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Research Article
Impact Assessment of Off-Road Activities for Sustainable Tourism Management in Khao Krajome, Thailand

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Abstract

Background and Objective: This study investigates the effects of off-road activities associated with nature-based tourism, an important head watershed of 16 km^2 in Khao Krajome, Thailand. This location is only accessible by off-road vehicles. The purpose of this study was to assess the impact of the use of off-road vehicles on the environment, in particular, by evaluating noise level, the number of animals, the number of vegetation and soil compaction. **Materials and Methods:** Data were collected in high and low tourist season. Wildlife number assessment was determined by the strip-transect method. Sixteen collection points were used to measure the impact of off-road vehicle use on vegetation and soil. Classification of the sampling sites was based on their distance from the road. To measure environmental impact, the first 8 collection points were located close to the road, while the remaining 8 collection points were located 14 m away from the road. Mann-Whitney U-Test was used to determine the data. **Results:** Mean noise levels were determined to be 24.3 dB(A) during the high season and 12.1 dB(A) during the low season. The noise levels were 2.5 times greater than regulations allow (10 dB(A)). This was also reflected in the number of animals, as fewer animals were found in close proximity to the road. The findings from Mann-Whitney U-Test revealed that the increased soil compaction along the road was significant ($\alpha<0.05$) when compared to locations away from the road. While the number of plant species was not statistically different between collection points. **Conclusion:** It was concluded that these off-road activities caused negative impacts on the environment, in particular wildlife. It is anticipated that these findings will assist in the regulation of nature-based tourism in comprehensively managing this location for environmental and tourism sustainably.

Key words: Nature-based tourism, off-road impact, tourism impact, impact assessment, sustainable tourism management

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

After the United Nations Conference on Environment and Development or Earth Summit was arranged in 1992 at Rio de Janeiro, Brazil, sustainable tourism has become a significant economic goal for many countries all over the world[1,2]. Developing countries, whose main incomes are from tourism, have focused more on sustainable tourism[3]. The World Tourism Organization (WTO) defined that sustainable tourism is the tourism which use environmental resources for tourism by balancing the utilizing between environment, social and economy. Tourism benefits have to return to local people, communities and tourist areas. Local people must participate in decision making on sustainable tourism management in their community[2]. In other words, sustainable tourism is the development that is able to satisfy tourists and fulfill the need of existing local people by protecting and preserving the opportunities of the future generations[2-5]. Consequently, based on beneficial of sustainable tourism has been brought a trendy of tourism from the former era[6]. The sustainable tourism has impact on the tourism development, tourism management system and tourism pattern which lead to the alternative tourisms such as nature-based tourism, ecotourism, adventure tourism, cultural tourism and rural tourism, etc[7].

At this time, nature-based tourism is an important part of the world tourism industry both in international and domestic tourism[7]. Definition of nature-based tourism is traveling with the purpose of visiting a natural destination[8,9]. It focuses on specific element of natural environment and enjoys activities of undisturbed nature[3,6,10]. Nature-based tourism comprises; (1) Learning in the tourist attraction through experiences or tourism activities, (2) Sustainably consuming resources by avoiding deteriorating them, (3) Elevating and developing the quality of life of local people by tourism, (4) Respecting culture, society and local values and (5) Returning the profit from tourism to the local community[11].

However, nature-based tourism activities can impact on the environment in several ways, if the appropriate management is not applied. For example, trekking can disturb wildlife, hiking can trample plant cover and camping can destroy forest area and generate waste[9,12,13].

For off-roading, it is becoming a popular nature-based tourism activity in worldwide tourist attractions. Therefore, without appropriated tourism management, off-roading activity can cause the negative impacts on environment. For instance, the impacts on soil were accelerating compaction and erosion, reducing water infiltration rate, increasing runoff and leading to deep gully. All types of soils were susceptible to damage by off-road vehicle[14,15]. As the impacts on vegetation, off-road activity effected on seedlings, saplings and plant cover by disturbance, trampling, crushing and destroyed[14,16,17]. Wildlife was also affected by off-roading activity, i.e. alerted and escaped behavior, accumulated stress, disturbed feeding, changed or loss habitat, increased injury or mortality, etc.[17]. The several impacts on wildlife were happened from noise of off-roading, the loud noise caused increased stress, accelerated heart rate and metabolism, decreased courtship, breeding, reproduction, raised migration, etc[15,18]. All of that were both short and long-term effects on environment. The diagram of effects of off-road driving in ecosystem was showed in Fig. 1[19].

The off-road activities on the tourism area may cause some direct and indirect effects. Therefore, the aim of this study was to assess impacts of the off-roading and propose a sustainable tourism management plan to minimize negative impacts on the study area, Khao Krajome.

MATERIALS AND METHODS

The study was carried out at Khao Krajome which has become the most famous nature-based tourist attraction for off-road activities over the last decades in Ratchaburi Province, Thailand. It is a part of Tanao Sri mountain range, with its height approximates 1,045 m above sea level. It was classified as class 2 watersheds with high biodiversity and should be sustained for being upstream. The high tourist season is in winter during November-February[20].

The authors conducted field survey along the 8 km trail of off-roading during November, 2015-May, 2016 for three months in high season and three months in low season. The study was focused on four environmental aspects. Two physical aspects were noise of the off-roading and soil compaction. The other biological aspects were wildlife and vegetation. Five steps of methodologies were implemented in this study.

- Noise of the off-road activities was measured by sound level meter far 1 m away from the edge of the road during 5-7 a.m., which was a prime time of off-roading. The measurement was conducted by following to noise measurement manual in standard IEC 61672. Background noise level (L_{A90}), residual noise level (L_{Aeq}) and specific noise level were recorded. Then, all values were applied to calculate the noise level[21]. In addition, we numbered the off-road vehicles by analog hand counter in the same period

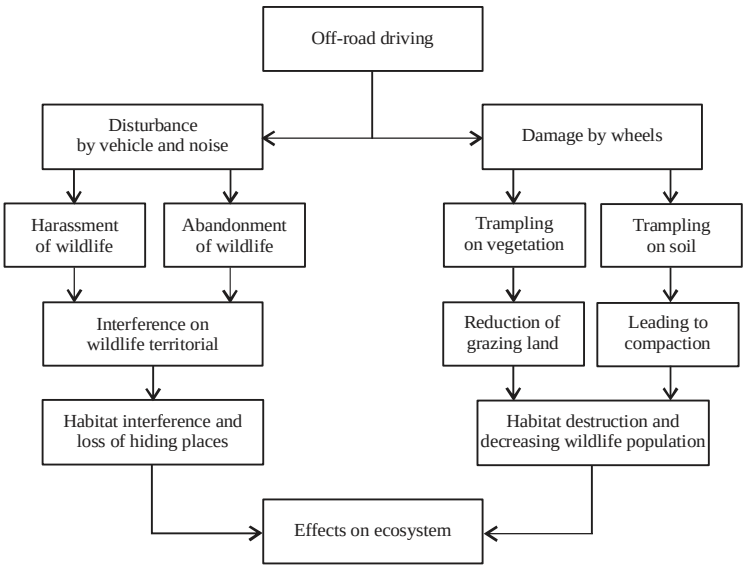

Fig. 1: Effects of off-road activities in ecosystem[19]

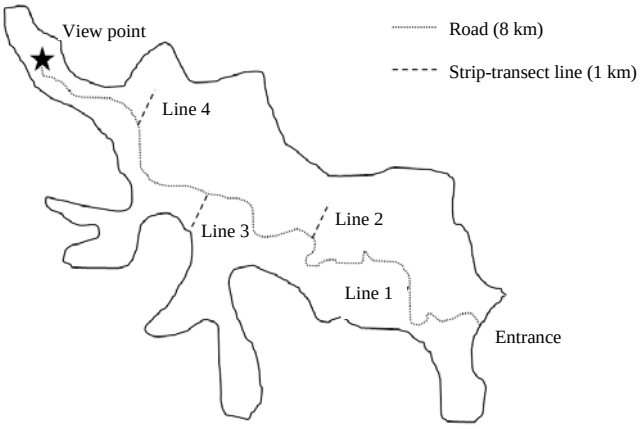

Fig. 2: Four strip-transect lines were perpendicular to road of off-road activities

- Wildlife was investigated by strip-transect in four lines, two lines on the left and two lines on the right of the off-road path. Every line was perpendicular to the road. Each line had 1,000 m length and 100 m width[22] (Fig. 2 and 3). One kilometer of strip-transect line was divided into five parts of length, namely 0-200, 201-400, 401-600, 601-800 and 801-1000 m. The authors focused on mammals, reptiles, amphibians and birds. The number of animals and their traces was counted and recorded. Animal traces covered footprints, dungs, nests, feeding traces, living traces and call. Then the number of animals and their tracts were considered with the distance far from the road
- Vegetation was inquired by quadrat sampling that focused on seedlings and saplings, which might be affected from trampling of the off-road vehicles[23]. Seedling height was lower than 1.30 m and sapling was less than 4.5 cm in diameter at breast height of 1.30 m. There were four sampling sites. Each of them was composed of two plots in tourism areas (edge of the road) and two plots in natural areas (14 m far from the road side). The quadrat area was 1×1 m^2 for seedlings and 4×4 m^2 for saplings (Fig. 4). Seedling and sapling were counted and recorded by their appearances. Then the number of vegetation was considered in the difference of tourist seasons and sampling areas
- Soil samples were collected by using soil core for Saturated Soil Hydraulic (K_s) assessment[24]. There were four sampling sites. Each of them was composed of two points in tourism areas (edge of the road) and two points in natural areas (10 m far from the road side). Each points of soil collection were in the middle of the plots of

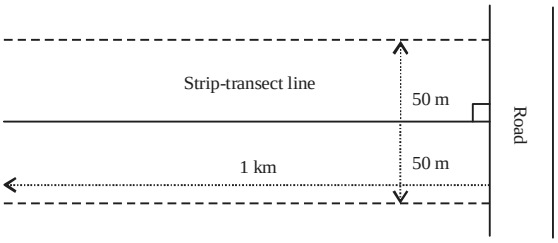

Fig. 3: Strip-transect line was set up to explore wildlife

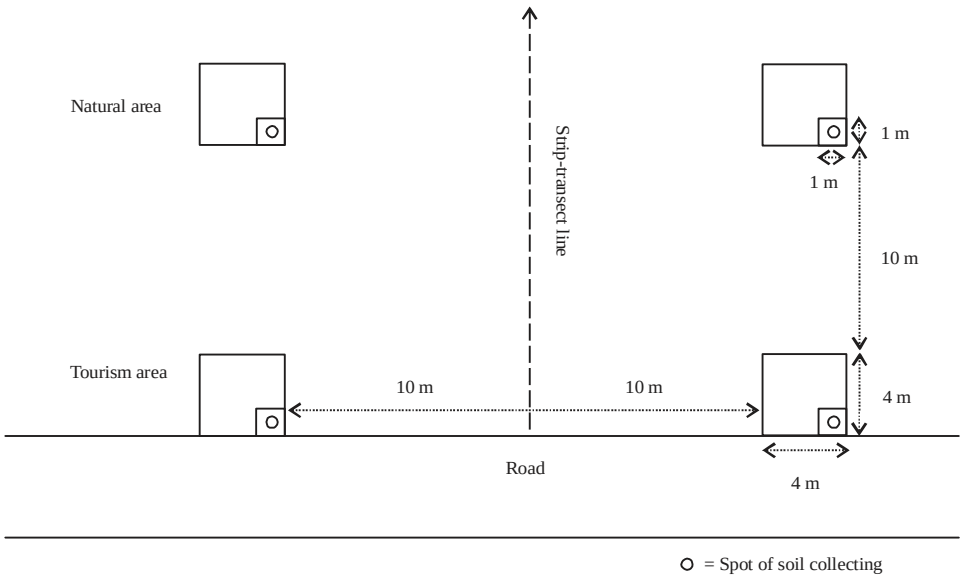

Fig. 4: Vegetation quadrat and point of soil collecting

seedling study area (Fig. 4). Soil analysis was studied in laboratory to find K_s. Then the average of K_s was considered in the difference of sampling areas

- The sustainable tourism management was developed for the study area based on the results from the first four step, ecological consideration, principles of conservation and principles of sustainable tourism management

Statistical analysis:

- Linear regression analysis was carried out to calculate the correlation between number of off-road vehicle and noise level of the off-road
- For consideration of the impact on vegetation from off-road vehicle trampling, Mann-Whitney U-Test was applied to compare the difference of average number of vegetation between high and low seasons and average number of vegetation between tourism and natural areas[16,23]
- For consideration of the soil compaction by off-road vehicle trampling, Mann-Whitney U- Test was applied to compare the difference of average K_s of soil between tourism and natural areas[16,24].

RESULTS

Noise of off-roading: The mean of noise level in six months, it was 18.2±6.9 dB(A) as shown in Fig. 5. The mean was 24.3±2.0 dB(A) in high season and 12.1±2.0 dB(A) in low season. During 6 months of surveying, the maximum number of off-roads was 89 cars/day in high season, meanwhile, the minimum number of off-roads was 4 cars/day in low season. The relationship between the mean of noise level and the number of off-roads as shown in Fig. 6. It was analyzed by linear regression which found that noise level has correlated significantly with number of off-road in high level ($R = 0.983$) indicated by Sig.=0.000 at least $p \leq 0.05$ ($R^2 = 0.967$).

Wildlife: Total number of animal traces in four strips-transect lines during 6 months as shown in Fig. 7. It shows that animal traces were likely to be found in the line distance 801-1,000 m

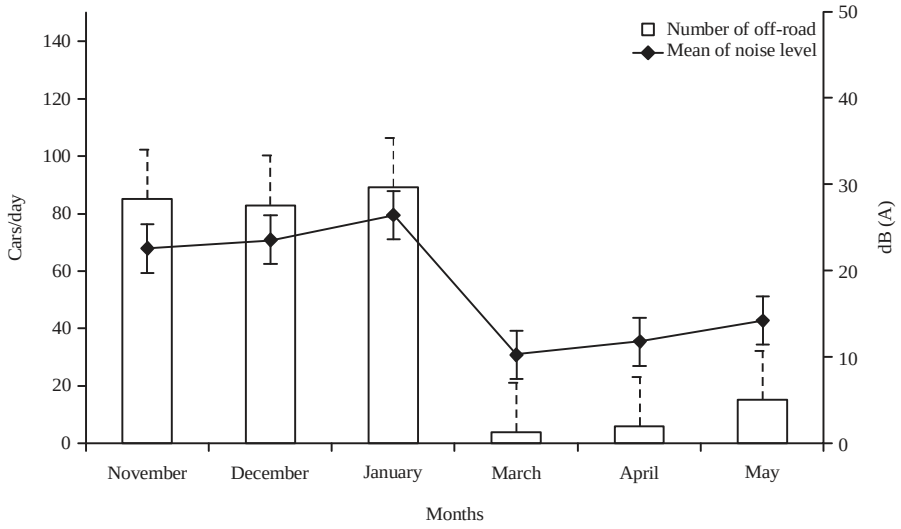

Fig. 5: Mean of noise level dB(A) ±SEM and number of off-roads ±SEM (cars/day)

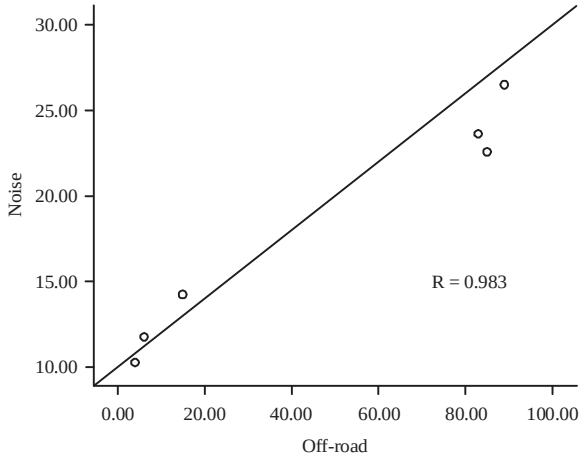

Fig. 6: Linear regression of noise level dB(A) and the number of off-roads (cars/day)

far from the road for every line. Meanwhile, the less number of animal traces was found in the 0-200 m far from the road.

Total number of animals in four strips-transect lines during 6 months as shown in Fig. 8. Most animals were found within the distance of 801-1,000 m lines. Meanwhile, the authors did not find any animals within the distance of 0-200 and 201-400 m for every line.

Total number of animals and their traces grouping by animal types are as shown in Table 1.There were 2 amphibian species, 2 reptile species, 26 bird species and 14 mammal species found during the field survey. The appearances of animals were increased along the distance far from the off-road site for all animal types.

Soil compaction: The statistical analysis was applied to compare the difference of average K_s at 8 points in soil between tourism areas and natural areas. K_s was indicated by Sig.(2-tailed) = 0.000 at least α = 0.05 [Sig.(2-tailed)/2= 0.000<α(0.05)] denied H_0, accepted H_1 that its result was able to explain the average K_s in the tourism areas was less than those found in the natural areas at 0.05 significant level.

Vegetation: From Table2, the statistical analysis was applied to compare the difference of average number of seedlings in high season and low season which was indicated by Sig.(2-tailed) = 0.050 at least α = 0.05 [Sig.(2-tailed) = 0.050 $\geq$ (0.05)] accepted H_0, denied H_1 that its result was able to explain the average number of seedlings in high season was not different those found in low season at 0.05 significant level. For sapling, it was indicated by Sig.(2-tailed)=0.050 at least α = 0.05 [Sig.(2-tailed)= 0.050$\geq$(0.05)] accepted H_0, denied H_1 that its result was able to explain the average number of saplings in high season was also not different those found in low season at 0.05 significant level.

From Table 3, the statistical analysis was applied to compare the difference of average number of seedlings in tourism area and natural area which was indicated by Sig.(2-tailed)=0.400 at least α = 0.05 [Sig.(2-tailed) = 0.400>α (0.05)] accepted H_0, denied H_1 that its result was able to explain the number of seedlings in tourism area was not different those found in natural area at 0.05 significant level. For sapling, it was indicated by Sig.(2-tailed)=0.958 at least α = 0.05 [Sig.(2-tailed)=0.958>α(0.05)] accepted H_0, denied H_1 that its result was able to explain the number of saplings in tourism area was also not different those found in natural area at 0.05 significant level.

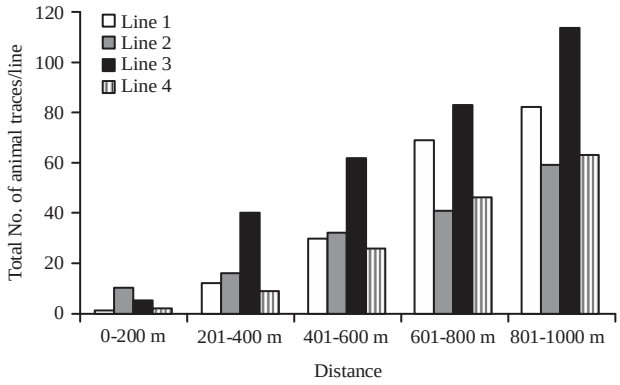

Fig. 7: Total number of animal traces in strip-transect lines

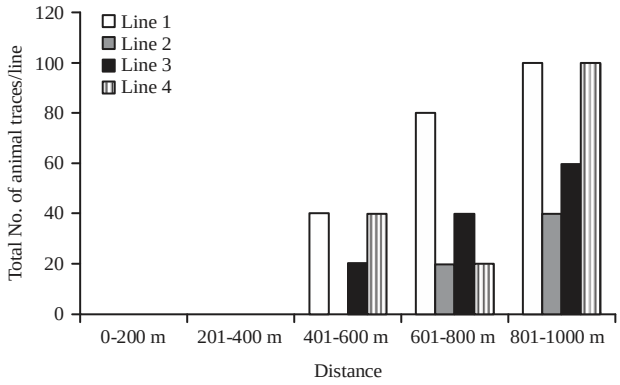

Fig. 8: Total number of animals in strip-transect lines

Table 1: Total number of animals and their traces grouping by animal types

	Animal types				
Distance	Amphibians	Reptiles	Birds	Mammals	Sum
0-200 m	0	0	7	11	18
	(0)	(0)	(0)	(0)	(0)
201-400 m	0	0	11	66	77
	(0)	(0)	(0)	(0)	(0)
401-600 m	0	0	38	112	150
	(0)	(1)	(3)	(0)	(4)
601-800 m	0	0	62	177	239
	(0)	(1)	(6)	(2)	(9)
801-1000 m	0	0	112	206	318
	(2)	(2)	(10)	(0)	(14)
Sum	0	0	230	572	802
	(2)	(4)	(19)	(2)	(27)
Average	0	0	46±43	114±80	160±121
	(0±1)	(1±1)	(4±4)	(0±1)	(5±6)

Number of animal traces (No. of animals), Average number±SD

Table 2: Statistical analysis comparing the difference of average numbers of vegetation between high season and low season

Vegetations	Seasons	N	Mean rank	Mann-whitney U	Significant (2-tailed)
Seedling	High season	3	5.00	0.000	0.050
	Low season	3	2.00		
Sapling	High season	3	2.00	0.000	0.050
	Low season	3	5.00		

N: No. of collection months, Indicates a significant difference($p<0.05$)

Table 3: Statistical analysis comparing the difference of average numbers of vegetation between tourism area and natural area

Vegetations	Area	N	Mean rank	Mann-whitney U	Significant (2-tailed)
Seedling	Tourism area	8	7.50	24.000	0.400
	Natural area	8	9.50		
Sapling	Tourism area	8	6.00	31.500	0.958
	Natural area	8	11.00		

N: No. of collection plots, Indicates a significant difference ($p<0.05$)

DISCUSSION

The result in this study showed that the noise level during high season reached 22-26 dB(A) which doubled the level of noise regulation (10dB(A)[21]. The number of animals and their traces were increased with the distance far from the road that tourist drove off-road vehicle up and down the mountain, which agree with the result in previous studies[25-28]. Amphibians and reptiles were not found in distances between 0-200 and 201-400 m far from the road, which was further than the distance that the previous study revealed. They reported that amphibians and reptiles reduced species richness up to 200 m from the road and enhanced diversity in the areas of plant cover[25-27]. Meanwhile, the number of birds and their traces in the study area increased in a distance further from the road. The former study found that noise level about 20-56 dB(A) was effect on birds[28-32]. Number of breeding birds in forest decreased significantly near the road. As same as Kaseloo[25], he revealed that some of birds became lower numbers up to distance of 250-500 m from the edge of road. They avoid the road to a distance of 500-600 m. Besides, there results conformed to the pervious study that animals tended to avoid the high disturbed area or route of off-roading[15,17,29]. Noise level will be higher with the number of off-road vehicles. At present, Khao Krajome is still an uncontrolled tourism area, lacking of regulation to limit the number of off-road vehicles especially during high tourist season. Undeniably, wildlife in this area has received effects by noise disturbance.

For vegetation observation, the results show that the number of seedlings in high season was not significantly different from those found in low season. Saplings were in the same result. The number of vegetation didn't depend on tourist season. It slightly varied in between high season and low season. The number of seedlings in tourism areas was not significantly different from those found in natural areas. Saplings were in the same result However, in other study showed that off-road could reduce plant cover, inhibit the germinating and seed emergence, change vegetation species composition, disturb natural plant succession, decrease mortality and extinct sensitive plants species[15]. Moreover, the survived trampling plants were weakened, malformed, limited growth, more vulnerable to disease and insect predation[17]. The degree of impact depended on the intensity of using off-road or associated with decreasing level of traffic[15,17].

The average K_s in the tourism area was significantly less than those found in the natural area. It could explain that low K_s in the tourism area implied high soil compaction because soil was trampled and compacted by off-roads so the water flowed with slow rate through the soil. On the other hand, high K_s in the natural area indicted low soil compaction because soil was not disturbed by off-roads. These results conformed to the previous study that off-road driving compressed and compacted soil which had effect to reduced water filtration[15,33]. Soil compaction was closely linked to plant growth and survival. It could restrict vegetation to uptake water and nutrient and confine root to penetrate into the ground[33,34]. Moreover, off-road vehicle using could change the properties of soil that led to increase erosion, inhibit seed germination and slow revegetation[15,34].

The sustainable tourism management is a significant tool for minimizing the impacts of tourism in pristine habitat. It should be developed based on ecological consideration that was supported by scientific knowledge, principles of conservation and sustainable tourism management. The applying of sustainable tourism management at Khao Krajome could be done in many ways as follows:

- The number of off-roads should be limited. Noise of off-roading disturbed wildlife. Moreover, too many numbers of off-road vehicles make congestion, which is the cause of high soil compaction and poor water filtration, respectively
- Routes or zones of off-roading should be confined to avoid the sensitive or critical habitat of rare or endangered species. In addition, tourists and off-road drivers should be informed about the concern so that they won't go out of the restricted zone
- The off-road period should be limited too. The tourism area should be temporary closed for natural recovery in low tourist season which is summer and rainy season. Plant covers and small vegetation can better grow when they are not disturbed by off-road vehicles. Furthermore, the soil compaction will be decreased during that time

- The engines of off-road vehicles should be checked up every year for effective operation to reduce the noise level of turbo diesel engine
- The impact of off-roading on soil, vegetation, wildlife and atmosphere should be monitored incessantly. The monitored data will be very useful for the future sustainable management and tourism development
- Stakeholders, experts and officials in the tourism area should collaborate to make a sustainable management plan. This is the appropriate method to compromise the economic benefits, the need of local people and the natural conservation
- Skillful local people for off-road service should be provided to the tourists instead of driving to Khao Krajome themselves, not only for their safety but also income distribution to the community. When local people obtain benefit from tourism, they will realize how important of the local tourism management and be willing to cooperate
- The tourists should be charged for entry. The entrance fee will be used for the tourism resource and environmental maintenance. In addition, the expenses of sustainable tourism management activities could be supported by this income
- Doing research about carrying capacity in the tourist attraction area is highly recommended because an appropriate tourism management corresponding to the existing natural resources is very important. The optimum number of tourists and off-road vehicles should be evaluated to avoid the deterioration accelerated by overcrowding, competition and over-consumption. In addition, the limited number of tourist can also mitigate the mentioned impacts

CONCLUSION

The off-road impact assessment showed that the noise level doubled during high season. More animals and their traces were founded in the area far from the off-road site, suggesting that wildlife was disturbed by the noise. The number of vegetation in the study areas was not significantly different from those found in natural areas. However, the soil around the route had high level of soil compaction, which might affect vegetation in the future. It could be concern that tourism in the areas needs some appropriate management to reduce the negative impacts and prevent unwanted problems that might occur.

SIGNIFICANCE STATEMENTS

To reduce the negative impacts from off-road activities in nature-based areas, it is necessary to assess the environmental effects both the biological and physical aspects. The number of animals and vegetation and soil compaction were investigated for assessing the impacts from off-road activities such as noise and trampling. The result can be beneficial to minimize the forthcoming negative impacts and apply sustainable tourism management plan.

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