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Forest Road Assessment in Ulu Muda Forest Reserve, Kedah, Malaysia

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Abstract

For the last few decades, forest road construction for forest harvesting in the tropical forest has been shown to cause considerable damage to the soil physical properties, forest environment and watershed areas. These effects can be minimized through implementation of proper harvesting procedure in the use of harvesting machines and forest road specification guideline. Forest road specification is important as technical guideline that must be comply by any loggers in order to construct forest roads. The road constructions that meet the outlined specification were potential to minimize the damage of forest roads and increase the efficiency in forest product output, while reducing harvesting cost. The purpose of the study is to evaluate the effectiveness of feeder road construction in compliance to the Forest Road Specifications 1999 as outlined by the Forest Department of Peninsular Malaysia. Systematic samplings were conducted along 14.5 km of feeder road where an observation and measurements has been taken at every 500 m points visited. A total of 30 samples were taken which incorporate dimensions of road specification elements for each point such as road cross section, vertical alignment, horizontal alignment, road failure and earth work. The comparison data was collected to determine whether the failure is due or not to the specification. Result presented that the total length of the road failure in the study area was 551.4 m or 3.8% out of 14.5 km. The types of the road failure were classified into five categories that were surface failure, surface run-off, wheel track, drainage failure and landslide. The major failure occurred on the feeder roads was surface failure, which represent about 38.2%. Reasons of non-compliance are ascertained and several recommendations were given to reduce the damage of feeder road.

Keywords: Forest engineering, Timber harvesting, Assesment, Road failure, Cost

1. Introduction

Forest roads are built to provide an access to the forest area for logging operation, general purposes and for the transports of timber to the mills. Forest road is an engineering structure; therefore compliance to technical specification is essential to ensure its safety and reliability. Proper construction according to specific guideline could help in reducing adverse impact to the forest environment. If the guideline does not meet to the specification it would cause a major impact such as soil degradation, vegetation loss, affect water and the environment quality. Forest road should be designed to minimize the soil disturbance and avoid stream crossing where possible. According to Kamaruzaman (1995), forest road construction in tropical forest have the most significant influence on water yield, water quality, soil erosion and nutrient loss. Meanwhile, the forest road construction within a few meters of streams or river edges are a common practice in harvesting operation and undoubtedly cause the large supply of sediment to streams Kamaruzaman *et al*. (1986). FAO (1977) reported that road damage also can occurs from the combined impact by heavily traffic and heavy rain. The road is thus vulnerable to being damage by the traffic on the surface and sometimes the underlying layers have become softened by the rain and than when it is dry. Proper planning is essential in order to avoid any adverse consequences to the forest ecosystem. As a result, forest road can contribute to the important of reduced impact logging, and therefore the key element towards sustainable forest management (Mohd Hasmadi, 2005).

For instance, harvesting guideline (1997) and forest road specification guidelines (1999) have been outlined by the Forestry Department of Peninsular Malaysia to ensure that the forest road operations are commencing accordance to high standard and consistent. Forest road specifications are a basic principal to guide the loggers in forest road construction, where specification for the road design should minimize negative impacts and improves safety of all employees involved in harvesting operations. The guideline must be used by all concessionaires or loggers as a principle and standard during constructing forest roads which is comply to engineering aspect such as road specification and geometric of the road. Forest engineering involves the specification of the standard design of forest road according to actual engineering design, field layout, construction and maintenance and subsidiary structures such as bridges and culverts.

Forest road are complex engineering structures, which transport efficiency and reliable access to the forest both depend. The building of forest road involves high capital expenditure and in addition, there is continuing cost for road maintenance. Road construction and maintenance are important to be considered, especially in tropical forest with a low yield of merchantable logs per unit area, hilly area and weather conditions such as rainfall density. Therefore, construction of the road should be carried out with close observation to economic aspect and consideration of the topographic difficulty such as forest terrain (Dykstra and Heinrich, 1996). On the other hand, the design of forest road not only should permit safety for the transportation traffic but should be comply with the specification or guideline. Thus, this study was carried out to evaluate the effectiveness of feeder road construction in compliance to the Forest Road Specifications 1999 as outlined by the Forest Department of Peninsular Malaysia.

2. Methodology

Description of study area

The selected study area is located at Ulu Muda Forest Reserve, Baling in the Kedah State, Peninsular Malaysia. The site covers an area about 1,948 hectare, situated in Mukim Siong, where the main entrance starts from Kg. Weng. The actual study site encompasses three forest compartments; 9, 25 and 26. The distance of main road from Kg. Weng to compartment 25 is 17.3 km. The location of the study area and feeder road is shown in Figure 1.

The forest road was built in 1960's for timber harvesting from compartment 7. The road was used for main access to study site called *Waduk*, which is part of compartment 25. The construction cost of 2.5 km in compartment 25 is about RM 105,000.00 at that time and the road maintenance was financed by the Department of Irrigation Malaysia and Muda Agriculture Development Authority (MADA). The maintenances includes installation of culverts, repairing side drain, road surface and bridge upgrade. The area experiences two dry seasons from January to February and June to July annually.

[Figure 1: A map of Peninsular Malaysia showing a feeder road in the study area]

Data collection

This study involved measurement of forest road specification element along 14.5 km of the feeder road under surveyed. Figure 2 showed the actual feeder road under studied in Ulu Muda Forest Reserve. A systematic sampling was done where the data were collected at every 500 m (0.5km) distance. Hundred percent sampling was done at the places or point visited, where damage occurred in order to study the cause of failure. The data were recorded to the specification designs which include:

i. Road Cross Section - The components measured are the right of way width, carriageway width, carriage way material, road camber and pavement material.

ii. Drainage structure - The data collected were the type and size of culvert, bridge and side drain that was divided into three parts which are depth, width at the top and bottom.

iii. Vertical alignment - This includes the measurement of the road gradient and length of gradient.

iv. Horizontal alignment - Super elevation and radius of curve measurement.

v. Road failure - The data measured on failure which occurs and thus covered the length of failure, causes failure, type of failure, failure position and type of soil.

vi. Earth work - Observation of excess earth that was disposed to approved dumpsite and the present of silt tarps to erosion prone areas.

The process of data collection involved the use of basic equipment to measure the geometric design of feeder road specification. The equipments used were compass, measuring tape (50m), Suunto Clinometer, and stick pole.

[Figure 2: Feeder road in compartment 25, Ulu Muda Forest Reserve]

Types of roads failure were classified into five categories. They were:

1. Surface failure - Occur on running surface between 0-10 cm depths.

2. Landslides - Initiate on side slopes with gradients ranging from 35-140%. Majority of the landslides started on slope between 70-90%. The soils on very steep slopes were typically very shallow and it is not well developed

3. Wheel track - Occurs on running surface when the soil could not support the weight of vehicles through tire pressure to sub grade.

4. Drainage failure - Drainage systems are not well-developed and caused water flow off road surface and disturbance to the water flow.

5. Surface run-off - The destruction or removal of the soil surface contributes to storm flow by decreasing the potential for water storage in the soil.

*Data analysis***s**

The data was analyzed into two parts, which are the roads failure and roads specification. The road failures were presented by percentage and number of failures occurs, meanwhile roads specification were covered the minimum and maximum value, average, percentage of differential in order to compare it to the forest road specification. All measured values were keyed in SPSS software to produce the result. Forest Road Specification 1999 manual by Forestry Department of Peninsular Malaysia was used as reference and standard for comparison to the geometric design of feeder road construction.

3. Results and Discussion

Road failure

The total length of feeder road failure at compartments 9, 25 and 26 in Ulu Muda Forest Reserve, Kedah is 551.4m or 3.8%. A total of 25 sites along the 14.5km stretch of road were evaluated as road failure. The major types of failure were surface failure, surface run off and wheel track. The main reason was caused by the soil factor, where occurring sites was categorized as clay type, which can less capability for water absorption. The smallest gaps between the fine particles were led to the formation of pond track or waterlogged on the running surface. This is also affected by the climate of the area that received a high volume rain during the time of the study.

The road failures were classified into five types of failures, namely surface failure, surface run off, wheel track, drainage failure and landslide that as shown in Figure 3. The major failure occurred on the feeder road was surface failure with 38% or 465m of road length. This was followed by drainage failure (30%), wheel track (23%), surface run off (5%) and landslide (4%), respectively. The failure such as wet or soft soil and pond occurrence caused by the damaged of the side drain and right of way built with too small construction design. All the causes influenced the road failures by influences the soil which has low water absorption in soil.

[Figure 3: Percentage of road failure by categories of failure type]

Road failure occurred by drainage was 367.9 m, this due to the absence of improper side drain, road chamber and damaged culvert. It occurred when the water flow-off and side ditch plugged by the sediment. Drainage failure has a very close relationship to surface failure and wheel track because it happened after the traffic allowed passage through the road and the capability of soil to absorb the surface water. Meanwhile, wheel track failure type recorded of 274.9m of road length. This occurred mainly because of the soil cannot support the weight of vehicles. The heavy traffic operation during the raining season affected the road damage and more slippery on the road surface. The drying process was very slow due to a small gap opening with less of light intensity and low water evaporation. Surface run-off and landslides are the minor failures occurred. Surface run-off occurred in the range of 64m caused by the too high of road gradient. Soil particles removed together which water flowed to a lower area. It also occurred by the pavement material type which has a sandy surface and not well compacted. Landslide with the value of 46m or occurred due to the side slope which was too steep and shallow with non-cohesive soils coupled with a side casting of excess material, probably occurs during raining season.

Road failures occur by several causes. The major causes of road failure were categorized to six factors which were shown in Figure 4. The failure caused by the small crown opening is 32% or 21 sections of the road failure. The minimum value of crown opening is 7.5m and the average is 14m. The minimum width of crown opening was blocked light intensity to reach ground that enable drying the road surface. A higher humidity is needed to allow evaporation process which air velocity is limited in contributing to the drying process on the road surface. Figure 5 showed the example of the failure caused by insufficient crown opening.

[Figure 4: Percentage causes of road failure]

Absence of road chamber was noted at 20 places out of 25 or 31% of the road failure. The maximum value of the road chamber was 10% or 1:10 that contribute to surface run off for sandy surface. Absence of road camber contributes to improper flow of water into the side drain, and finally damaged the road surface. In addition, heavy traffic density also contributes to the removal of existing chamber at every time traffic passed through.

[Figure 5: Road failure caused by insufficient crown opening]

Side ditch is the main component in controlling water direction to avoid damages on the road surface. The absence of side ditch was observed at 8 places out of 25 sections, represented about 12%. The total of side ditches that complies with the specification is 68%. This revealed that the side ditch was constructed according to the specification but the rate of 68% was still lower because sometimes damaged can occurs by a high rate of water flow and erosion. Surface flow from several sources collected into small natural drainage, were not capable in handling the increased volumes of water. Figure 5 showed consequences of improper maintenance of the side ditch that caused high rate of water flow on the road surface.

The total number of unstable sub-grade or not compacted soil was 13 sections or 20% in the study area. Unstable sub grade has a low moist condition in order to support the weight of vehicle pressure. It encourages damage by wheel track because there were wide gaps exist between the fine particles. The absence or damaged culvert with the value 3% on stream crossing also caused the road failure. The lack of culvert or spaced too far apart forced the ditches to collect too large amount of water. Sometimes the culvert inlets were stuck with sediment and debris.

[Figure 6: Consequences of improper maintenance of the side ditch caused water flow on road surface]

Factors contributing to the failure are caused by geometric specifications that were not properly applied during the construction of the forest road. The measurement of different forest road components compared to specification on failure points was shown in Table 1. Meanwhile, the measurement of compliance to geometric specification on failure point was shown in Table 2.

[Table 1: Measurement of differential of forest road components compared to the specification on the road failure]

Forest road specification

The main components that have been measured in the forest specification 1999 were carriage way, right of way, side ditch, road chamber, pavement material, road gradient and length of gradient. Table 3 shows the different of each component compared to the standard design, and Table 4 showing the percentage of compliance and non-compliance of the road constructed to specification.

The minimum limit of carriageway width is 3.5m and maximum limit is 5.5m. The standard width for road design of feeder road must be ≤ 5m. It was noted that 29 out of 30 samples measured were met to standard or specification with the percentage of 96%, and only one sample or 3% did not meet the specification. The minimum figure of 3.5m width is too small to be counted and do not influence the log transportation due to the low traffic density except at passing sight distance. Mostly 30 samples of the road surface are in good condition and suitable for the traffic usage.

[Table 2: Measurement of compliance to geometric specification on the road failure]

[Table 3: Road construction practices compared to Forest Road Specification]

[Table 4: Percentage of compliance and non-compliance of road constructed to specification]

The percentage right of way meet the standard specification was 73.3% (22 samples) and about 26.7% (8 samples) did not meet to specification. Most of the rights of way widths were sufficient for road condition and traffic (96.7 %). Forest road requires a high level of light intensity and air circulation to keep it dry. There are few things which are detrimental to the road than overhanging trees, which produce a moist surface and an eventual reduction of the bearing power. Right of way constructed does not related to the specification that contributes to the road damage and mainly it does not affect the environment.

The components of side ditch were divided into two sections, namely width at the top and depth. The percentage widths at the top constructed meet to specification was 60% and 40% does not follow the specification. There were 18 samples totally constructed which met the specification with an average level of 0.5m. The depth of side ditch is 56.7% compliance to specification and the minimum value is 0.2m. This does not contribute to a consistent depth because some of particle soils running with water flow onto the side ditch. The absence or damaged of the side ditches occurred mostly along steep terrain contributed to a surface failure. Surface flows occurred when the water flows-off onto the running surface because the soil moisture content is higher and the strength of the road will drop very fast, thus the bearing capacity of the road may change radically.

There were only 30% or 9 existed cambers met the specification with maximum values was 1:10 (10%) and the minimum value was 1:25 (4%). There are 70% absences of the road chamber, which contributed to the road failure caused by the water, which could not flow onto the side ditch very well. The existence of road camber however is very important to avoid the formation of ponds and damages to the road surface. Road chamber more than 1:20 (5%) is suitable since it has less affect to the road failure. Absence of the road camber contributed to surface erosion and formation of pond on the road surface. The slope of road camber must be steep enough to ensure rapid water run off and gentle enough to prevent gulling.

There are 86.7% of the road gradients that were constructed meet the specification and 13.3% constructed do not meet the specification. The maximum value of road gradient is 220 and the minimum is 10 with an average of 2.10. All the samples of gradient length are less than 200m or presented 100% constructed meet to the specification. The function of the road gradient is to provide a smooth movement for all transportation and user safety in harvesting operation. The higher road gradients with unsuitable gradient length causes surface run-off and contributes to surface cracking that affect the log transportation, maintenances cost and high risk to the user.

Pavement material is the total forest floor which is removed using excavator or bulldozer with no compaction process. Gravel is very suitable in usage as material in order to avoid slippery and surface failure; however the construction cost is too high. Therefore it was observed that natural material in the forest was used to reduce the construction cost.

Conclusion

It can be concluded that most of the road constructed is in compliance to the Malaysian forest harvesting road construction specifications. However, lack of the road maintenance results in the occurrence of damages during harvesting. The roads should be maintained to ensure a stable running surface and to keep the drainage system operating. Therefore, it is necessary to maintain the road according to the specification. On the other hand, the success of the road construction was largely dependent on the raining season. The wet running surface was unable to support a vehicle load that was transferred to the ground (sub-grade) through the pressure and encourages wheel track. In all phases of road construction, adequate drainage should be provided to achieve stability of road structure. Wherever practicable, permanent drainage should be installed in advance from other construction in order to keep the roads as dry as possible. In addition, the insufficient crown opening resulted in the inability of the running surface to dry as fast as possible. The implementation and enforcement of a forest road specification guideline outlined by Forestry Department of Peninsular Malaysia before the commencement logging operation can reduce the ecological effect. In order to overcome the problem current research activities has to be put forward for formulating research with problems affecting the forest road activities. It is concluded that a wide variety of problems occur pertaining to forest road failure in forest operation can be solved through science and applied research.

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Table 1. Measurement of differential of forest road components compared to the specification on the road failure.

	Carriageway width (m)	**Right of way (m)**	**Side ditch (m)**			**Road camber (%)**	**Road gradient (^{0})**	**Length of gradient (m)**
			Top width	**Bottom width**	**Depth**			
Feeder road specification	≤5	≤ 12	≥ 0.5	0.2	≥ 0.3	≥ 1:20 (5%)	≤ 11.3	≤ 200
Total	115.6	251.5	17.9	5.9	11.3	26	158	940
Average	4.6	10.1	0.7	0.2	0.5	5.2	5.3	31.3
Maximum value	6.8	14.0	1.9	0.8	1.2	10	14	70
Minimum value	3.0	7.5	0.6	0.2	0.4	3.3	1	20

Table 2. Measurement of compliance to geometric specification on the road failure

	Carriage Way Width	**Right of Way**	**Side Ditch**			**Road Camber**	**Road Gradient**	**Length of Gradient**	**Pavement Material**
			Top width	**Bottom width**	**Depth**				
Number of road constructed to specification	21	24	17			2	23	25	25
Percentage (%)	84	96	68			8	92	100	100
Number of road constructed not to specification	4	1	8			23	2	-	-
Percentage (%)	16	4	32			92	8	-	-

Table 3. Road construction practices compared to Forest Road Specification

	Carriageway width (m)	Right of way (m)	Side ditch (m)			Road chamber (%)	Road gradient (^{0})	Length of gradient (m)
			Top width	Bottom width	Depth			
Feeder road specification	≤ 5	≤ 12	≥ 0.5	0.2	≥ 0.3	≥ 1:20	≤ 11.3	≤ 200
Total	120.8	414.2	17.4	6.6	9.3	64.2	196.5	1385
Average	4.0	13.8	0.5	0.2	0.3	2.1	6.6	46.2
Maximum value	5.5	21.0	2.3	0.7	1.4	10	22	150
Minimum value	3.5	9.0	0.5	0.3	0.2	4	1	20

Table 4. Percentage of compliance and non-compliance of road constructed to specification

	Carriage way width	Right of way	Side ditch			Road chamber	Road gradient	Length of gradient	Pavement material
			Top width	Bottom width	Depth				
Number of road constructed to specification	29	22	18	18	17	9	26	30	25
Percentage (%)	96.7	73.3	60	60	56.7	30	86.7	100	100
Number of road constructed not to specification	1	8	12	12	13	21	4	-	-
Percentage (%)	3.3	26.7	40	40	43.3	70	13.3	-	-

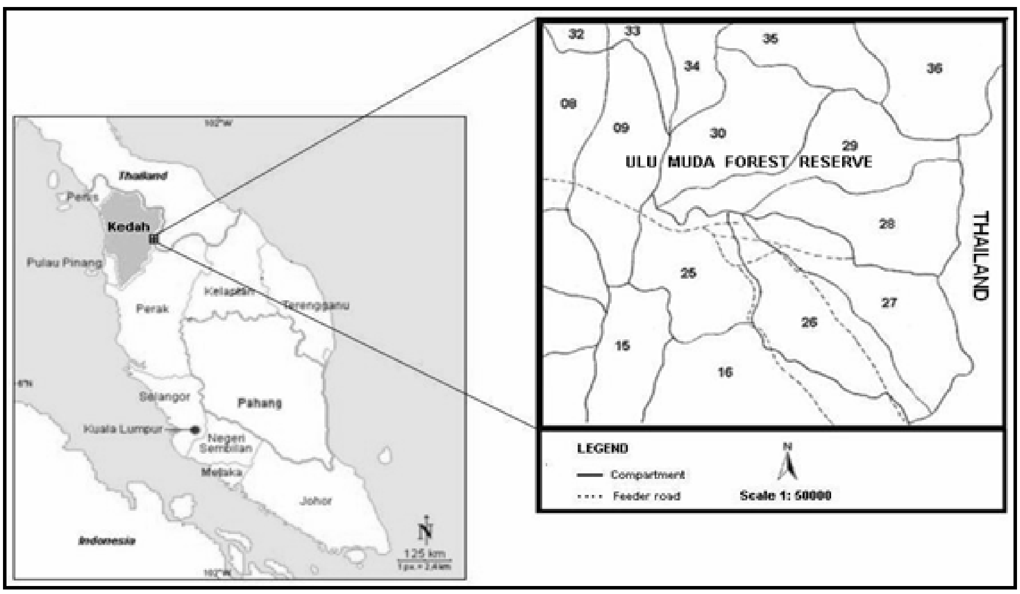

Figure 1. A Peninsular Malaysia map showing a feeder road in the study area

Figure 2. Feeder road in compartment 25, Ulu Muda Forest Reserve

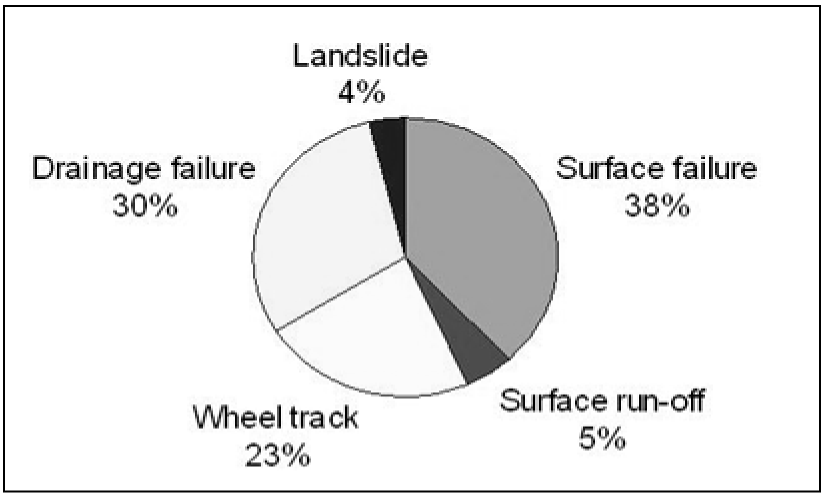

Figure 3. Percentage of road failure by categories of failure type.

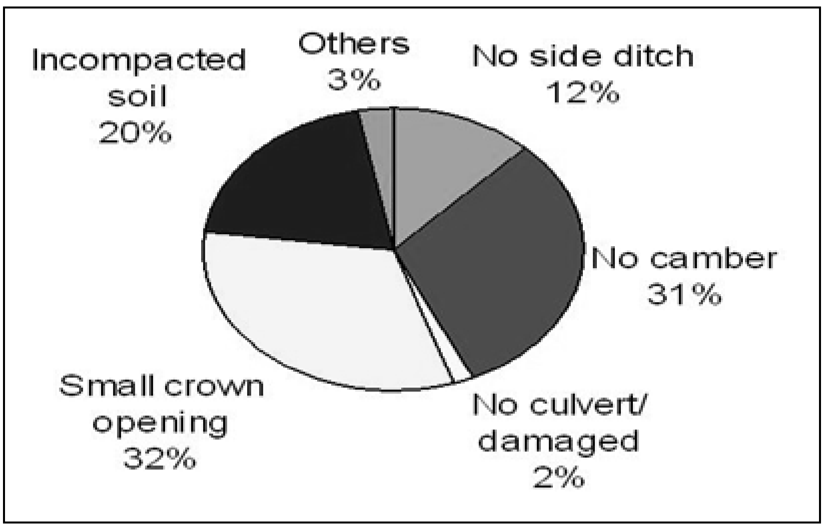

Figure 4. Percentage causes of road failure

Figure 5. Road failure caused by insufficient crown opening

Figure 6. Consequences of improper maintenance of the side ditch caused water flow on road surface.