 2007).

At the local level of a forest station, rangers are responsible for law enforcement of a certain area of the sub-forest of a nature reserve. A regular foot patrol is the basic method to control the extraction of timber, reduce poaching, avoid encroachment, and restrict livestock grazing by local residents (Allendorf, Smith, & Anderson, 2007). Law enforcement by foot patrols is the common approach to prohibit illegitimate activities in tropical forests, though the efficiency of such patrols has often been questioned (Mukul *et al.*, 2014). If such patrols are not organized well and unreliable there is great potential for illegal activities to get out of control and depletion of biodiversity in a protected area can be irreversibly severe. Effective protection of biodiversity needs professional planning and the implementation of an efficient control mechanism. Therefore, an important priority is to achieve and maintain a functioning system which indicates environmental changes and different scenarios (Schaubroeck *et al.*, 2016).

Knowledgeable forest management demands dependable information on the circumstances and conditions of each forest location and reacts to altering forest conditions over time (Noss, 1999). Staff personnel necessarily need to adapt to become more dedicated and vigilant if there are changes in illegal activities, and to react appropriately and responsibly in such occurrences in the protected forest areas (Food Organization Agriculture [FAO], 1996). Most of the previous research found in the literature was related to the analysis of law enforcement performance of poaching for high-priced commodities (Critchlow *et al.*, 2016; Gandiwa *et al.*, 2014; Jachmann, 2008c). Several studies reported the relationships between a number of illegal activities with senior forest ranger efforts (Jachmann, 2008a). Since the patrol-basis monitoring system is rather simple (Jachmann, 1998), there is no known method of recording the illegal activities during patrol efforts along the patrol routes. Most of the protected areas in Vietnam do not properly apply a technological way of recording illegal activity. The main issues of an efficient enforcement were defined as regularly conducted patrols that are recorded and improved supervision by management is properly checked (Abbot & Mace, 1999). However, the main issues were several illegal activities in the Hon Can protected area which were not satisfactorily recorded. In reality, the monitoring system gives good feedback for forest protection management (Jachmann, 2008a, 2008c). It is crucial to recognize the areas where illegal activities were reduced or eliminated because of concentrated conservation and management efforts (Rica *et al.*, 2017). The Hon Can protected area was taken as an example for a case study. This location has a variety of illegal activities that have not been recognized. Therefore, the purpose of the study was to (1) identify illegal activity occurring along the patrol routes and map the existence of these issues and (2) compare the number of illegal activity encounters in terms of patrol-distance and patrol-hours if patrolling was conducted.

2. Materials and Methods

2.1 Location of the case study

The common method of this study suggests that the protection activity efforts, including the number of illegal activity points and other descriptions, may provide an important indicator of sustainable forest management. The Hon Can forest station (HCFS) is important for biodiversity conservation and was selected for the survey because this area is known for illegal activities and considered one of the problem zones. It belongs to the Xuan Lien Nature Reserve (XLNR) located in Thuong Xuan District in Thanh Hoa Province in the northeastern part of Vietnam near the border with Nam Xuan Biodiversity Conservation Area in neighboring Laos. The XLNR is divided into 5 law enforcement areas of which HCFS is one sub-station that controls and patrols about 2,355 ha of the core-zone of the nature reserve. Four forest officers are based at the HCFS and they are responsible for law enforcement. The fully protected core-zone of the XLNR borders the southern area which is a less protected buffer zone with 355 households and 1.612 inhabitants in the villages of Hang Cau, Quan, and Thac Lang. Due to the high population density in the buffer-zone, there is constant pressure on the protected area with illegal activities such as logging, encroachment, and poaching.

2.2 Data collection

The research was conducted in the HCNR and the data were collected from March to May 2017 (Figure 1). The survey was conducted by following the main tracks because of expected high level illegal activities and lessons learned from the past (Plumptre *et al.*, 2014). All recorded observations indicated prohibited activities caused by humans or livestock. The locations of illegal activities were evidenced by marks on the ground and on trees and stones. In addition to this, we could use other senses such as hearing, feeling, and direct observation of the landscape. The locations of the changes were recorded using a Global Positioning System (GPS) device. Indications of illicit activities were footprints of humans or livestock as well as location and direction marks made by humans with stones, sticks or marks on trees. Slip or drag-marks on the ground caused by tree trunks, bamboo, branches or hunted animals.

The primary observations of distinguished marks and indicators of illegal activities was collected on such field trips and filed by the author in cooperation and with the support of forest officers of Hon Can Station, Department of Science and International Cooperation and the Department of Law Enforcement of the Head-Office of XLNR as well as the Nature Protection Groups of the adjoining villages. The patrol tracks and coordinate points (the longitude and latitude points of appearance of illegal activity (Jachmann, 2008a) were tabulated with Microsoft Excel and transferred into MapInfo Software. The proportion of illegal in term of patrol-distance and patrol-time by using Microsoft Excel was differently

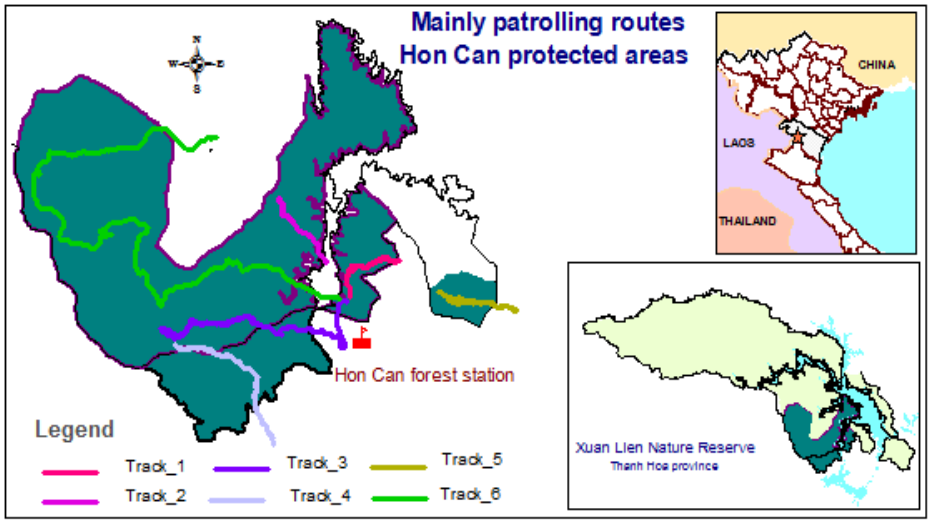


Figure 1. Location of the study area.

descriptive. Furthermore, the Kruskal-Wallis test was applied for to evaluate the differences in the variables among the patrol-tracks.

3. Results and Discussion

3.1 Threat facing HCFS protected areas

In total, six patrol-tracks in five sub-areas (i.e. 521, 513, 520, 516 and 522) were selected which were normally patrolled on foot by forest officers at the Hon Can sub-area forest plots. Furthermore, a summary of the relative altitude, size, and distance from the forest station to the beginning of the patrol routes for each of the six tracks is represented in Table 1. The tracks were divided into different categories, such as distance, time consumed, and problem zones that have a high level of illegal activities. All patrol tracks are illustrated on the map (Figure 1). Institutional data in relation to illegal activities in the forest areas were encountered during field-work covering the period of patrol routes (Ayivor, Gordon, & Ntiamoa -Baidu, 2013).

The spatial dispersion of illegal activities encountered differed among the main patrol routes. Encroachment was the most common in the core-zone, where there was a high population density of cattle in the neighboring area and protected area (Critchlow *et al.*, 2015) (Figure 2). Of the threats that face protected areas, as reported by Fleischner (1994) and Gurung, Nelson, and Smith (2009), livestock grazing restrictions are the most common condition in the protected areas followed by fringe communities and NTFPs. Furthermore, livestock grazing activities have been implicated as an unhealthy condition of conservation (Borman, 2005; Yates, Norton, & Hobbs, 2000) or damage to trees (Adams, 1975). Other threats in the order of severity were gunshots heard, collecting firewood, and timber cutting. While some of the threats such as timber cutting or the transport of timber were obviously illegal activities, other factors, such as the living standard in the immediate communities and the high population density, might not have direct impacts but could aggravate illegal activities (Ayivor *et al.*, 2013).

Table 1. Summary of the sub-forest plots in the protected area of HCFS.

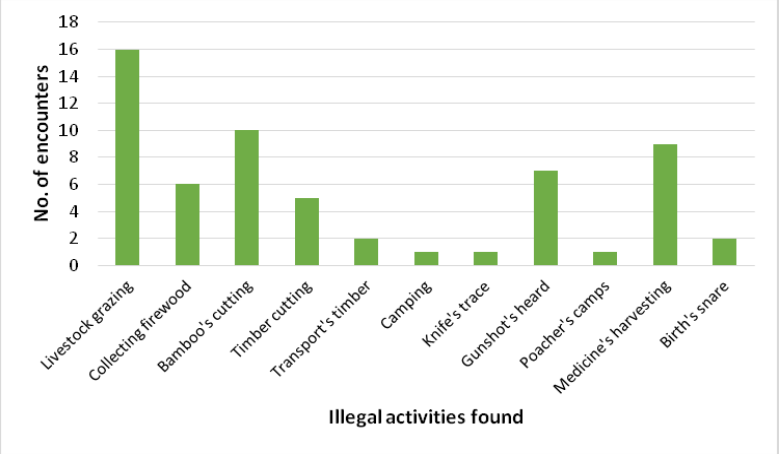
Name	Name of sub-areas	Size (Ha)	Patrol distance (Km)	Relative altitude (m)
Track 1	521	385.24	2.5–3.5	95–326
Track 2	513	485.56	2.9–4.6	87–257
Track 3	520	450.32	8.7–9.2	145–589
Track 4	520		6.6–7.2	124–560
Track 5	522	364.09	3.6–4.3	103–276
Track 6	516	670.28	9.9–12.1	115–1,596

3.1.1 Sub-area No. 521

Track 1 is called the 'utilization track' because it was an access road for trucks to extract timber which would have been inundated after the construction of Cua Dat Hydro Power Station. This track is 3,270 m long and required about 3 h walking time (Figure 1). The starting point of the track was about 600 m from the HCFS and one needed to enter through the security station of at the Cua Dat Hydropower Station which protects a small sub-dam of the lake. Most of the illegal activities that included signs of collecting firewood and footprints, sound, and live cattle and buffalo were observed (Table 2). In general, human activities along this track have been reduced because of the nearby HCFS and more often short patrols in the area were conducted. However, there was a big problem at five coordinate points where there was free-range grazing of cattle and buffalo in the core and buffer zones.

3.1.2 Sub-area No. 513

Track 2 is called Dinh Wharf or Burning Camp and covered a distance of 3,970 m and took about 4 h to walk. The starting point of the track (Figure 1) was near the starting point of Track 1 and ended at the border of the Son Khao protected area. Along this track, multiple signs of human



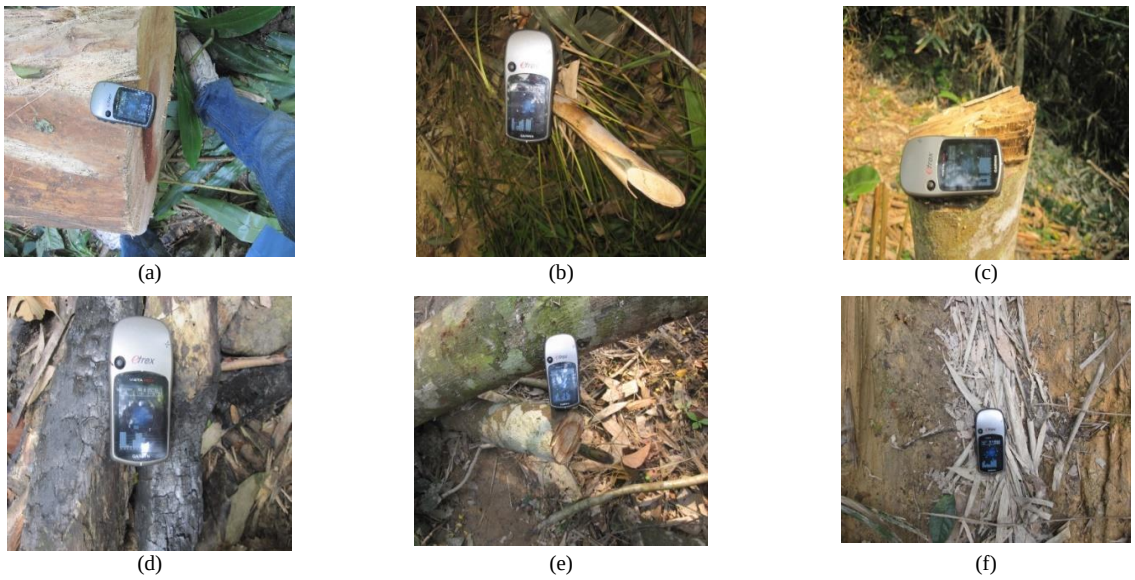


Figure 2. Number of illegal activities encountered as shown in the pictures: (a) Cattle footprint; (b) Bamboo cutting; (c) Timber harvesting by knife (d); Firewood using; (e) Cutting wood; and (f) Timber transport

Table 2. List of illegal activities found.

Activities found	Noted points	Coordinate points	
		x	y
Livestock grazing	Heard	525 307	2196 855
		526 267	2196 965
		526 058	2197 469
		526 224	2197 423
Collecting firewood	Two persons	526 159	2197 442

Table 3. List of illegal activities found.

Activities found	Noted points	Coordinate points	
		x	y
Livestock grazing	Footprint	524 613	2197 856
	Making noise	524 301	2198 086
		524 549	2197 948
Bamboo harvesting		524 640	2197 744
Timber cutting	New	524 540	2196 013
	Old	524 116	2198 297
Collecting firewood		523 966	2198 426
Transport of timber		524 634	2197 813

activities were observed (Table 3). It was quite obvious that the local people from the adjacent village commonly entered the nature reserve without permission. Eight recorded coordinate points showed proof of bamboo and timber cutting, firewood collection, and slip marks on the ground that indicated transport of timber. There was extensive timber cutting, logging and transporting going on in the area. The law enforcement rangers reported that they attempted to find out who the culprits were and what the illegally obtained forest produce was used for, but most likely the use was firewood for cooking and warming of the house.

3.1.2 Sub-area No. 513

Track 2 is called Dinh Wharf or Burning Camp and covered a distance of 3,970 m and took about 4 h to walk. The starting point of the track (Figure 1) was near the starting point of Track 1 and ended at the border of the Son Khao protected area. Along this track, multiple signs of human activities were observed (Table 4). It was quite obvious that the local people from the adjacent village commonly entered the nature reserve without permission. Eight recorded coordinate points showed proof of bamboo and timber cutting, firewood collection, and slip marks on the ground that indicated transport of timber. There was extensive timber cutting, logging and transporting going on in the area. The law enforcement rangers reported that they attempted to find out who the culprits were and what the illegally obtained forest produce was used for, but most likely the use was firewood for cooking and warming of the house.

Table 4. List of illegal activities found.

Activities found	Noted points	Coordinate points	
		x	y
Livestock grazing	Making noise	523 123	2196 429
	Making noise	522 902	2196 310
Banana leaves	Three persons	524 310	2196 043
		524 107	2196 117
Transport of timber		524 024	2196 126
Banana trunk		523 390	2196 172
Timber cutting	Long time ago	522 192	2196 229
	New	522 833	2196 498
Camping		521 798	2196 117
Collecting firewood		524 089	2196 098

3.1.3 Sub-area No. 520

1) Track 3 tourist track

The total distance of this combined tourist track covered a round-trip tour of 9,025 m that took 1 h by motorbikes and walking (Figure 1). This track is a path for tourists developed by the government and the end of the track finishes at the Mu waterfall. However, at the same time, the trail for walking is also perfect for illegal extraction of NTFPs as well as poaching. There were 10 recorded coordinate points of illegal activities. Local rangers should urgently strive to prevent these ongoing illegal activities because it certainly has a negative impact on tourism. The Management Board of the XLNR has considered the impacts on the environment and biodiversity and they have provided clear rules for activities such as campfires and garbage collection. It also needs clear guidelines for the organization of tourist groups visiting these areas. Eco-tourism also provides a good chance to involve the local people and come into a productive dialog between the rangers and the villagers. It could help resolve the people/ ranger conflicts in the protected areas by reducing the disturbance of biodiversity conservation (Jachmann, 2008c; Rica *et al.*, 2017).

2) Track 4 Tat Mu area and Mu waterfalls

This track started in the Tat Mu area and was 6,997 m long. It took 3.5 h of walking and ended up at the same point as Track 3 at the top of Mu Waterfalls (Figure 1). The distance between the starting point of that Mu area and HCFS was about 7 km and led through the village of Quan. Signs of human activities along the track were common and eight coordinate points were recorded for cattle grazing, cutting, and non-timber harvesting. Grass shacks had been built and cigarette packages and other garbage were commonly found (Table 5).

Table 5. List of illegal activities found.

Activities found	Noted points	Coordinate points	
		x	y
Livestock grazing	Footprint	523 271	2195 089
		522 395	2195 661
	Making noise	522 283	2195 671
Knife traces	New	521 606	2195 764
Collecting firewood		521 624	2195 766
Gunshots heard	Estimate	522 021	2195 766
	Estimate	521 624	2195 906

3.1.4 Sub-area No. 522

Track 5 was about 3,921 m long and it took about 2.5 hours of walking time. The track started about 10 km from the HCFS and led through the village of Thac Lang which was situated in the middle of this area (Figure 1). Nine points of illegal activities were recorded which were cattle grazing, bamboo shoot harvesting, cuttings of wild banana leaves and trunks, and the camps of poachers (Table 6). Evidence of illegal timber logging was discovered whereby big trees had been felled. Such timber has been confiscated and sold by the government to earn revenue. In general, this area was greatly difficult for the rangers to patrol and protect from illegal logging. Even the local rangers were supported by a mobile team from the head office which regularly patrolled the roads leading out of the area. The HCFS was at the end of the main road and it was therefore easy for the illegal loggers to transport timber out of the area (Figure 1).

Table 6. List of illegal activities found.

Activities found	Noted points	Coordinate points	
		x	y
Timber's harvest	New	527 623	2196 534
Bamboo shoot's		528 311	2196 527
		527 637	2169 632
		527 520	2196 611
Banana's leaves		527 823	2196 570
Collecting firewood		527 441	2196 603
		527 678	2196 498
Banana's trunk		527 786	2197 566
Poacher's camps	Bamboo	527 752	2196 573

3.1.5 Sub-area No. 516 and part of sub-area No. 520

The so-called Pu Gio mountain track was Track 6. It was the longest and most difficult patrol route in the Hon Can protected area (Figure 1). The track covers a distance of 15.84 km and about 3 patrolling days are required. There were 21 locations where illegal activities occurred (Table 7). This track led 4.8 km and 11.04 km through the two sub-areas of 520 and 516, respectively. Like the other patrol tracks, the most common illegal activities were signs of illegal cattle grazing, bamboo shoot harvesting, and NTFP harvesting in both sub-areas. Interestingly, most signs of poaching were discovered in the sub-area of 516 (5 marked points) while in the sub-area of 520 only one location was marked because a poaching shelter discovered. It is urgently needed for the Management Board to confiscate guns in the adjacent villages with the local authorities because of illegal possession of firearms by the local people.

Table 6. List of illegal activities (520 and 516 sub-area forest plots).

Activities found	Note points	Coordinate points		Sub-areas
		x	y	
Livestock grazing		523 960	2197 051	
		523 796	2197 203	
		523 621	2197 273	
Bamboo shoots		524 404	2196 782	
		523 937	2197 028	520
Harvesting medicine				
		522 955	2197 798	
		523 026	2197 682	
Gunshots heard		522 991	2197 810	
Livestock grazing		521 134	2200 134	
		521 005	2200 017	
Harvesting medicine		521 274	2200 239	
		521 180	2200 239	
		521 180	2200 111	
		518 693	2198 861	
		519 078	2199 702	516
Gunshots heard	2 times	520 701	2198 429	
	3 times	520 258	2198 102	
		519 206	2198 055	
		519 171	2198 476	
Birth's snare		519 393	2199 947	
		519 604	2199 877	

3.2 Efficiency of patrolling

According to patrol efforts of the HCFS (including distance or the hours or both in terms of illegal activity encounters), there was no correlation between illegal/patrol-distance and illegal/patrol-time (r_s=0.107, P>0.05). However, based on the research by Jachman (2008b) any correlation depended on topography and senior staff performance. Nonetheless, there was a noticeable trend in the great number of illegal activities based on patrol-time more than patrol-distance in all patrolling tracks. Clearly, the 10 illegal activity points following patrol-time in Track 3 were the highest and biggest compared to the other tracks and patrol-distances (Figure 3) which was contrary to the results of Jachmann (2008a). However, a negligible number of illegal activities

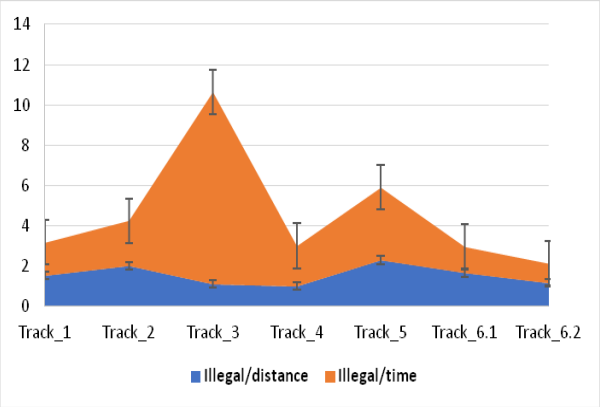


Figure 3. Trends of encounters of illegal activities in respect to distance and time.

found in terms of patrol-distance and patrol-time was encountered in Track 6 of 4.8 km. Quite surprisingly, all of the illegal activities encountered among the patrol tracks were not significant (H=4.19, P>0.05), which was similar to the results of (Wiafe, 2016).

4. Conclusions

Overall, this information on the distribution of illegal activities determines targeted patrol coverage to address specific threats (Gray & Kalpers, 2005). Nonetheless, the dynamics of alternative needs and aspirations require periodic feedback for continuing enhancement (Varma, Ferguson, & wild, 2000). Livestock grazing was commonly found in the core zone of the Hon Can forest during the patrolling activity. However, according to the information from the rangers, each patrol has the potential of being dangerous. Therefore, enhancing the frequency of patrol efforts and a greater presence of patrol activity in the field could greatly reduce the danger. The survey revealed manifold challenges to get biodiversity destruction under control. This research attempts to find a basic strategy to work out planning tools, skills, and active efforts to significantly improve sustainable forest protection at the local level. A long-term investment in the motivation and social aspects of staff personnel to prevent illegal activities is needed. Further research is needed to analyze the long-term patrols of the tracks before considering the prevention of illegal activities.

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