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ANALYSIS OF TWO ALTERNATIVE HARVESTING SYSTEMS IN PENINSULAR MALAYSIA: SENSITIVITY ANALYSIS OF COSTS, LOGGING DAMAGE AND BUFFERS

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SAHARUDIN, A., BRODIE, J. D. & SESSIONS, J. 1999. Analysis of two alternative harvesting systems in Peninsular Malaysia: sensitivity analysis of costs, logging damage and buffers. An economic study of two alternative timber harvesting systems was carried out in Peninsular Malaysia to evaluate and compare existing and improved harvesting systems in terms of their costs, efficiency and productivity. The results showed that distance and diameter^2 were significantly related to delay-free cycle time in felling in Jengai and Tembat, the two areas studied with contrasting harvesting systems. In skidding, distance and number of logs were significant in Jengai, while distance and diameter were significant in Tembat. Logging cost excluding cost of conservation, premium and royalty under the new system was RM 50.89 m^{-3} or 4% lower than logging cost under the old system of RM 52.9 m^{-3}. Under average conditions, it takes 0.31 h to fell a tree under the new system compared to 0.39 h (simulated) under the old system. This suggests that the improvement made in the Jengai Forest Reserve has increased productivity of felling. In skidding, it takes about 0.55 h to travel one round trip under the new system compared to 0.77 h (simulated) under the old system. This suggests that the improvement in road construction in Jengai has increased productivity of skidding.Under average conditions, the costs of felling and skidding were lower under the new system as compared with the old system (simulated). Simulating the new system, the cost of felling and skidding were slightly higher as compared with the old system.The present value of cost of damage discounted at 4% discount rate was RM 3.62 m^{-3} compared to RM 5.02 m^{-3} under the old system. The Present Net Worth (PNW) of the new system with buffer cost was RM 577.07 m^{-3}

compared to PNW of the old system of RM 566.53 m^{-3} without buffer cost. This shows that the reduction in damage to the residual stand has increased the net future harvests as shown by the higher PNW of the new system. The study also shows that it is more economical to install the buffer zone in the new system based on the higher PNW of the new system.

Key words: Productivity - new system - old system - buffer costs - PNW - damage costs - logging costs - opportunity costs

SAHARUDIN, A., BRODIE, J. D. & SESSIONS, J. 1999. **Analisis terhadap dua sistem pengusahasilan hutan alternatif di Semenanjung Malaysia: analisis kepekaan bagi kos, kerosakan pembalakan dan penampan.** Satu kajian ekonomi terhadap dua jenis sistem pengusahasilan hutan telah dijalankan di Semenanjung Malaysia bertujuan untuk menilai dan membuat perbandingan antara sistem pengusahasilan sedia ada (sistem lama) dan ubahsuai (sistem baru) dari segi kos, kecekapan dan produktiviti. Hasil kajian menunjukkan iaitu jarak antara pokok dan garis pusat[2] berhubung kait dengan bererti dengan masa pusingan tanpa kelewatan bagi aktiviti penebangan di kedua-dua kawasan kajian, manakala dalam aktiviti penarikan, jarak dan bilangan balak berhubung kait dengan bererti dalam Jengai manakala jarak dan perepang berhubung kait dengan bererti dalam Tembat. Kos pembalakan tanpa kos pemuliharaan, premium dan royalti di bawah sistem baru ialah RM 50.89 m^{-3} atau 4% lebih rendah daripada kos pembalakan di bawah sistem lama iaitu sebanyak RM 52.9 m^{-3}. Aktiviti penebangan bagi sebatang pokok di bawah sistem baru mengambil masa selama 0.31 jam berbanding dengan 0.39 jam (simulasi) di bawah sistem lama. Ini menunjukkan bahawa pembaikan yang telah dibuat di Hutan Simpan Jengai telah meningkatkan produktiviti penebangan. Bagi aktiviti penarikan, ia mengambil masa selama 0.55 jam untuk satu pusingan di bawah sistem baru berbanding dengan selama 0.77 jam (simulasi) di bawah sistem lama. Ini menunjukkan bahawa pembaikan yang telah dibuat ke atas pembinaan jalan di Hutan Simpan Jengai telah meningkatkan produktiviti penarikan. Kos penebangan dan penarikan di bawah sistem baru adalah lebih rendah berbanding dengan sistem lama (simulasi). Kos penebangan dan penarikan di bawah sistem baru (simulasi) lebih tinggi sedikit berbanding dengan sistem lama. Nilai kini kadar kerosakan pada kadar diskaun 4% ialah sebanyak RM 3.62 m^{-3} berbanding dengan RM 5.02 m^{-3} di bawah sistem lama. Nilai Bersih Kini (PNW) bagi sistem baru dengan kos penampan ialah sebanyak RM 577.07 m^{-3} berbanding dengan RM 566.53 m^{-3} tanpa kos penampan. Ini menunjukkan bahawa pengurangan dalam kerosakan bagi dirian tinggal telah meningkatkan hasil tebangan pusingan akan datang seperti yang ditunjukkan oleh peningkatan nilai PNW bagi sistem baru. Kajian ini juga menunjukkan bahawa lebih ekonomi untuk mewujudkan zon penampan di bawah sistem baru berdasarkan peningkatan nilai PNW bagi sistem baru.

Introduction

A study was carried out under the Project B7: Malaysia-United Kingdom Programme of Cooperation on Forest Management and Conservation to evaluate and compare existing and improved harvesting systems in terms of their costs, efficiency and productivity. Forest harvesting is the most important activity of the forestry sector and how it is being done will directly influence the other related forestry activities. Unfortunately, over the years, insufficient attention has been given to the forest harvesting operations other than the control in areas opened for logging. Most of the loggers are only interested in the short-term benefits with scant regard to the nation's needs in the long run.The attitudes and actions of the loggers have resulted in damage and pollution of the environment leaving large quantities of potential wood and other forest goods as logging wastes. The main problem currently faced by the Forestry Department is the lack of provisions for adequate rules and regulations for stricter control on the forest harvesting operations and insufficient experience and technology in maximum utilisation and production in forest harvesting operations.The lack of sufficient knowledge and technical know-how was the main obstacle to the planning, evaluation, management and control of forest harvesting activities. This study was carried out to recommend the most efficient forest harvesting system which would minimise damage to the environment with minimum cost. An economic model of harvesting costs in order to assess the opportunity costs of timber left in buffer strips and the costs and benefits of directional felling was developed.

Under the new or improved harvesting system, buffer strips are installed and marked on the ground with width of at least 20 m from either side of the streams[1]. There is no marked buffer strips under the old or existing system. Directional felling is incorporated in the new system showing the direction of trees to be felled. There is no directional felling under the old system.Under the new system, there is improved road construction where road location is made on the plan before logging licence is approved, that is road construction according to the standards and specifications of forest roads in Peninsular Malaysia, while under the old system, road location and construction do not follow the standards and specifications of forest roads in Peninsular Malaysia.

The Jengai Forest Reserve which is under the new system is located in Compartment 123, Block B, in the district of Dungun, Terengganu, with an area of 197 ha while the Tembat Forest Reserve which is under the old system is located in Compartment 204, Block 12 A, covering an area of 135 ha. Both study areas were mostly hilly and rocky with elevation between 100 and 600 m and slope ranging from 5 to 22°.

The study areas were managed under the Selective Management System (SMS) with rotation length of 30 y. The cutting limits were 45 cm dbh and above both for the dipterocarp and non-dipterocarp groups for the Jengai Forest Reserve and 50 cm dbh and above both for the dipterocarp and non-dipterocarp groups for the Tembat Forest Reserve, based on the Pre-Felling Inventory (Pre-F Inventory) of the two areas. The Pre-F Inventory was carried out for all trees of diameter classes of 5 cm and above.

In the Jengai Forest Reserve, there was a total of 48 species and the yield was 65 $m^3 ha^{-1}$ and 3.2 m^3 per tree. In the Tembat Forest Reserve, there were 51 species with a yield of 92 $m^3 ha^{-1}$ and 3.3 m^3 per tree.

The harvesting system used in the Jengai and Tembat Forest Reserves was a combination of chainsaw, crawler tractor and a winch-lorry called San Tai Wong. In the felling site, a chainsaw was used to fell the tree and to cross-cut the log

[1] Buffer strips are forested area on either side of the streams left unlogged for protection of the streams from soil erosion and sedimentation.

immediately at the felling site or at the temporary log-landing. A crawler tractor was used to transport the log from the felling site to the log-landing. The winch lorry was used to transport logs from the temporary log-landing to the permanent log-landing.

Literature review

Other studies on cost studies in harvesting includes comparison of a logging system with only one crawler tractor and a system with a crawler tractor combined with the FMC skidder and a simple model was used.This comparison showed that the system with the combination of crawler tractor and FMC skidder was more economical than using the crawler tractor only when the average skidding distance of the tractor exceeded 0.38 km (Marn *et al.* 1982).

In another study on logging cost and productivity (Marn *et al.* 1981), the time study was conducted on the traditional type of skidding operation in which three different ways of skidding were studied, namely down hill skidding, uphill skidding and neutral. Regressions were made for time and distance on main, secondary, no trail and opening trails. Generally good correlations were found. In the case of loading, no good correlation could be found, but on average, good correlations were found in skidding for time related to volume and distance.

Comparison of felling time and cost per m^3 between directional felling and traditional felling was studied by Marn (1982). Cost of directional felling was RM 2.29 m^{-3} compared to RM 2.31m^{-3} for the traditional felling. Directional felling was thus achieved without any extra cost. In the log extraction, two different operations both using CAT D6C were compared. A carefully planned operation where felling had been done towards already opened main skidtrails and chokers were used was compared to extraction by traditional method. The results showed that increase in production was 36% compared to traditional felling and reduction of cost was 26% compared to traditional felling.

On the effects of directional felling to the remaining stand, the study showed that the number of trees lost was reduced by 33% and the volume of felled sound timber left was reduced by 48%. The combined effect of the directional felling, the use of chokers and good skidtrail network, planned and opened before the start of the felling, contributed mostly to the increase in production and reduction of damage to the remaining stand.

Methodology

Data were collected using a combination of time-study and survey-questionnaire method. The study sites were randomly selected from those with similar forest types, zones and forest management systems.The forest type selected was the hill dipterocarp forest from the eastern zone of Peninsular Malaysia. Interviews were conducted to obtain information on fixed and operating costs as well as harvesting systems used. Information on forest stand, topography and departmental costs was collected from the District Forest Office. Production times were taken from the five sub-systems: felling and cross-cutting, skidding or off-road transportation, loading, short distance transportation or short hauling, and road construction.

Comparisons of productivity and costs between the Jengai and Tembat Forest Reserves were made using average conditions in each area. Equations developed for the Jengai Forest Reserve were used to represent the new system while those developed for the Tembat Forest Reserve were used to represent the old system. The same contractor wage rates and equipment costs were used for each area to simulate the new system in Jengai and the old system in Tembat.

For the sensitivity analysis on the damage to the residual stand after logging, comparisons of damage costs between the new and the old systems were made. Comparison of the Present Net Worth (PNW) between the new and the old systems without buffer cost was made to evaluate the impacts of future damage on the PNW returns for each of the systems. Comparison of PNW between the new and the old systems with buffer costs was also made to project the impacts of the future damage and buffer zone on the PNW returns for each system. The percentage damage for breakeven on the new system was determined for each of the analyses to justify the new system.

Statgraphics (Windows Version 2) was used to analyse the Jengai and Tembat Forest Reserves and to find significant independent variables (95% confidence level) that could be used to predict cycle times.

Results and discussion

Felling

The model for the Jengai Forest Reserve (new system) is:

delay-free cycle time(s) = -241.51 + 0.98 distance + 0.20 diameter^2

R^2 = 68.4%, SE = 691.1, MAE = 500.3
t- statistics: distance = 2.3, diameter^2 = 7.8

The model for the Tembat Forest Reserve (old system):

delay- free cycle time(s) = 47.64 + 5.92 distance + 0.09 diameter^2

R^2 = 53.4%, SE = 502.7, MAE = 313.7
t- statistics: distance = 3.9, diameter^2 = 4.6

The above model shows that distance between trees is relatively more important in the Tembat Forest Reserve as shown by the greater regression coefficient. It shows that for the same distance, the felling operator takes 5.92 s to travel 1m as compared to 0.98 s in the Jengai Forest Reserve. Felling time increased with increase in distance between trees and diameter². In a similar study carried out by the FAO, 1966-1968, it was found that felling time increased with increase in diameter and number of logs per tree (Anonymous 1974).The improvements made in road construction on the Jengai Forest Reserve had increased productivity. The model also shows that it takes 0.09 s per square centimeter to fell and cross-cut the tree with the same diameter in the Tembat Forest Reserve as compared to 0.20 s per square centimeter in the Jengai Forest Reserve. The longer time taken to fell a tree with the same diameter in the Jengai Forest Reserve as compared to the Tembat Forest Reserve may be due to the longer time taken in directional felling in the Jengai Forest Reserve.

The results showed that under average conditions, under the new system in the Jengai Forest Reserve it takes 0.31 h to fell a tree compared to 0.39 h (simulated) in the Tembat Forest Reserve. This suggests that the improvement made in the Jengai Forest Reserve had increased the productivity of felling.

Skidding

The model for the Jengai Forest Reserve (new system) is:

delay-free cycle time (s) = 569.85 + 1.72 distance + 324.15 log number

R^2 = 62.7%, SE = 337.3, MAE = 240.5
t-statistics: distance = 4.5, log number = 2.3

The model for the Tembat Forest Reserve (old system) is:

delay-free cycle time (s) = 119.3 + 3.67 distance + 4.11 diameter

R^2 = 57.6%, SE = 270.9, MAE = 203.2
t-statistics: distance = 8.2, diameter = 3.3

The model shows that skidding distance is more significant in the Tembat Forest Reserve as compared to the Jengai Forest Reserve as shown by the greater regression coefficient. It shows that for the same distance, the crawler tractor takes 3.67 s to travel one round trip meter as compared to 1.72 s in the Jengai Forest Reserve. The improvement in road construction in the Jengai Forest Reserve had increased skidding productivity as compared to the Tembat Forest Reserve. It also shows that the number of logs per trip is significantly related to time in Jengai and diameter of logs per trip in Tembat. In a similar study carried out by the FAO, 1966-1968, it was found that skidding time increased with increase in distance, number of logs and diameter (Anonymous 1974).

In skidding, it takes about 0.55 h to travel one round trip in Jengai as compared to 0.77 h (simulated) in Tembat. This suggests that the improvement in road construction in Jengai had increased productivity of skidding. It was also found that in Jengai it was more efficient to transport more than one log to increase production as the distance increased.

Short hauling

As only one travelling distance was used in the short hauling system, it is not possible to predict the cycle time using multiple linear regression. The equation for the short hauling system was estimated based on the time taken to travel the hauling distance, excluding the loading and the unloading time as follows:

The model for the Jengai Forest Reserve (new system) is:
delay-free cycle time (s) = 1500 + 0.70 distance

The model for the Tembat Forest Reserve (old system) is:
delay-free cycle time (s) = 1338 + 0.62 distance

The model shows that hauling distance is more significant in the Jengai Forest Reserve as compared to the Tembat Forest Reserve as shown by the greater regression coefficient of the hauling distance. It shows that for the same distance , the winch lorry takes 0.70 s to travel one round trip meter as compared to 0.62 s in the Tembat Forest Reserve.

For the same average distance of 15 200 m as in the Jengai Forest Reserve, the time taken in short hauling in the Tembat Forest Reserve was 10 762 s which is still lower than the time taken in the Jengai Forest Reserve. However, comparisons of productivity between the two areas was not possible since only one observation for distance was used in the model.

Costs and productivity

Logging costs for the Jengai Forest Reserve using the new system and the Tembat Forest Reserve using the old system are given in Table 1.

Table 1. Logging costs for the Jengai and Tembat Forest Reserves

Activity	Jengai (RM m^{-3})	Tembat (RM m^{-3})
Felling and cross-cutting	4.79	6.20
Skidding	10.93	11.03
Loading and unloading	2.49	0.94
Short hauling	8.72	10.60
Supporting costs	23.96	24.14
Total logging cost	50.89	52.91

From Table 1, the cost of logging in the new system was RM 50.89 m^{-3} or 4% lower than the cost of logging under the old system, RM 52.91 m^{-3}, excluding conservation costs, royalty, and premium.

The study was designed in such a way that comparison of logging costs was made possible using the criteria of similar forest types, zones and forest management systems. However, to make a more even comparison between the new and the old systems we established a standard set of physical, biological, and economical conditions, that is tree size, trees per acre, walk-in distance and contractor costs, and then used these conditions in the models developed from Jengai and Tembat in the simulation process. Two obvious sets of standard conditions are available. We could use either the average values in Jengai or Tembat (machine's cost, operator's cost and volume $tree^{-1}$) and repeat the analyses first using the average values at Jengai and then the average values at Tembat. In doing this, the model (equation) developed for Jengai would be used to represent the technical relationships of the new system and the model developed from Tembat would be used to represent the technical relationships of the old system.

In terms of costs, under average conditions, the cost of felling under the new system is RM 44.49 $tree^{-1}$ or 0.34% lower than the old system (simulated) of RM 44.64 $tree^{-1}$. The cost per tree would be approximately the same using the new system as the old system. Simulating the new system in Tembat, the cost of felling in the new system is RM 50.55 $tree^{-1}$ (simulated) or 0.28% higher than the old system of RM 50.41 $tree^{-1}$. The cost per tree is approximately the same under the new system as the old system, but the productivity of the new system (0.22 h $tree^{-1}$ per tree) is slightly lower under the new system than under the old system (0.19 h $tree^{-1}$).

In skidding, the cost under the new system is RM 78.12 log^{-1} or 14 % lower than the old system (simulated) of RM 90.74 log^{-1}. This suggests that under the same conditions of distance, diameter and number of logs as in the Jengai Forest Reserve, the cost per log is lower using the new system.

The cost of skidding under the new system (simulated) is RM 84.48 log^{-1} or 3.6% higher than the cost under the old system of RM 81.56 log^{-1}. The productivity of the new system (simulated) is 0.30 h per trip compared to 0.22 h per trip under the old system.

Sensitivity analysis on the damage to the residual stand after logging

Volume of trees damaged in the residual stand in the 30–39 cm dbh and >40 cm dbh classes is 0.5 $m^3 ha^{-1} y^{-1}$. The total volume of trees damaged at 30% damage under the new system in the next rotation is 15 $m^3 ha^{-1}$. Assuming the damage under the new system is about 30%, the damage under the old system is estimated

[2] A 30% damage refers to the damage to the residual trees in the 30-39 cm and >40 cm diameter class under the new system while 40% damage refers to the damage to the residual trees in the 30-39 cm and >40 cm diameter class under the old system.

at about 40% (Johnson & Cabarle 1993).[2] The percentage growth of damaged trees in the next rotation is 18% under the new system and 22.7% under the old system (Forestry Department of Peninsular Malaysia 1991).The total volume of trees damaged at 40% damage under the old system in the next rotation is 20 $m^3 ha^{-1}$. The net future volume of harvests for the next rotation after allowing 30% damage under the new system is 50 $m^3 ha^{-1}$ and 45 $m^3 ha^{-1}$ under the old system at 40% damage. At 30% damage under the new system, the present value of costs of damage discounted at a 4% discount rate is RM 3.62 m^{-3}, based on yield of 65 $m^3 ha^{-1}$ and RM 5.02 m^{-3} under the old system at 40% damage based on yield of 65 $m^3 ha^{-1}$, as shown in Table 2. From Table 2, the breakeven percentage damage under the new system was about 41% with a present value of RM 5.02 m^{-3}. Hence the percentage damage allowable under the new system should be less than 41% in order to justify the viability of the new system.

When the yield is 92 $m^3 ha^{-1}$ for the old system, the present value of damage cost is RM 3.55 m^{-3} at 40% damage, as shown by Table 3. Breakeven on the new system decreased from 41 to 28%. This shows that yield other than logging cost plays an important role in influencing the viability of the new system.

Table 2. Comparison of present value of damage costs under the new and old systems (RM m^{-3}), based on yield of 65 $m^3 ha^{-1}$ for the new and the old systems

Damage (%)	New system	Old system
0	0.00	0.00
10	1.21	1.25
20	2.41	2.51
30	3.62	3.76
40	4.83	5.02
50	6.03	6.27
60	7.24	7.53

Table 3. Comparison of present value of damage costs under the new and old systems (RM m^{-3}), based on yield of 65 $m^3 ha^{-1}$ (new system) and 92 $m^3 ha^{-1}$ (old system)

Damage (%)	New system	Old system
0	0.00	0.00
10	1.21	0.89
20	2.41	1.77
30	3.62	2.65
40	4.83	3.55
50	6.03	4.43
60	7.24	5.32

Under the new system, the cost of buffer zones is RM 19.09 m^{-3}. The difference between the PNW of the new system with buffer and the PNW of the new system without buffer is the present value of the cost of buffer, which is RM 4.53 m^{-3} or about 7.63% of the present value of logging cost.

Under the old system , the cost of buffer zone is RM 24.50 m^{-3}. The difference between the PNW of the old system with buffer and the PNW of the old system without buffer is the present value of the cost of buffer, which is RM 5.92 m^{-3} or about 9.52% of the present value of logging cost.

The PNW of the new system with buffer cost at 30% damage is RM 577.07 m^{-3} compared to the PNW of the old system of RM 566.53 m^{-3} at 40% damage without buffer cost, using the same yield of 65 $m^3 ha^{-1}$ and revenue of RM 521 m^{-3} as the new system, as shown by Table 4.

Table 4. Comparison of PNW between the new and the old systems (RM m^{-3})

Damage (%)	New system (with buffer cost)	Old system (without buffer cost)
0	609.16	612.40
10	598.46	600.93
20	587.77	589.46
30	577.07	577.08
40	566.38	566.53
50	555.68	555.06
60	544.98	543.59

This shows that the PNW of the new system is approximately 2% higher than the PNW of the old system. Hence the reduction in damage to the residual stand has increased the net future harvests as shown by the higher PNW of the new system with buffer cost. From Table 4, the percentage damage under the new system for breakeven is about 38%; hence the percentage damage allowable under the new system should be less than 38% in order to justify the viability of the new system.

Without buffer cost, the PNW of the new system is RM 581.60 m^{-3} or approximately 3% higher than PNW of the old system of RM 566.53 m^{-3} based on the yield of 65 $m^3 ha^{-1}$ and revenue of RM 521 m^{-3} as the new system, as shown by Table 5.

Table 5. Comparison of PNW between the new and the old system without buffer cost (RM m^{-3})

Damage (%)	New system (without buffer cost)	Old system (without buffer cost)
0	615.04	612.40
10	603.90	600.93
20	592.75	589.46
30	581.60	577.00
40	570.45	566.53
50	559.30	555.06
60	548.15	543.59

This shows that the reduction in damage to the residual stand has increased the net future harvests as shown by the higher PNW of the new system and the presence of buffers had decreased the PNW of the new system by about 1%, from RM 581.60 m^{-3} to RM 577.07 m^{-3}. From Table 5, the PNW of the new system for breakeven is RM 566.53 m^{-3} at about 42% damage; hence the percentage damage allowable under the new system should be less than 42% in order to justify the viability of the new system.

Sensitivity analysis was also done on the new system, with and without buffer costs and on the old system with and without buffer costs. Table 6 shows comparison of PNW between the new and the old systems

Table 6. Comparison of PNW between the new and the old systems(RM m^{-3})

Damage (%)	New system (with buffer cost)	Old system (with buffer cost)
0	609.16	534.19
10	598.46	527.65
20	587.77	521.13
30	577.07	514.60
40	566.38	508.08
50	555.68	501.55
60	544.98	495.02

From Table 6, the PNW of the new system with buffer cost was RM 577.07 m^{-3} at 30% damage compared to the PNW of the old system of RM 514.60 m^{-3} with buffer cost. This shows that it is more economical to install the buffer zone in the new system based on the higher PNW compared to the old system with buffer zone.

Conclusion

The new system is more productive at the Jengai Forest Reserve, and less productive at the Tembat Forest Reserve, than the old system.

In felling, it was found that distance and diameter^2 were the two variables that were significantly related to time in both study areas. The time of felling increases as the distance and diameter^2 increase in both areas. It takes less time to travel between trees in the Jengai Forest Reserve as compared to the time taken to travel the same distance in the Tembat Forest Reserve. For the same average distance and diameter, it takes a shorter time to fell a tree in Jengai than in Tembat. This suggests that the improvement made in the Jengai Forest Reserve has contributed to the higher productivity in the Jengai Forest Reserve.

Distance and number of logs were significantly related to delay-free cycle time in skidding in the Jengai Forest Reserve while distance and diameter were significant in the Tembat Forest Reserve. The time of skidding increases in Jengai as the distance and number of logs increase while in Tembat the time of skidding increases as distance and diameter increase. Productivity in the Jengai Forest Reserve is higher than that in the Tembat Forest Reserve based on the same average distance, number of logs and diameter as given by the shorter time taken to skid a log in Jengai than in Tembat. This suggests that the improvements in road construction in the Jengai Forest Reserve increased productivity of skidding. From the study, it was also found that the number of logs was significantly related to delay-free cycle time in the Jengai Forest Reserve. The delay-free cycle time increases with increase in the number of logs skidded. This shows that it is more efficient to transport more than one log as the distance increases in order to increase production.

On average it took a longer time to haul logs in the Jengai Forest Reserve than in the Tembat Forest Reserve. However, due to the lack of a range of operating conditions for the short hauling system, it is not easy to compare productivity between the two study areas. A more detailed study consisting of more than one hauling distance is needed to arrive at a model of the short hauling system.

The new system is cheaper in Jengai than in Tembat because the model for the new system was developed based on the improved conditions with respect to road construction, directional felling and buffer strip.

Under the same conditions of distance and diameter as in the Jengai Forest Reserve, the cost of felling per tree was RM 44.49 or 0.34% lower using the new system than the simulated cost of using the old system (RM 44.64). Under the same conditions of distance and diameter as in the Tembat Forest Reserve, the cost of felling per tree was RM 50.55 or 0.28% higher using the simulated cost of the new system than the old system (RM 50.41).

Under the same conditions of distance, diameter and number of logs as in the Jengai Forest Reserve, the cost of skidding per log in the Jengai Forest Reserve using the new system was RM 78.12 or 14% lower than the simulated cost of using the old system (RM 90.74). Under the same conditions of distance and diameter and number of logs as in the Tembat Forest Reserve, the cost of skidding per log was RM 84.48 or 3.46% higher using the simulated cost of the new system than using the old system (RM 81.56).

On average, the cost of hauling was lower (RM 8.72 m^{-3}) in the Jengai Forest Reserve than in the Tembat Forest Reserve (RM 10.60 m^{-3}). Because of the lack of predictive model for the hauling system in each area, it was not possible to compare productivity and costs between the two areas.

Yield other than logging costs plays an important role in influencing the viability of the new system. When yield per hectare is increased from 65 to 92 m^3 ha^{-1}, breakeven on the new system decreased from 41 to 28%. This shows that viability of the new system is decreased from 41 to 28% damage.

The PNW of the new system with buffer cost is RM 577.07 m^{-3} or approximately 2% higher than PNW of the old system of RM 566.53 m^{-3} without buffer cost.The reduction in damage to the residual stand from 40 to 30% damage had increased the net future harvests as shown by the higher PNW of the new system.

It is more economical to install the buffer zone in the new system based on the higher PNW of RM 577.07 m^{-3} compared to the PNW of RM 514.60 m^{-3} in the old system.

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