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MULTI-STANDARD FOREST ROAD NETWORK AND FOREST HARVESTING SYSTEM -A MONORAIL-BASED NEW OPERATION SYSTEM FOR FOREST HARVESTING AT STEEP HILLSIDE

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Abstract: *Monorail and low standard forest roads were used to construct the road network. This multi-standard forest road network was developed and reformed log harvesting operation at steep hillside. Vehicle machineries were transported by the monorail into the forest hillside and logging operation was done by them on the road network. Logs were collected by forwarder and moved to monorail cargo in forest stand and transported to landing spot at downward then moved to forwarder to pile up. Owing to automatic monorail transport, productivity of the operation system was 7m3/man-day in spite of steep hillside. The system decrease road opening at sensitive sites and promote flexibility to find suitable location of low standard forest roads. A support mechanism was developed, which move load between vehicle and monorail cargo, is expected gain the productivity 30 percent.*

1. Introduction

Building an efficient operational system is indispensable to activate forest resource utilization. A new efficient operational system was developed by the compound standard road network with which forest roads, operational roads and monorail road were combined. The labor productivity of 7m3 was also achieved per a man-day in thinning operation by the operation system that compact vehicle machines were integrated with the road networks to perform operation. This system is effective in a forest resource utilization operation at a mountain forest, and it can be applied as a standard system at steep forestry areas. An outcome of an operational experiment using this road network is indicated as well as its possibility is introduced.

Labor productivity achieved here is 2.5 times larger than that by the conventional operation system usually by light cable yarding and it will be improved more by container transship system.

2. The Multi-Standard Forest Road Network

The multi-standard forest road network is a road network, which combines forest roads, operational roads and monorail roads. Using the road network of these three standards, a forest resource utilization operation was performed. And walk path way design is also would be arranged for refreshing in the forest environment.

Basically, a monorail road is established at a steep hillside from a forest road, where an operation field locates its upper slope, and reaches at the field by a short distance. Then, establish an operational road network in there, and conduct a forest resource utilization operation by the vehicle machines (Figure 1).

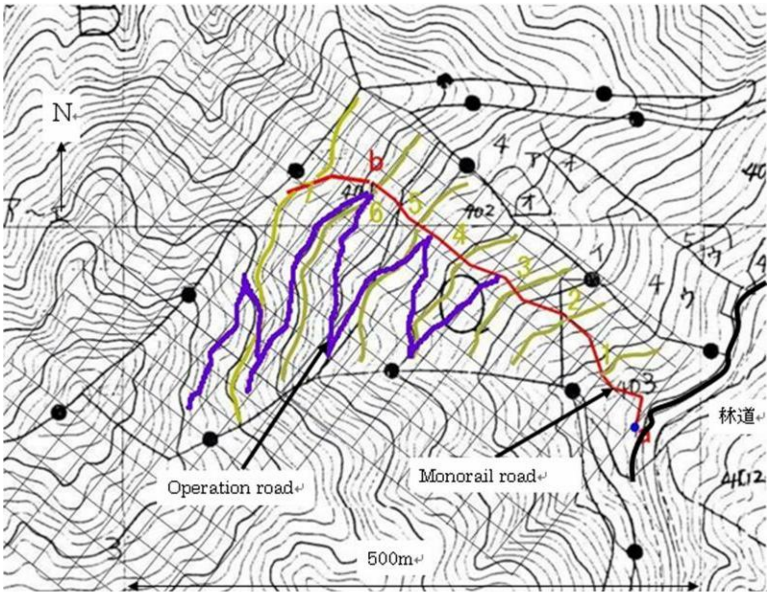

Figure 1: Layout of multi-standard road network

The monorail road performs to carry a small forestry vehicle and the timbers by the large carrying capacity (Figure2). The monorail capacity is 4t. The vehicle machines to carry up for the operation are a small excavator and a small forwarder.

Figure 2: Large monorail engine car and the container cargo in front of the thinning operation stand for the experiment

The steepest longitudinal slope of the road route is about 16% by a second grade forest road and 25% by an operational road, but it can be set by 100% by a monorail road. When hillside inclination is uniform, the road whose longitudinal slope is 100% reaches at a target point by 1/10 of the road length of 10%-longitudinal ascending section. Monorail road section decreases road network total length in the operation field in large undulate mountainous area to shorten logging distance and increase operational efficiency.

The longitudinal slope limit and the function of the assumed vehicle are different in each road standard, and the appropriate alignment of roads will be given according to the area of the operational field and the mountainous undulation. It is designable that by balance each road functions to have their each proper extension ratio under condition that the road network covers whole hillside and reaches at the highest point in the field (Nitami, 2002). A temporary decision and simulation evaluation in the arrangement location of the monorail road are repeated and the appropriate location is found (Nitami 2003, 2004a, 2004b, 2004c) so that road arrangement may be connected to an established operational road network appropriately in the location of the road section which becomes bones and hillside upper area and its vicinity.

Operational road is designed suitable for the small vehicle machine, and established with 2m width, but it was about 2.5 m width at most because of frequent fine terrain heaves on a hillside. Operational road was constructed by a small excavator which was carried in up by the monorail vehicle. The excavator changed the bucket for grapple and operated the logging after operational road construction. The interval of operational road was set to at most 50m and made the ground hauling distance small (Figure 3).

Figure 3: Log ground hauling, loading, behind three railed large monorail road

3. Operational setup and the efficiency

An experimental thinning operation was carried out at 5 ha sub-compartment of prefecture forest in Chichibu, Saitama The stand was about 50 year artificial forest, Japanese cypress and partly cryptomeria. The inning intensity was about 50%. The steepest monorail road was 47 deg, and the operation field where operational road was constructed was about 35 ° of hillside slope. The forest resource utilization operation efficiency was 7m3 per a worker through the operational system. It was consistent, and it was processed continuously at the same time from felling to piling at the road side. Operation crew were 4, and each processes was treated by single person for manual felling, logging and loading to forwarder, forwarder logging and transship to monorail cargo and transship to forwarder to pile aside the forest road.

The monorail transports logs about 300 m, and the forwarder runs on the operational road about 200m in the average. It's necessary to make felling and logging process balance with log hauling process by a monorail to improve the efficiency of this system-wide. Logs were cut into 4m. Forwarder reshipped load to monorail cargo at one station where connects operational road and monorail road. Like mentioning later originally reduction in working hours was expected by doing a transshipment every the container, but it was transshipped by grapple loader from forwarder to monorail cargo due to restriction of container forwarding mechanism this time. A monorail cargo departs after being transshipped by forwarder, and run down automatically to forest road side. Monorail cargo stops automatically at the unloading terminal forest road side to transship to forwarder to pile at a landing.

The cycle time of the logging system was 43 minutes according to the departure time of loaded monorail cargo (Figure 4).

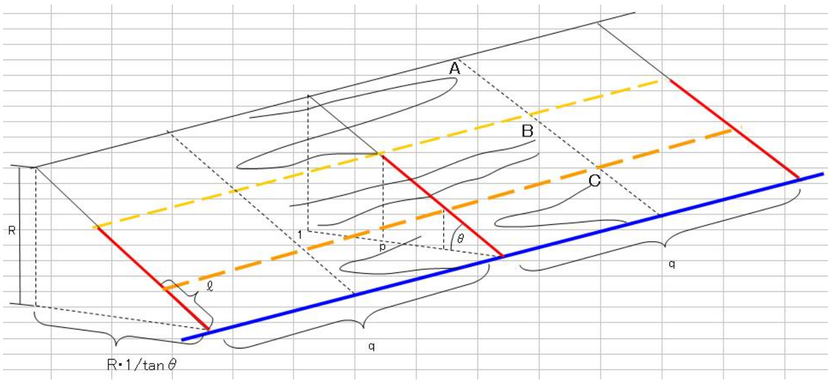

Figure 4: Model illustration of multi-standard road network location

One day operation resulted in 10 monorail cargos. The average size of log was 0.14 m3 and one cargo had 20 logs in average. This showed daily productivity of an operation team was it was 28 m3 and that of one crew was 7m3.

4. Advantage and the Applicable Condition

That a high operating efficiency is expected can apply it in a steep slope, and is a big advantage for the standardize operation system in steep mountainous area. A logging is done efficiently in the short cycle time without running through a long operational road at the operation field of large mountainous height difference owing to the high ascent and descent ability of the monorail. The driving speed of the monorail was stable at about 2.4 km/hr. The length of monorail road can be a quarter of the operational road, and forwarder requires double length road even if which could run double speed of the monorail, so that forwarder transportation process needs as twice duration as monorail dose. The larger mountainous heave is there in a valley area, the more the duration difference will be. Multi number of forwarder will be applicable but no effect improve of will be expected due to increase number of operation crew.

As operational technology, it's also an advantage that there are no processes which ask a high skill and special safety control. The local forestry workers were utilized to the operation for the first experiment and conducted it to finish without trouble. The favorable operational efficiency was obtained in spite that some machines were not well accustomed to maneuver. There occurred no operation jam with smooth process flow.

A waiting of forwarding process was happened at the log transship station from forwarder to monorail cargo. A discussion on the size of operation filed and the capacity of machinery equipment is needed. Time to have a round trip run of a monorail vehicle is 15 minutes, and the rest 28 minutes from whole operation cycle are log hauling at felling site and transshipment time. Considering the driving speed of a forwarder at about 4 km/hr, 200-300m monorail road length will be balanced with about a half hour operation for felling and site hauling.

The condition of the mechanical function and number to use and the area size of the operation field are being studied and the relation with a break-even line is being made clear. Depending on the results form this experiment, a field can be divided into three sections (Figure 5) to have balanced operational efficiency among these different slope area locations (Nitami, 2007a).

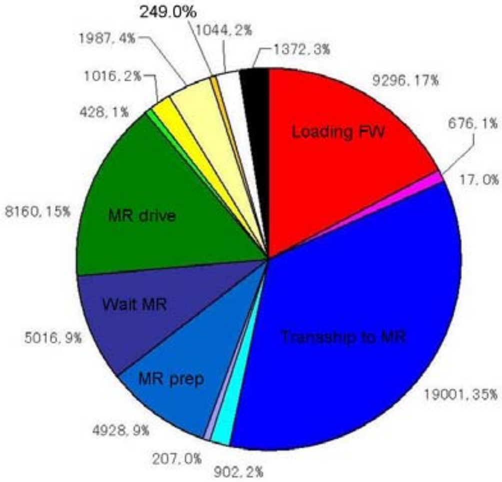

Figure 5: Operation time observation of thinning harvest operation by multi-standard road network system

5. Cell system forestry

I showed that much time was spent on transshipment of logs in an operational experiment. Originally, the system was designed to utilize containers to load logs and transfer them in order to reduce transshipment time substantially. It was not fulfill smooth container transfer at the moment of field operational experiment, when we regard some functional test results at factory, remarkable improvement is expected further.

The 35% of the observed working hours was transshipment time between monorail and log hauling forwarders. It is 15 minutes of the cycle time 43 minutes. When this could be set to one minute by an automation mechanism, the cycle time improves operating efficiency 48% for 29 minutes. A process is under development to handle container system for smooth transshipment. Longer transshipment time at factory experiment tells the improvement is around 30% at the moment.

This container system offers the various functions by installing the operation function onto it as well as loading carriage of logs. It's possible to combine those and build a mechanized operation system. It can be named Cell System Forestry (Figure 6) and standardize a slope ground forest resource utilization operation based on the multi-standard forest road network. Cell System Forestry may have variety of functions such as felling, processing as well as load and transport and perform a series of timber harvesting operation by connecting them in sequence. The biomass cell, as follows, achieves the process to utilize operation woody residuals.

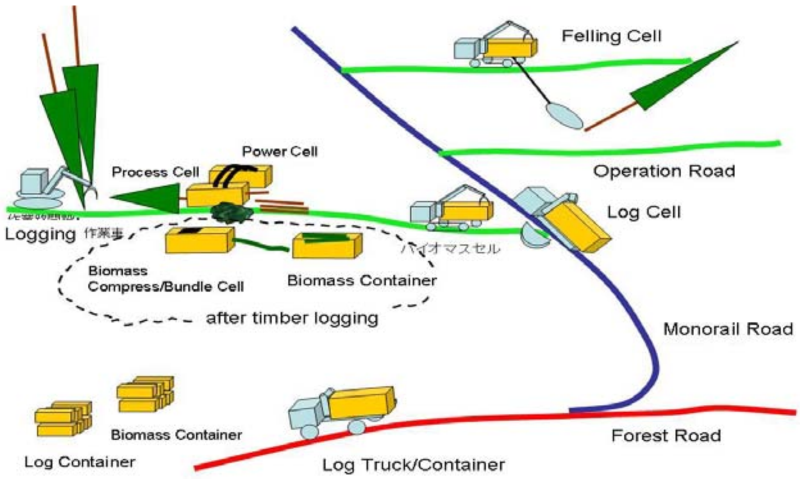

Figure 6: Model Illustration of Cell System Forestry based on the Multi-Standard Forest Road Network

6. Forest biomass harvest operation

One extended function of cell system forestry may be harvesting of forest biomass. The forest biomass is the curve part and the branch remaining materials which are left after a forest resource utilization operation, but their thin shape and bulky state does not easily make the operation efficient. It's necessary that their harvest operation keeps efficient by targeting residuals only on operational road and at logging landings. Also compressing bulky residuals is useful to make the volume decrease. In Europe, bundling machines are introduced to the operation, but in the country of steep terrain and soft ground prevent to use large vehicle based machinery in forest stands, and requires the function on a small unit/vehicle on roads.

Some preliminary experiment was conducted to obtain fundamental characteristics of processing man made forest residuals after a thinning operation and to know possibility of container based simple bundling mechanism. The one obtained at a site is the Japanese cryptomeria (Sugi) branch delimbed before half year, that of fresh and a fresh Japanese cypress (Hinoki) branch. Forest biomass compression to a bundle was experimented on a log container loaded full residual and tied by three wire rope winches installed on the container (Figure 7).

Figure 7: A Simple Wire-Winch Bundler based on a Log Container

Forest residual was compressed rapid until the wire rope tension increase to 3.6kN but it made no clear compaction thereafter (Figure 8), which made volume to the half. It indicated about 0.2t/m3 which was not so dense but is favorable when consider its simplicity and also another residual feeding sequence and wire exchange mechanism may improve the compaction.

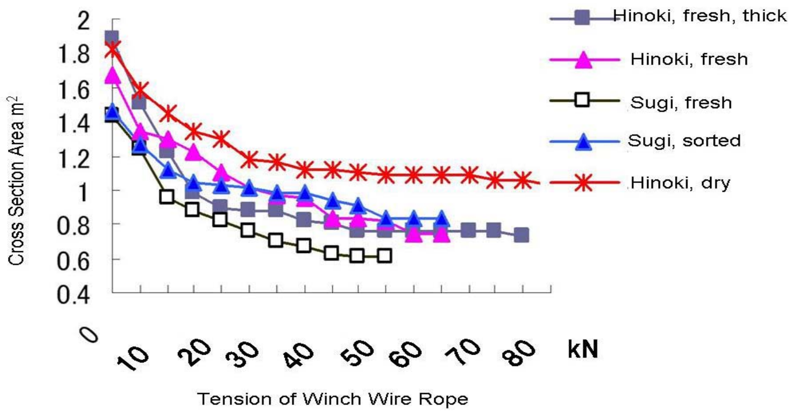

Figure 8: Tension of Wire Rope and Compression of Logging Residuals

7. Conclusion

Multi-standard road network showed remarkable efficient in steep hillside to conduct timber harvesting operation. This operation system enabled 7m3/man-day or more even at thinning operation. Utilization of monorail road in the system is useful to make the operation standardized. Through the standardized operation skill of working crews affect not much on the productivity.

The operation filed where will be conducted by the multi-standard road network can be divided into three sections regarding alignment to monorail road location to balance labor productivity among section areas.

Multi-standard forest road network offers Cell System Forestry. This has expandable possibilities with introducing containers installed operational functions. Forest biomass harvesting is one of the addable functions.

8. References

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