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SHORT HISTORY OF FOREST MECHANIZATION AND ITS PERSPECTIVES IN JAPAN

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Abstract: *This study aimed to obtain future perspectives of forestry mechanization by analyzing the statistic of forest machinery in Japan. The mechanization was proceeded by introducing processors, harvesters, and forwarders with the historical background where the Japanese forest conditions for harvesting were not always suitable for cut-to-length systems. Swing yarders were introduced as a cable system although they required high-dense road network than tower yarders. It was also verified that the machineries were introduced for their renovation of operation systems and the increase in the number of machines shown in statistic could not be directly regarded as the increase in the domestic timber production at the national level. Forestry mechanization process should be reviewed for realizing high productivity and safety works. The development and expansion of tower yarders for downhill yarding would be the issue to move Japanese forestry forward.*

Key words: *forestry mechanization, harvesting system, productivity, safety, downhill yarding.*

1. Introduction

As a renewable material, the demand for wood has boosted the development of forest machinery. Forest machinery has always required reasonable development from the viewpoint of not only the economic advantages but also the ergonomics, safety, and ecological functions. They introduced the most advanced technologies at that time such as engines, hydraulic systems, electronic devices, sensors, and Information Communication Technology (ICT). The development in forest machinery will change not only the harvesting systems but also the management of supply chain. This study aims to obtain future perspectives of forestry mechanization by analyzing the history of forest machineries in Japan by referring the domestic timber production and by reviewing the national policies.

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1.1. The Dawn of Forest Mechanization in Japan

The conditions surrounding the forest industry made differences in the progress of forest mechanization among countries. From the aspect of forest engineering, steep terrain and the ownership of planted forests characterized the harvesting systems in Japan. Forest area occupied two-thirds of Japanese land. The 58 %, 12 %, and 31 % of it were owned by private, local-publicly, and the national government, respectively [3]. The quarter of Japanese land is the coniferous forest which has been planted mainly after the clear cut of natural forest since ‘50s. The 65 % of them are privately owned and there are 0.6 million of small-scale forest owners who have less than 5 ha of forest [3].

In the middle of ‘80s, thinning operations in private forests inspired the need for mechanization instead of manual logging and horse skidding which was the main method especially in the northern part of Japan. Small forwarders were invented [5], and they equipped a hydraulic grapple loader imported from Scandinavian countries after a while. The introduction of grapple loaders apparently improved the efficiency of log loading operation [6]. National forest had introduced tractors for whole-tree skidding and yarders for clear cuts on steep terrain in the middle of ‘50s.

1.2. Short Review of Policies Related to Forestry Mechanization

As the planted forests matured and needed thinning, “the Forest Act” was renewed in 2001, and the aim of Japanese forestry shifted to the promotion of large-scale industrial forestry to utilize the matured planted forests effectively by modernized forestry machinery. “Fundamental Plan of Forest and Forestry” was announced in 2009 and the Forest Act was revised again in 2011. The aim of the original plan was to improve the self-sufficiency rate of timber production up to 50 % from 30 % in ten years. From 2011, the national government started to subsidize the forest road construction and the thinning operation in the forest where the management plan was established, and the forestry machines such as farm tractors with remote controlled winches [8], wheel-based harvesters and tower yarders were imported from oversea countries for the forestry enterprises who had motivation and operation skills. The annual volume of timber production hit the bottom at 16 mills. m^3 in 2002. It reached to 20 mills. m^3 in 2012 and produced a similar amount till 2015.

2. Materials and Method

The Japanese statistic had made public the number of forestry machinery introduced and the annual production amount [2]. The numbers of feller bunchers, harvesters, processors, skidders, forwarders, tower yarders, swing yarders and the others were recorded from 1988 to 2015. The characteristic of machinery was that almost of machinery was excavator-based or crawler-equipped in Japan. Swing yarders were the excavators with two-drum winches for short distance cable logging. The others indicated mainly the lately-developed excavators with the felling-bucket [5] which used for earth works and tree-felling and suited to road construction. In the statistic, the data of tower yarders

included the number of swing yarders until 1999 and the record of the others started from 2000. The trend of mechanization was overviewed at first. Since the subsidy started in 2011 would influence on the number of machinery, the increase in the number of machinery was compared before and after 2011 in this study.

We supposed that the introduction of new machines would be recognized as the direct increase of the production amount at the beginning of mechanization. For example, we experienced the increase of timber production by introducing chainsaws and tractors which were imported to deal with the damaged forest attacked by the typhoon in Hokkaido Island in 1954. Therefore, the ratio of increased production to the previous year was analysed in the increasing of timber production started in 2003 as defined in Table 1.

Table 1

The unit increased production each year

Operation	Machinery	Formula	Definition
Harvesting	Harvesters Feller bunchers Processors	$\frac{p_i - p_{i-1}}{n_i - n_{i-1}}$	p_i: the production amount in the year of i (10 thousands m^3) n_i: the number of harvesters, feller bunchers, and processors in the year of i
Prehauling	Skidders Forwarders Tower yarders Swing yarders	$\frac{p_i - p_{i-1}}{m_i - m_{i-1}}$	m_i: the number of skidders, forwarders, tower yarders, and swing yarders in the year of i

3. Results

Figures 1 and 2 showed the changes in the numbers of introduced forestry machinery in every year from 1988 to 2015. The total number of forestry machines was 7,686 in 2015 and about half of them was achieved by forwarders and processors.

According to Figure 1, forwarders and processors were the modern-machines which were introduced at the very beginning and mostly spread. The number of forwarders increased especially in 1999 and 2010. The processors expanded the share in 1993 and 2014 while its spread was relatively stagnant between ca. 2000 and 2004. The small number of feller bunchers could be explained by the steep terrain condition in Japan. They were used dominantly in Hokkaido Island. The number of harvesters increased in 2010 and kept increasing like forwarders. Tower yarders were expected to be suitable for the Japanese steep terrain conditions [7] and were introduced in 1990. They were, however, not expanded. Swing yarders were not popular at first. They were introduced instead of tower yarders in 1999 and constantly increased the number until 2015. The number in the "others" category was rapidly increased in 2012 and kept increasing.

According to Figure 2, the numbers of harvesters, forwarders and the others were increased after 2011. It indicated that the year of 2011 was a turning point of forestry mechanization. On the other

hand, the numbers of feller bunchers, skidders, tower yarders, and swing yarders were slightly increased or not increased. The introduction of the others from 2012 made the variance wider. The reduction in the number of tower yarders was because the statistic excluded the number of swing yarders in 1999.

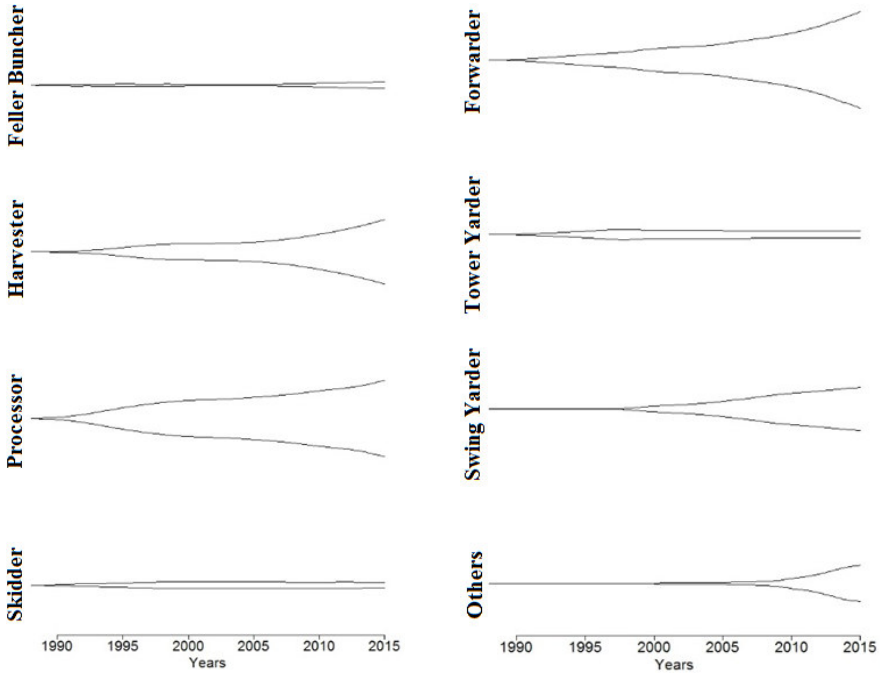

Fig. 1. The introduction of each forest machinery from 1988 to 2015

Figure 3 showed the unit increased production to the previous year. It did not show any trend. It was 3,600 m^3 per a harvesting unit and 2,300 m^3 per a prehauling/skidding unit on average.

4. Discussion

The forestry mechanization was driven by introducing processors, harvesters, and forwarders in Japan which were used in the cut-to-length system (CTL system). CTL system was established in Scandinavian countries and we compared Japanese history of forestry mechanization with that of Finnish history [1]. The shape of the harvester in Figure 1 was similar to that of Finland [1], but harvesters had already been introduced approximately in 1975 and rapidly spread in ca. 1990 in Finland. Forwarders had used in the mid of ‘60s prior to harvesters in Finland. In 1990, about half of timbers were produced by harvesters and almost timbers were transported by forwarders in Finland [4].

In Japan, the introduction of processors preceded earlier than that of harvesters because of steep terrain and soft soil conditions which were not suitable for harvesters to move in the forest and the insufficient forest road network which was still an issue in Japanese forestry. At first, they were imported after the Plaza agreement in 1985 and a domestic processor was developed in 1997.

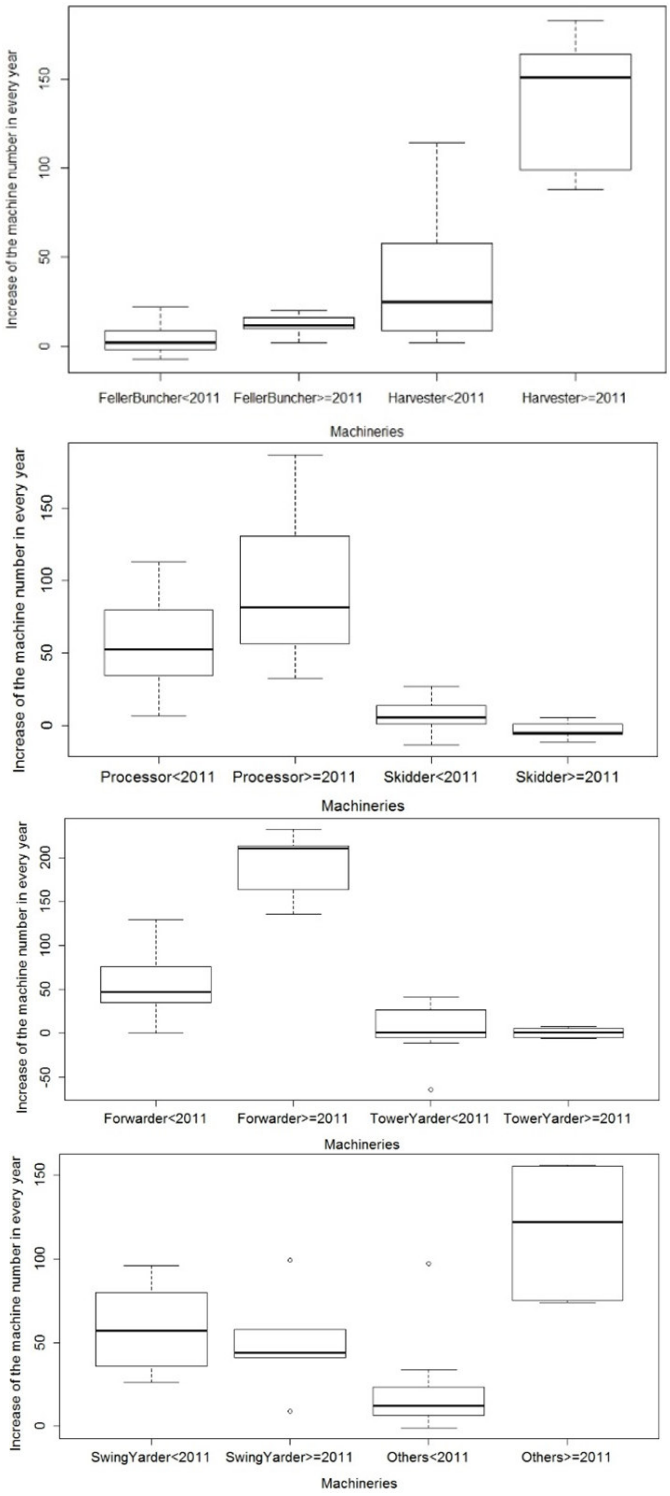

Fig. 2. Comparison of machine numbers introduced before and after 2011

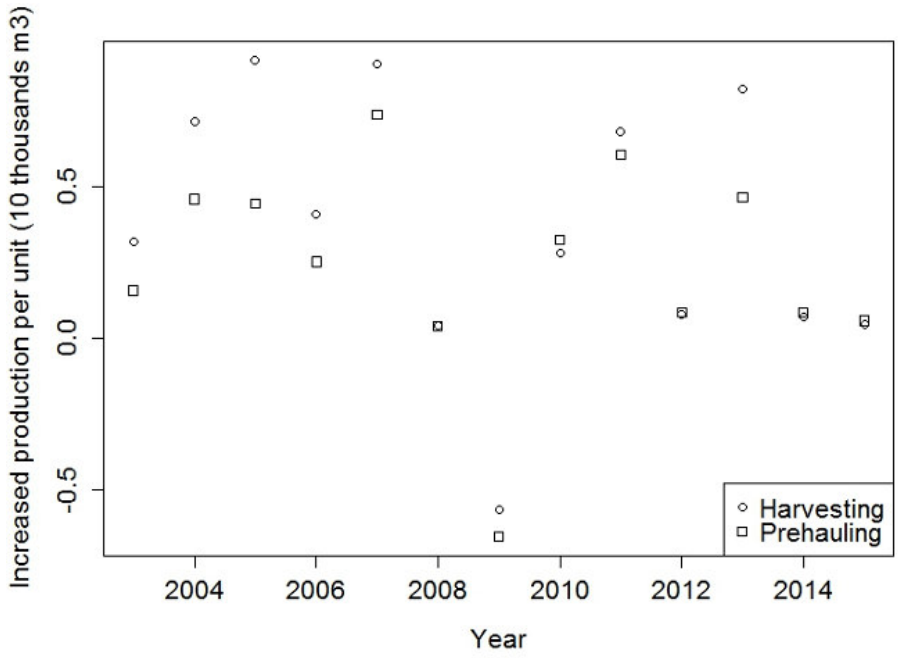

Fig. 3. Increased production per one harvesting or skidding unit every year

The development of a domestic processor did not seem to accelerate its spread although processors were constantly introduced. Since the harvesters were used at roadside, they equipped with a small winch for prehauling (Figure 4) and forwarders transport bucked logs from roadside to the landing. This point was different from the Scandinavian CTL system. The introduction of harvesters was 15-years later in Japan compared to Finland. Although forwarders also required the high-dense forest road network, the introduction was supposed to have proceeded because they were familiar to operators who usually drove vehicles on forest roads and transported timbers by domestic small forwarders [5].

According to Figure 3, the unit increased production was small and the minus growth in 2009 might be affected by Lehman shock in 2008. This small amount of the unit increased production indicated that some of the machineries were introduced mainly for its renovation from the behind mechanization. Therefore, the increase of machinery would not be directly regarded as the increase of the production.

Fig. 4. A typical harvester mounted on excavator at roadside equipped with a small winch for prehauling
(Photo: Hideo Sakai)

The increase in the number of the harvesters and forwarders in 2010 and the others in 2012 indicated that the change of policy in 2011 and the subsidy for forest road construction possibly contributed the introduction of those machines among private forests.

The implementation of cable harvesting systems was preceded by introducing swing yarders. The preparation of swing yarders was easier than that of tower yarders because they did not require guy-lines. It could be also used for loading operations as a grapple loader. Operators preferred the simplicity of its operation and its bi-functionality. However, the disadvantage of swing yarders was the shorter skidding distance requiring high-dense forest road networks consequently. As the harvesting operation moved to the more difficult terrain condition, the introduction of swing yarders slightly decreased after 2011 as shown in Figure 2, and the tower yarders would be necessary. Since it is challenging to construct the roads in Japan [5], tower yarders should be suited for downhill yarding in the forest with insufficient forest road density. Additionally, education and training were essential to spread the use of tower yarders on the operational level. In practice, there were the operators who trained the tower yarding operation in oversea countries and the importance of guy-lines was recognized for safety.

The increase in the price of machinery could be expected because of emission regulation of engine. It would require the increase in the productivity of machinery to reduce the harvesting cost. Another solution for cost reduction would be the use of the forest machinery with the base which was mass-produced such as excavators or farm tractors because of their widespread use and its relatively lower purchase price.

The data did not include the mobile chippers for wood chip production for energy. The steep terrain condition sometimes prevented mobile chippers and larger trucks to drive into forest so that the landing for chip production should be planned between a harvesting site and a demand [9]. Since the wood demand for energy was enlarging, the number of mobile chippers should be recorded, and the better location of intermediate landings should be considered into the plan of forest road network.

5. Conclusion

The mechanization in forestry was basically preceded by introducing harvesters, processors, and forwarders. The increase in the number of machinery did not directly indicate the increase in production. We supposed that they were basically introduced for renovation. Forestry mechanization process should be reviewed for realizing high productivity and safety works. The introduction of cable systems was not preceded compared to the machines for CTL ground-based systems although the cable systems were necessary in terms of terrain condition. The development and expansion of tower yarders suitable for downhill yarding would be the issue to move Japanese forestry forward because the slopes is steep to construct forest roads.

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