EVALUATION OF RECREATIONAL TRAMPLING IMPACT ALONG NATURE TRAILS IN SANDAKAN RAINFOREST PARK

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THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotation, excepts, equations, summaries and references, which have been duly acknowledged.

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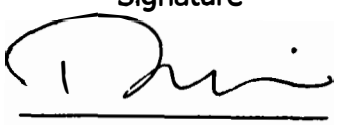

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ABSTRACT

A recreational trampling study is the scientific study of environmental impacts resulting from trampling in natural trails. Most of these studies involves intensity of usage, impact on vegetation and long-term effect of trampling. Nature trails in Sandakan Rainforest Park experience impacts from trampling. The objective of this study is to identify the impact of trampling by ascertaining the physical changes of soil and vegetation as well as to determine the trail disturbance based on trail assessment method. Trampling impacts depends on visitor use and rainfall. This study was carried out using fieldwork sampling adopted by Cole (1978) and Malandi (2012). Questionnaire survey data collection was modified by Tomes *et al.* (2005) and Marion *et al.* (2006). Convenient sampling was conducted in the trail and also in the undisturbed site which acts as a control point. 30 checkpoints were determined along the nature trail for sampling purpose. Each checkpoint has three subplots; (Plot A; on trail), within five metres from the trail (Plot B; <5m) and beyond five metres (Plot C; >5m) from the trail. Quadrat plots of 1m×1m were placed on every subplot, and soil compaction was measured using a FieldScout SC 900 Soil Compaction Meter. The average of compaction (kPa) until soil depth of 15 cm was taken in each plot. All the readings taken on trail plot will be compared to the control plot using ANOVA. The biodiversity index for the vegetation species was calculated. The result was also compared between the high use and low use trail using t-test analysis. The impact of visitor use and rainfall on soil and vegetation was tested using multiple regression analysis. The result found 916 vegetation from 58 species and 34 families in the study site. The ANOVA result indicated a definite difference in vegetation abundance among the plot. Margelef's index, Simpson's index and Shannon's index proved that Plot C (>5m) had the highest diversity, followed by Plot B (<5m) and Plot A (on trail). The average soil compaction is 934.59 kPa on the trail, 486.09 kPa within five metres from the trail and 462.74 kPa beyond five metres from the trail. This result shows a clear impact of trampling on soil compaction because the compaction on the trail subplot is almost doubled the compaction further from the trail subplots. The questionnaire survey indicate that the trail in SRFP is in good condition. The predictive equation from regression analysis of the soil compaction were produced with the independent variables of rainfall amount, visitor use and distance from trail. This study can be a baseline to reduce the impact on nature and increase the sustainability as well. The excessive trampling activity can cause damage to ecology in future and need to be monitored appropriately to maintain the ecosystem.

ABSTRAK

PENILAIAN KESAN PIJAKAN REKREASI SEPANJANG DENAI HUTAN DI TAMAN HUTAN HUJAN SANDAKAN

Kajian kesan pijakan rekreasi adalah kajian saintifik terhadap kesan alam sekitar daripada kesan pijakan di denai semula jadi. Kebanyakan kajian kesan pijakan rekreasi melibatkan intensiti penggunaan denai, kesan terhadap tumbuh-tumbuhan dan kesan jangka masa panjang. Pijakan rekreasi memberikan kesan ke atas denai semulajadi di Taman Hutan Hujan Sandakan. Objektif kajian ini adalah untuk mengenal pasti kesan pijakan dengan menentukan perubahan fizikal tanah dan tumbuh-tumbuhan semasa keadaan cuaca yang berbeza serta menentukan gangguan jejak berdasarkan kaedah penilaian denai. Kesan pijakan bergantung kepada bilangan pelawat dan kadar hujan. Kajian ini dijalankan menggunakan persampelan lapangan yang diterima pakai daripada Cole (1978) dan Malandi (2012). Pengumpulan data kajian soal selidik pula diubahsuai daripada Tomes et al. (2005) dan Marion et al. (2006). Pensampelan mudah dilakukan di atas laluan denai dan juga di tapak yang tidak terganggu dimana ianya bertindak sebagai plot kawalan. 30 titik pemeriksaan ditentukan sepanjang denai semulajadi untuk tujuan pensampelan. Setiap titik pemeriksaan mempunyai tiga subplot; (Plot A; di atas laluan denai), dalam jarak lima meter dari laluan denai (Plot B; <5m) dan melebihi lima meter (Plot C;> 5m) dari laluan denai. Plot kuadrat 1m × 1m diletakkan pada setiap subplot, dan pemadatan tanah diukur dengan menggunakan 'FieldScout SC 900 Tanah Compaction Meter'. Purata pemadatan (kPa) sehingga kedalaman tanah 15 cm diambil di setiap plot. Semua bacaan yang diambil pada plot di atas denai akan dibandingkan dengan plot kawalan menggunakan ANOVA. Indeks biodiversiti untuk spesies tumbuhan dikira. Hasil kajian juga dibandingkan antara penggunaan denai yang tinggi dan rendah menggunakan analisis t-test. Kesan penggunaan pengunjung dan kadar hujan terhadap tanah dan tumbuh-tumbuhan diuji menggunakan analisis regresi berganda. Hasilnya mendapati 916 tumbuh-tumbuhan daripada 58 spesies dan 34 keluarga di tapak kajian. Hasil ANOVA menunjukkan perbezaan yang jelas dalam bilangan tumbuhan di antara plot. Indeks Margelef, Indeks Simpson dan indeks Shannon membuktikan bahawa Plot C (>5m) mempunyai kepelbagaian tertinggi, diikuti oleh Plot B (<5m) dan Plot A (di atas laluan denai). Min pemadatan tanah adalah 934.59 kPa di atas laluan denai, 486.09 kPa dalam jarak lima meter dari laluan dan 462.74 kPa melebihi lima meter dari laluan itu. Hasil ini menunjukkan kesan pijakan yang jelas pada pemadatan tanah kerana pemadatan di subplot atas laluan denai hampir dua kali ganda pemadatannya dari subplot berjauhan dari laluan denai. Kajian soal selidik menunjukkan bahawa denai di SRFP berada dalam keadaan baik. Ramalan persamaan dari analisis regresi untuk pemadatan tanah dihasilkan dengan pembolehubah tak bersandar iaitu kadar hujan, bilangan pengunjung dan jarak dari denai. Kajian ini boleh menjadi asas untuk mengurangkan kesan alam semula jadi dan meningkatkan kemampanan. Aktiviti pijakan yang berlebihan boleh menyebabkan kerosakan pada ekologi pada masa depan dan perlu dipantau dengan sewajarnya untuk mengekalkan ekosistem.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

mm	-	millimeters
cm	-	centimeters
m	-	meters
m^2	-	meter squared
PSI	-	per square inch
kPa	-	kilopascal
%	-	percentage
<	-	less than
>	-	more than
=	-	equal to
°C	-	degree celsius

LIST OF ABBREVIATIONS

SRFP	-	Sandakan Rainforest Park
SFD	-	Sandakan Forest Department
BACI	-	before-after-control-impact
GPS	-	global positioning system
GIS	-	geographic information systems
RVC	-	relative vegetation cover
FRIM	-	Forest Research Institute of Malaysia
SPSS	-	Statistical Package for the Social Sciences
ANOVA	-	Analysis of Variance
USA	-	United States of America
UK	-	United Kingdom

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter provides brief information on the introduction of the impacts of recreational trampling. The next section of this chapter is research problem followed by the research gap of this research. Then, the objective of this research is stated subsequently.

1.1 Introduction

One activity that fundamentally every park visitor involves in is walking on trails. Trails are a means of communication within natural areas, and their routes are usually designed to adapt favourable criteria that would bring maximum impacts on the visitors in terms of expectation and satisfaction. Trail usually pass through accessible areas which are generally safe for visitors, although some activities may involve an adventure trail. Trail impact includes all the physical, ecological and aesthetic effects due to construction works and intensive trail use are considered as the most prominent recreational use impact in natural areas (Leung and Marion, 1996; Symmond *et al.*, 2000).

According to Cole (2004), even light traffic can remove protective layers of vegetation cover and organic litter from formal or informal visitor-created trails. Trampling in fact, walking on the same trail over and over again will trample the soil and vegetation which causes damage to biodiversity. Such damage can be even more extensive when visitors frequently stray off established trails (Korkanc, 2014).

The abundance and uniqueness of our natural resources, as well as the improved tourism accessibility in the country, attract tourist to explore the natural areas of Malaysia. However, the rapid growth of ecotourism and recreation use can be a threat to these natural areas (Hassan *et al.*, 2017). Eroding trails treads,

damaged trees, stressed wildlife, and dispersal of invasive species are a common sign of trampling impact in the protected area and national park which can have landscape level impact (Daim *et al.*, 2011). Trampling also can alter the appearance and composition of trailside vegetation by reducing vegetation height and favouring trampling-resistant species (Cole, 1995b). Trampling also can contribute to soil compaction, trail widening, exacerbate problems with muddiness, and accelerate soil erosion (Leung and Marion, 2000). Soil erosion, unlike most other forms of trail impact, is critical because it is not self-limiting.

Rapid degradation of plant and animal assemblages in response to experimental increases of trampling pressure would indicate the continued vulnerability of this critical and highly visible park resource. Rapid recovery of plant and animal populations following the reduction of trampling on experimental plots would be hopeful because this result would indicate that widespread recovery would be possible via modification of visitor behaviour (Holmquist and Schmidt, 2008). The knowledge of the ability to recover different types of vegetation and soil can be used to select areas, which will quickly recover following recreational trampling (Daim *et al.*, 2011).

The are several factors affecting the intensity of ecological impacts which includes the type of usage, amount and timing of usage, distribution of usage and the environmental characteristics of the site (Liddle, 1997; Monz *et al.*, 2010a; Pickering *et al.*, 2010; Barros, 2013). Information about the relationship between these factors and the severity of impacts is useful in the formation of guidelines for protected area managers on how to limit the impacts of visitor use (Monz *et al.*, 2010a).

1.2 Problem Statement

The lack of recreation ecology studies in our country is a problem which resulted in this research. Since the documentation of trampling experiment in Malaysia is too low, this study emphasizes the impact of recreational activity in the nature-based area. The recreation ecology experiments conducted in Malaysia are related to

specific vegetation resistance and soil properties (Jusoff, 1989; Sulaiman, 1998; Pamin, 2005) as well as visitor monitoring (Nor'Ain *et al.*, 2010; Daim *et al.*, 2011; Hassan *et al.*, 2017). Even though the nature tourism in our country growing actively, the management of resources in natural places is still less developed (Hassan *et al.*, 2017).

Particularly in Sabah, the engagement of people with nature based recreational activities increases rapidly. The Sabah State Forestry Department announced to The Borneo Post newspaper on July 2015 that Sandakan Rainforest Park (SRFP) was fully utilised before it was gazetted due to its open access to the park. The usage of SRFP is still considered high, even though the number of visitor decreases as the park demanded entrance fees. SRFP is serving as a favourite recreational forest in the district. This park has become a place for organised exercise with proper upgraded facilities. This is due to the loyalty of the consumer as well as the nature lovers who willing to pay the entrance fees (Sabah Forestry Department, 2015). However, excessive recreation usage can be a threat to the nature trail in SRFP.

The vegetation in SRFP is found to be less productive in growth and the vegetation in the park tends to stunt which will eventually result in species extinction (Lee and Damit, 2010). SRFP is protected and conserved in its natural conditions because there are many rare and endemic species located in this forest reserve. Furthermore, soil erosion also founded in some of the areas in the park due to soil compaction which leads to a reduction of macro soil pores (Ajik and Kimjus, 2014). Therefore, SRFP is in the urge to identify the impact caused by the visitors to the nature trail, vegetation, and soil so that the resources in the park could be protected and preserved for the much more extended period.

Therefore, the vegetation cover in the park, the soil compaction and the trail condition was selected as the main variables for the research. Based on the research gap, the effect of weather condition as rainfall amount on the variables also included in this study. A variety of assessment and monitoring methods have been developed for nature trails and are described in the literature, as reviewed and compared by

Cole (1983; 2004; 2014), Leung and Marion (2000), Olive and Marion (2009), Cole and Bayfield (1993), Growcock (2005), Olafsdottir and Runnstrom (2013).

1.3 Research Gap

Based on the literature review, most of the recreation ecology research has been actively carried out in a temperate environment, and relatively fewer studies conducted in the tropical region in the past (Talbot *et al.*, 2003). Notably, in Malaysia, studies on recreation ecology is still lacking in spite of the active participation in nature tourism (Daim *et al.,* 2011). Activities such as hiking and trekking are physically affecting resources, especially along the trail. Even though there are many studies regarding trampling conducted nowadays, there are still some factors less considered to be included in trampling studies. The summary of the selected literature on recreational trampling reviewed have been tabulated in Table 1.1.

Firstly, there are reduced number of studies using the mixed method as the previous studies mostly concentrates on quantitative sampling method (Cole, 1987a; Cole and Bayfield, 1993; Marion and Cole, 1996; Hesp *et al.,* 2010; Pickering *et al.,* 2011; Barros *et al.,* 2013; Korkanc, 2014; Tomczyk *et al.,* 2017; Rowe *et al.,* 2018 and more) and a few on qualitative questionnaire (Leung and Marion, 1999a; Lynn and Brown, 2003; Marion and Olive, 2006; Dorwart, 2007; Naber, 2008; Olafsdottir and Runnstrom, 2013; Verlic *et al.,* 2015; Hassan *et al.*, 2017; Schirpke *et al.,* 2018). The parameters selected for the study plays an important role in determining the method of study. An experimental study is used when the soil and vegetation parameters selected while the qualitative survey is selected for trail monitoring. Studies using both questionnaire and sampling together (Bates, 1935; Farrell and Marion; 2001b; Nepal, 2003) is rarely noted. As this trampling study involves soil, vegetation and trail as a parameter, it has prompt this research to combine both the sampling and survey as a mixed method.

Furthermore, this research includes weather condition in the form of rainfall amount as a variable because there was a lack of similar studies during different season. Previous studies have often been quantifying the impact of trampling on soil

and vegetation but the variable season have been overlooked. Research by Cole (1987a), Moles (1992), Gallet and Roze (2001), Mason *et al.* (2015) are among the few studies conducted comprising seasonal change. Since the soil and vegetation parameter acts as the essential and easiest way to identify trampling impact, this research also accesses those parameters together with visitor's perception on the trail condition.

In addition to that, the analysis used mostly for recreational trampling is the primary statistic and formulae. A maximum number of journals reviewed have been primarily using relative vegetation cover, statistical analysis and also ANOVA to analyze the variables as Table 1.1 suggests. Therefore, the advanced statistical analysis was used in this study to find the relationship of factors influencing trampling with the parameters tested. Descriptive, t-test, ANOVA and multiple regression analysis were carried out to justify the objective of this study. The biodiversity indices of the vegetation species also taken into consideration in this research.

Table 1.1: Summary of trampling studies on method, parameters and analysis used.

Author (year)	Method			Parameter/ Variable							Analysis								
	Questionnaire	Sampling	Mixed	Trail	Soil	Vegetation	Season	Forest / Area	Trampling intensity	Activities	Descriptive	ANOVA	t-test	Simple Regression	Multiple regression	Chi square	Biodiversity	Multivariate	Dissimilarity
Bates, 1935			✓		✓	✓		✓			✓						✓		
Cole, 1978		✓				✓											✓		✓
Cole, 1987		✓			✓	✓	✓	✓			✓			✓			✓		
Moles, 1992		✓			✓	✓	✓			✓	✓						✓		
Cole and Bayfield, 1993		✓				✓			✓		✓						✓		
Marion and Cole, 1996		✓			✓	✓		✓	✓	✓			✓				✓		✓
Leung and Marion, 1999	✓			✓				✓	✓		✓	✓		✓					
Rochefort and Swinney, 2000	✓			✓	✓	✓		✓			✓								
Farrell and Marion, 2001			✓	✓				✓			✓								
Gallet and Roze, 2001		✓				✓	✓	✓	✓			✓		✓			✓		
Lynn and Brown, 2003	✓			✓						✓						✓			
Nepal, 2003			✓	✓					✓		✓				✓				
Growcock, 2005		✓			✓	✓		✓	✓	✓	✓	✓					✓		
Marion and Olive, 2006	✓			✓	✓	✓				✓	✓	✓						✓	
Dorwart, 2007	✓			✓						✓	✓								
Nepal and Way, 2007		✓				✓		✓					✓				✓		✓
Naber, 2008	✓			✓						✓	✓				✓				
Kissling *et al.*, 2009		✓			✓	✓		✓	✓		✓	✓	✓				✓		
Olive and Marion, 2009		✓			✓				✓	✓		✓						✓	

Table 1.1: Continued

Author (year)	Method			Parameter/ Variable							Analysis								
	Questionnaire	Sampling	Mixed	Trail	Soil	Vegetation	Season	Forest / Area	Trampling intensity	Activities	Descriptive	ANOVA	t-test	Simple Regression	Multiple regression	Chi square	Biodiversity	Multivariate	Dissimilarity
Hamberg et.al., 2010		✓				✓		✓	✓					✓					✓
Hesp *et al.*, 2010		✓				✓		✓	✓		✓						✓		
Pickering *et al.*, 2011		✓			✓	✓			✓	✓		✓							✓
Barros *et al.*, 2013		✓		✓	✓	✓						✓	✓						✓
Olafsdotir and Runstrom 2013	✓			✓	✓	✓		✓								✓			
Korkanc, 2014		✓			✓	✓			✓		✓	✓					✓		
Barros and Pickering, 2015		✓		✓		✓			✓	✓		✓	✓				✓		
Mason *et al.*, 2015		✓				✓	✓		✓		✓						✓	✓	
Verlic *et al.*, 2015	✓			✓				✓						✓		✓			
Sujetovien Baranauskien 2016		✓			✓	✓					✓						✓		
Bar, 2017		✓			✓	✓					✓	✓		✓					
Hassan *et al.*, 2017	✓			✓	✓	✓					✓								
Pickering and Norman, 2017		✓		✓		✓		✓			✓							✓	✓
Tomczyk *et al.*, 2017		✓		✓				✓							✓				
Rowe *et al.*, 2018		✓		✓	✓	✓					✓	✓						✓	
Sabri *et al.*, 2018		✓			✓			✓			✓	✓							
Schirpke *et al.*, 2018	✓			✓						✓	✓	✓							
Yang *et al.*, 2018		✓				✓				✓	✓			✓				✓	
THIS RESEARCH			✓	✓	✓	✓	✓				✓	✓	✓		✓		✓		

1.4 Objective of Research

The overall objective of the study is to determine the impact of trampling and the influence of rainfall on nature trail, soil and vegetation at Sandakan Rainforest Park. The specific objectives are listed below:

1) To identify the impact of trampling by ascertaining the physical changes of soil compaction and vegetation abundance along a nature trail.
2) To determine the visitor's perception of trail condition based on trail assessment survey.
3) To predict the effect of visitor use and rainfall amount on soil compaction and vegetation abundance.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the background information about the topic of this research is provided including relevant literature and information from secondary sources. Hence, starting from the core topic of recreation ecology, followed by trampling was discussed. The impacts of trampling on trail, soil and vegetation, together with the factors affecting trampling also discussed in this chapter. Since there a wide range of methods to conduct a trampling experiment, further discussion on the methods of accessing trampling is mentioned in this chapter. This chapter was concluded with the discussion of previous studies conducted in our country and also in tropical settings.

2.1 Recreation Ecology

Recreation ecology can be defined as a scientific study that assesses, examines and monitor environmental impacts in natural and protected areas (Liddle, 1997; Manning *et al.*, 2017). Recreation ecology describes the types, amounts and rate of ecological changes resulting from recreational use which includes the relationship with the environment and usage factors (Cole, 2014). This field of study is a new and evolving science. Studies in recreation ecology have been actively carried out since the late 1960s in response to growth management concerns over increased visitors in natural areas. The rapid growth of ecotourism activities and concern about impacts at natural areas play an essential role in the uprising trend of visitor impact research.

Managers of national parks are often faced with the contradictory management goals of conserving the natural environment while also providing the opportunities for recreational use (Worboys *et al.*, 2005). The balance, however, is rarely maintained. Recreational use of protected areas inevitably has negative impacts on the environment (Cole, 1995a; Leung and Marion, 2000; Newsome *et*

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