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Research Paper

Examining the rate of vegetation diversity under abandoned skid trails in peninsular Malaysia forest

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Abstract. Skidding operations have been widely reported as a source of negative impact on soils and damage to vegetation. The diversity of species regenerated includes species richness, dominancy and evenness index that were discovered within abandoned skid trails after timber harvesting operations were enumerated in this study. Three classes of habitat were sampled: skid trail tracks, edges of skid trail and adjacent forests. Shannon's diversity index shows different indices are recorded for seedlings and saplings within the three habitats studied. Some seedlings were found to exist in all three habitats studied, and fewer or even none of the saplings were found within skid trail tracks; on the contrary, many saplings were found within edges and adjacent forests. While no dipterocarp species was found within skid trail tracks, *Shorea* sp. was found within edges and adjacent forests, and *Hopea pubescens* was only found within adjacent forests. The results show that there are different regeneration rates among the three different habitats depending on the size of gaps created during skidding operations. High regeneration rate was found to occur within edges habitat since it is more suitable compared with the other two habitats.

Keywords: Regeneration growth, gap areas, skidding activities, timber harvesting.

INTRODUCTION

Forest road is an important element in ensuring availability of timber products. However, forests roads are significantly affected by the machinery that frequently passes through the roads during timber harvesting operations. Road surfaces tend to be damaged, and the soil physical characteristics are changed. Severe impact is likely to happen if roads are constructed improperly with poor drainage system, which consequently exposes the roads to erosion problems. A couple of studies on forest road impacts have been conducted by researchers such as Tavankar and Bodaghi (2011), Ampoorter et al. (2010), Way et al. (2009), Demir et al. (2007) and Zenner et al. (2007). In Malaysia itself, several researches on forest road impacts after timber harvesting operations have been reported by researchers, including Mohd Hasmadi and Norizah (2010), Pinard et al. (2000), Kamaruzaman and Nik Muhammad (1992), Kamaruzaman (1991, 1988) and Kamaruzaman et al. (1986).

Skidding a log from stump site to the exit point or log landing does not require road construction. This process is referred to as road extraction, and the access route is called skid trail. Skid trail is a temporary route created to facilitate skidding activities by giving access to skidder machine to visit stump site and skid the timbers into log landing. As such, impacts on the soil surfaces are supposedly minimal since no earthworks are required for skid trail creation compared with the road surfaces used for main transportation activities, which require earthworks (Pinard et al., 2000). However, Demir et al. (2007, 2010) reported that frequent passes by particular skidding machines to transport timber from stump site to identical exit points still cause damage to skid trail surfaces, and this varies with factors such as terrain condition, harvesting system used and skid trail layouts. Wan Mohd Paiz (2003) and Dykstra and Heinrich (1996) pointed out that trail clearance made by skidding machine to visit the stump site creates impact and damages the residual vegetation. It is important to note that damage is not limited to the edges of skid trails. According to Ozturk et al. (2010), damage to vegetation is severe during construction works and the types of damage reported are tree bending, crushing and wounding. Tavankar and Bodaghi (2011) in their study examined the damage intensity on residual vegetation during skidding operations and concluded that damage can be minimized by a sound road network location. In addition, the system used during timber harvesting operations has an influence on the degree of damage caused to the residual vegetation. A study by Pinard et al. (2000) in Sabah, which compares the reduced impact logging (RIL) system with the conventional system, proved that the RIL system causes fewer disturbances to the vegetation, and reports from post-timber harvesting assessment showed that vegetation recovered fast, within four years after timber harvesting operations.

The tree tagging system introduced by the forestry department for trees to be felled was used as a point of reference to determine the safe felling direction and to plan and design good road networks. With this system, damage to other trees and gaps created as a result of fallen trees can be minimized (Hamzah et al., 2012; Sist et al., 1998). When skid trails are created the expected gaps caused by tree removal is at minimum a width of about 3.5 m (FDPM, 2010). Frequent machinery passes at the same skid trails cause additional damage to the edges of skid trail with soil compactions (Demir et al., 2010; Mohd Paiz, 2003; Pinard et al., 2000). Nevertheless, the extent of damage and impact is still unknown even after post- harvesting assessment is conducted. Assessment after timber harvesting operations is necessary to determine the status of the forests and available stocks for the next harvesting, and actions required for silvicultural treatment planning. Thus, gaps created from skidding activities need to be assessed to examine the emergence of new vegetation. According to Yamamoto (2000), when gaps are formed in a forest canopy, growth of advance regeneration within gaps is promoted and new seedlings turn into gaps. Species that emerge may vary depending on the size of gaps, survival rates and ability of species to adapt to the gap environments. If no assessment and silvicultural treatment prescription are made for skid trails, damage and impacts remain; vegetation growth will probably slow down and in the worst-case scenario, no vegetation will be able to grow.

The Shannon diversity index in terms of general diversity is appropriate to assess the rate of regeneration growth. Therefore, this study intends to quantify the growth rate of vegetation at abandoned skid trails after timber harvesting operations. Three different habitats of: 1) skid trail tracks, 2) skid trail edges, and 3) adjacent forests are sampled to allow a comparison of species regeneration to be done.

METHODOLOGY

Sampling design and description of data

Three sampling plots were established throughout the route of abandoned skid trails in order to estimate the intensity of expected regenerated species after skidding operations and the results from canopy removal. The sampling plots were 100 m apart, with five parallel subplots each measuring 2 m × 2m (4 m^2) covering the tracks of skid trail (referred to as subplot 1), the edges of skid trail (referred to as subplot 2) and adjacent forests (referred to as subplot 3). Sampling plots were kept at a distance of 100 m apart as a measure to cover the regenerated species along the alignment of abandoned skid trails from the exit points of skid trails, the middle of skid trails, and the end which is the farthest point of skid trails from exit point. Subplot 1 lies in between subplots 2 and 3 where vegetation is completely removed, and they have a wide canopy opening. Meanwhile, vegetation in subplot 2 is expected to be moderately disturbed subject to unexpected skidding operations that occur, which deviate from the originally planned skid trails. Subplot 3 is undisturbed areas adjacent to skid trail tracks and edges where there was no direct skidding impact; it served as a control plot. Figure 1 illustrates the layout of the five subplots established for species regeneration data collection.

Within the established subplots, seedlings with a height of more than 0.05 m, and saplings with a height of at least 1.5 m and 0.10 m in diameter size were collected; species identification was then conducted in Herbarium of the Faculty of Forestry, Universiti Putra Malaysia. The regenerated species collected are woody plants that consist of both dipterocarp and non-dipterocarp species. The rate of regeneration in terms of diversity index was computed by using Shannon's diversity index (Equation 1) introduced by Claude Shannon in 1948, and this idea originated from the theory of mathematics in communication (Spellerberg and Fedor, 2003). In order to obtain a better estimation of the rate of regeneration throughout the abandoned skid trails, three indices, which are species richness (Equation 2) (Menhinick, 1964), dominance index (Equation 3) (Simpson, 1949) and evenness index (Equation 4) (Pielou, 1966) were computed together with the diversity index (Sundarapandian and Karoor, 2013). In addition, the number of regenerated species and species density over one route of skid trails were also computed.

$$H^1 = \sum \left(\frac{n_i}{N}\right) ln \left(\frac{n_i}{N}\right) \quad (1)$$

Where H^1 is Shannon's index of species diversity, n_1 is

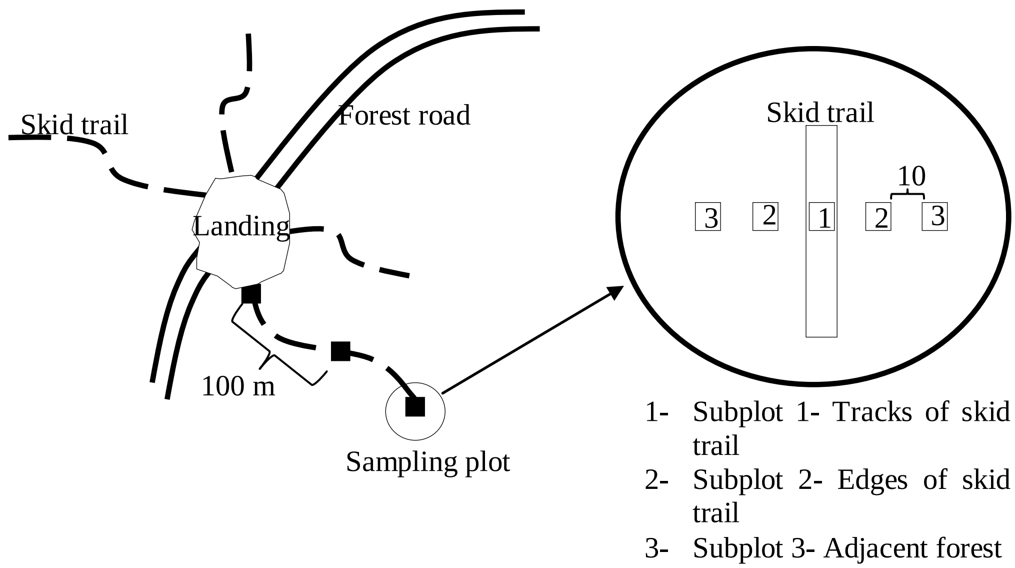

Figure 1. Layouts of sampling plots with a distance of 100 m apart throughout 1 skid trail, and 3 subplots with a distance of 10 m apart.

importance value index of species *i*, and *N* is importance value index of the population.

$$d = \frac{S}{\sqrt{n}} \quad (2)$$

Where *d* is the species richness index, *S* is the number of species, and *n* is the number of individuals.

$$c = \sum \left(\frac{n_i}{N}\right)^2 \quad (3)$$

Where *c* is the index of dominance, n_1 is importance value index of species *i*, and *N* is importance value index of the population.

$$e = \frac{H^1}{\log S} \quad (4)$$

Where *e* is the evenness index, *S* is the number of species, and H^1 is Shannon's species diversity index.

Data analysis

The research question formulated for this study was, "Are the species regenerated after skidding operations statistically different at different levels of canopy removal?" Thus, to answer the research question, the species diversity index, species richness index, dominance index and evenness index, number of species and the density of regenerated species under three different habitats were tested with one way ANOVA to determine if the null hypothesis is accepted or rejected; H_0: μ1 = μ2 = μ3, and H_1: not all μ's are equal, respectively. Where μ's are the three different habitats sampled for species regeneration data collection.

Study area

We conducted the study at one of the concession areas of Kompleks Perkayuan Kelantan Sdn Bhd (KPKSB), located in the state of Kelantan of East Peninsular Malaysia. This is a state-owned company for timber harvesting operations and sawn timber production. To be specific, this study took place at an operation unit in Compartment 47 of Balah Forest Reserve with an area of 299 ha, located at a latitude of 5° 18' 40.49 N and a longitude of 101° 45' 29.52 E (Figure 2). Some forest roads within the operation unit were constructed permanently and some were constructed temporarily. Meanwhile, all skid trails were constructed temporarily as prescribed by the rules and regulation for forest road construction for Peninsular Malaysia's forest (FDPM, 2010). The skid trails studied have been abandoned for two years, since 2012. The system and method used for timber harvesting operations for the study area are summarized in Table 1.

RESULTS AND DISCUSSION

Species diversity

A total of 238 seedlings and saplings representing 19 species from 15 families were recorded from the three

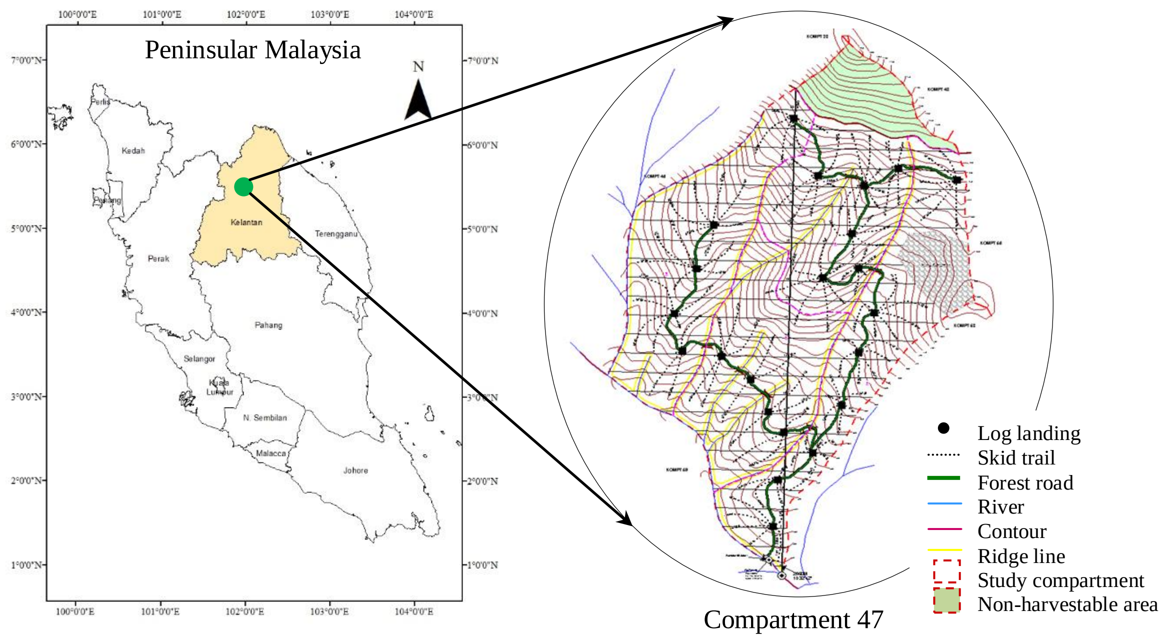

Figure 2. Study area located at Compartment 47 of Balah Forest Reserve, Kelantan, Peninsular Malaysia.

Table 1. Summary of timber harvesting operation practices conducted in the study area.

Details	Explanation
Harvesting system	Selective management system (SMS)
Harvesting method	Ground based harvesting
Harvesting season	All years (from 2010 to 2012) with fewer operations conducted in November until March due to wet season
Forest road density	39 m/ha
Skid trail density	300 m/ha
Skid trail width	3.5 m
Number of landing	22, measuring 0.25 ha for each landing
Timber volume harvested	68 m^3/ha
Wood product	Sawn timber

different habitats under the abandoned skid trail routes. Of that, 23 seedlings and saplings were found within subplot 1, while 136 and 69 were found within subplot 2 and subplot 3, respectively. Table 2 shows the attributes of diversity index measured from the study. From the results, subplot 1 has greater diversity index and species richness for seedlings, while saplings were found to have larger values for diversity index and species richness within subplot 2, followed by subplot 3. Single species was found for saplings within subplot 1 with a dominance index of 1, and this indicates only one species of sapling was found for every 300 m, and the number of species recorded was 0.003. For seedlings, the highest dominance index and number of sapling species were recorded within subplot 2, when compared with subplots 1 and 3. The trend of evenness of species populations shows a greater index recorded within subplot 2 (seedling was 0.92; sapling was 2.17), followed by subplot 3 (seedling was 0.58; sapling was 2.01), while low evenness index was recorded within subplot 1 (seedling was 1.44). The density of species shows the highest indices were recorded within subplots 2 and 3 for seedling and sapling, respectively. According to selective management system (SMS) practiced by the Forestry Department of Peninsular Malaysia (FDPM) (Norizah et al., 2011), it is necessary to assess the density of the presence of dipterocarp and non-dipterocarp species after timber harvesting operations under gap areas. By determining the current stocks of potential timber, the management strategies of strategic planning can be implemented as early as two years after timber harvesting operations. Such management strategies are

Table 2. The attributes of regenerated species under three different habitats of abandoned skid trails.

Attributes		Subplot 1	Subplot 2	Subplot 3
Shannon's index	Seedlings	1.9763	0.7128	0.1732
	Saplings	0	3.578	3.4581
Species richness	Seedlings	64.2211	21.965	2.4171
	Saplings	1	61.735	80.3651
Dominance index	Seedlings	0.161	0.66	0.92
	Saplings	1	0.36	0.45
Evenness index	Seedlings	1.4405	0.9161	0.57538
	Saplings	0	2.1735	2.01
No. of species/300 m	Seedlings	0.0333	0.02	0.0067
	Saplings	0.003	0.0267	0.0367
Species density/300 m	Seedlings	0.0733	0.25	0.08
	Saplings	0.0033	0.0867	0.1666

designed to prepare a local volume table of estimated growth performance of timber species and can be used to estimate allowable cut for the next harvesting (Rosli and Gang, 2013; Nur Hajar et al., 2010); by doing so, the primary goal of carrying out timber harvesting operations while optimizing the production of timber in view of constraints and possible negative impacts can be achieved (Davis et al., 2001). The details of species density of dipterocarp and non-dipterocarp species found in the study are presented in the following subsection.

Although there are differences recorded between these three different habitats for the regenerated species, the one-way ANOVA test shows no significance at a probability of 5% (Table 3).

Species heterogeneity

The maximum allowable timber cut was determined based on the measurements of diameter breast height (dbh) of dipterocarp and non-dipterocarp species, which have a minimum difference of 5 cm. In order to strategically plan the management strategies for the next timber harvesting cycle, the species heterogeneity for regenerated species in the study was enumerated based on dipterocarp and non-dipterocarp species group. Results from Table 4 show that non-dipterocarp species of *Elateriospermum tapos* has the highest density compared with dipterocarp species within subplots 2 and 3, while *Canarium* sp. was found to have the highest density within subplot 1. However, no dipterocarp species was found within subplot 1. Since the gap created from skid trail construction has a width of about 3.5 m, the concentration of light is probably high at subplot 1, resulting in no dipterocarp species found to be regenerated. Brown and Whitmore (1992) conducted a study concerning the classification of dipterocarp species as shade tolerant species, and its characteristic of slow regeneration rate under wide gap areas. Nevertheless, they also pointed out that some dipterocarp species may have high regeneration rates below wide canopy opening depending on the seedling size. Because all seedlings found in this study were naturally regenerated after skidding operations, we concluded that dipterocarp species would not be regenerated naturally under abandoned skid trails. This statement was confirmed by a study conducted by Itoh (1995) and Denslow (1987) where they suggested that dipterocarp species could be well regenerated at one large gap area depending on the suitability of the site such as light environment, soil conditions and effects of seed establishments.

Analysis of vegetation

Table 5 presents the importance value index (IVI) for two groups, dipterocarp and non-dipterocarp species found in the study. Non-dipterocarp species was found to be dominant in the three subplots studied; the greatest IVI was recorded within subplot 3 with 93.68, followed by subplot 2 (87.69) and finally, subplot 1 (50.35). The highest relative frequency, relative density and basal areas recorded for non-dipterocarp species were within subplot 2 (57.14%), subplot 1 (40.05%), and subplot 3

Table 3. Results of one way ANOVA for the index of regeneration rate.

	Df	Sum sq	Mean sq	F value	Pr(>F)
Shannon's index					
Subplots	2	1.422	0.711	0.186	0.839
Residuals	3	11.453	3.818		
Richness index					
Subplots	2	108	54.2	0.028	0.973
Residuals	3	5827	1942.4		
Dominance index					
Subplots	2	0.0310	0.01551	0.092	0.915
Residuals	3	0.5074	0.16914		
Evenness index					
Subplots	2	0.7141	0.3570	0.375	0.716
Residuals	3	2.8571	0.9524		
No. of species/300 m					
Subplots	2	0.0000282	1.412e-05	0.045	0.956
Residuals	3	0.0009315	3.105e-04		
Species density/300 m					
Subplots	2	0.01344	0.006722	1.128	0.431
Residuals	3	0.01788	0.005961		

Table 4. The heterogeneity of species under one route of abandoned skid trails (300 m).

Habitat sampled	Dipterocarp spp.	Spp. density (*no./300 m)	Non-dipterocarp spp.	Spp. density (*no./300 m)
	-	-	*Canarium* sp.	0.0167
	-	-	*Eugenia* sp	0.0133
	-	-	*Cinnamomum* sp.	0.0133
	-	-	*Goniothalamus* sp.	0.0100
Trails	-	-	*Macaranga* sp.	0.0067
	-	-	*Vitex* sp.	0.0067
	-	-	*Ficus* sp.	0.0033
	-	-	*Pometia* sp.	0.0033
	-	-	*Durio* sp.	0.0033
	Shorea sp.	0.0133	*Elateriospermum tapos*	0.3033
	Shorea ovalis	0.0033	*Goniothalamus* sp.	0.0733
	-	-	*Macaranga* sp.	0.0267
	-	-	*Eugenia* sp.	0.0233
Edges	-	-	*Canarium* sp.	0.0067
	-	-	*Nephelium* sp.	0.0066
	-	-	*Anthocephalu chinensis*	0.0033
	-	-	*Artocarpos* sp.	0.0033
	-	-	*Cinnamomum* sp.	0.0067
Adjacent forests	*Shorea sp.*	0.0133	*Elateriospermum tapos*	0.0967

Table 4. Contd.

	Hopea pubescens	0.0033	*Eugenia* sp.	0.0433
	-	-	*Macaranga* sp.	0.0433
	-	-	*Goniothalamus* sp.	0.0167
	-	-	*Canarium* sp.	0.0133
	-	-	*Baccaurea kunstleri*	0.0067
	-	-	*Anthocephalu chinensis*	0.0033
	-	-	*Intsia* sp.	0.0033
	-	-	*Mangifera foetida*	0.0033

*no. is to the abbreviation for number.

Table 5. Importance value index (IVI) of dipterocarp and non-dipterocarp species in three different habitats occurring under abandoned skid trails.

Species group		RF	RD	BA	IVI
Subplot 1	Dipterocarp	0	0	0	0
	Non-dipterocarp	9.66	40.05	0.64	50.35
Subplot 2	Dipterocarp	2.10	23.56	8.08	33.74
	Non-dipterocarp	57.14	0.87	29.68	87.69
Subplot 3	Dipterocarp	2.10	23.56	8.88	34.54
	Non-dipterocarp	28.9	11.96	52.72	93.68
Total		100	100	100	300

RF: Relative Frequency, RD (tree no/300 m): Relative Density, BA (m^2): Basal Area.

(52.72%), respectively. The IVI recorded confirms that depending on the habitat environments, the regenerated rate of species can be different. While there is a positive relationship between the natural dispersal of seeds with known distribution of adult trees for dipterocarp species in a canopy gap of tropical forests (Bunyavejchewin et al., 2003), the germination of non-dipterocarp seeds is high; therefore, they regenerate successfully without the presence of adjacent adult trees (Raich and Khoon, 1990).

CONCLUSION

Results analysis reveals that the size of gap opening after skidding operations has different effects on regeneration growth rates and species density. The higher diversity index of seedlings within subplot 1 shows that there is positive emergence of species within the two years after timber harvesting operations at abandoned skid trails. Soil disturbance resulting from skid trail did not prevent the emergence of new vegetation. Although fewer dipterocarp species were found within these larger gap areas, some non-dipterocarp species that are of high-value timber had been found for the next harvesting rotation. The presence of saplings of dipterocarp species within subplots 2 and 3 proved that vegetation growth of dipterocarp species performed better under little concentration of light. Thus, with these preliminary results (after two years of timber harvesting operations), it is expected that dipterocarp species can emerge after several years within subplot 1 when the environment is suitable for them to emerge. With upcoming additional data collection, collaboration with a paired soil compaction study after timber harvesting operations, and more sophisticated analyses (proximity of regenerated species from gap area), this study should be able to provide valuable information regarding the long-term impact of abandoned skid trails on vegetation structure and species density, richness, dominancy, evenness, and soil productivity.

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