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Basic examination on the harvesting of small-diameter trees as unutilized forest biomass in Japan

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Introduction

●The Feed-in Tariff scheme for renewable energy (FIT) was launched in Japan in 2012, and the initiation of the plants' operation are progressing, since the purchase price of electricity from forest biomass has been set higher than that from other wood-based materials, e.g., mill residues and imported woods.

⇒3.03 million bone dry tons (BDT) of wood chips derived from thinnings and logging residues were used as energy in Japan in 2019.

Introduction (continued)

●The area covered by planted forests that have undergone final cutting and subsequent reforestation is now gradually increasing. Thus, a cleaning operation in young planted forests will be necessary 15-20 years from now, when the FIT will expire.

⇒The use of small-diameter trees is also promising.

●Broad-leaved woody coppices have a huge potential.

⇒The rich ecosystems of coppice forests were traditionally maintained by periodic cutting. Broad-leaved forests are now left unutilized, and degradation is progressing. Therefore, a new type of hardwood forest management under cyclic logging for the purpose of energy use is proposed so that the former rich ecosystems can be restored.

Objective of this study

●The authors’ research group has been studied technologies and systems for harvesting, transporting, and chipping logging residues on steep terrain in Japan.

⇒In the case of logging residues, calculation of the procurement cost begins from the harvesting process at a logging site where the process of limbing and bucking is carried out, while the felling and accumulating processes have to be considered additionally to calculate the procurement cost of small-diameter trees. Thus, forest biomass from small-diameter trees is considered to be a resource second to that from logging residues.

In this study, with the aim of discussing the effective method of harvesting such small-diameter trees as unutilized forest biomass appropriate for Japan, the harvesting of small-diameter trees was experimented with a truck-mounted multi-tree felling head and time-studied.

Previous studies

●Harvesting small-diameter trees has never been examined in Japan since the Japanese forestry fell behind in mechanization.

●In Nordic countries, the accumulative function which can be equipped with by feller-bunchers and harvesters is utilized in harvesting small-diameter trees for the purpose of bioenergy use.

⇒Belbo (2010) compared two working methods for small tree harvesting with a multi-tree felling head mounted on a farm tractor. Laitila et al. (2007) examined forwarding of whole trees after manual and mechanized felling and bunching in pre-commercial thinnings.

Materials and Methods

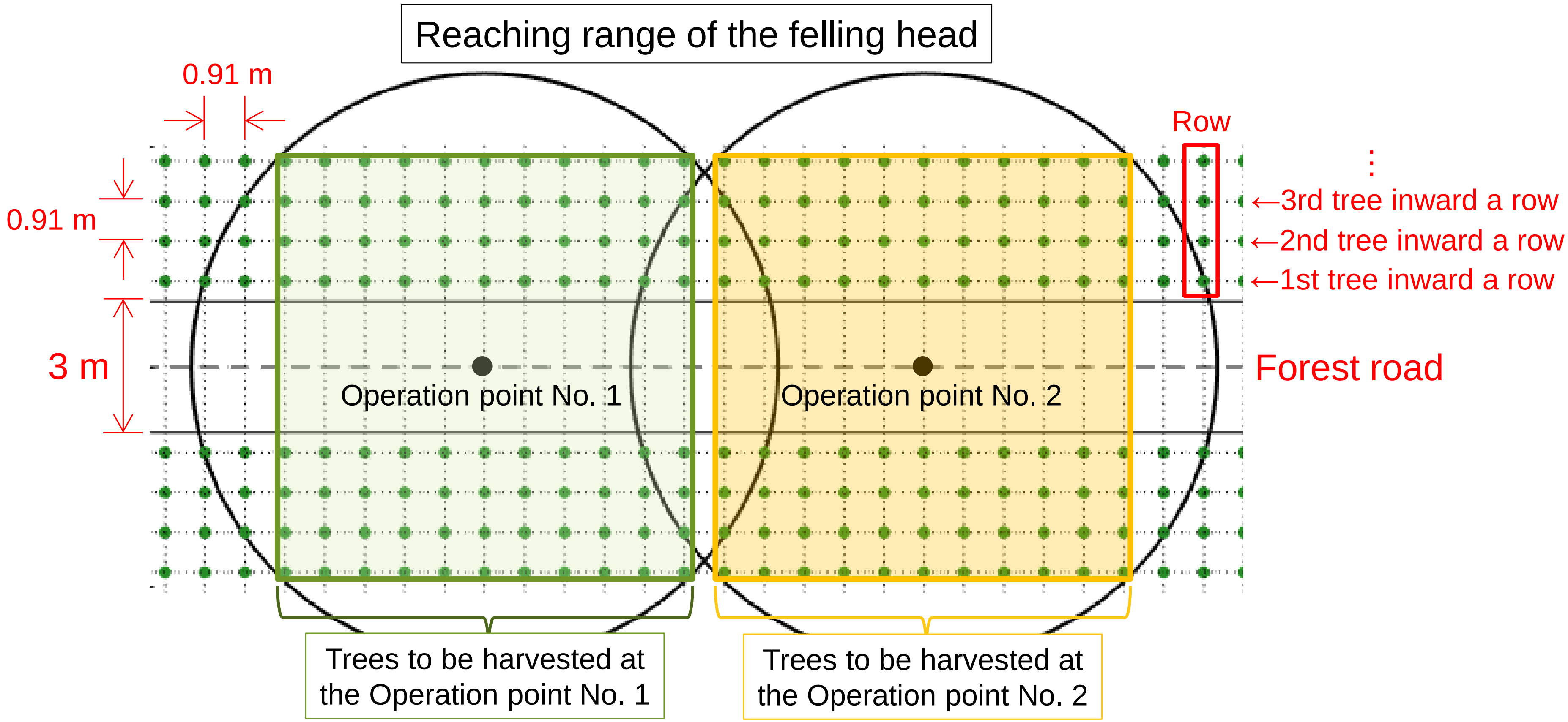
Machine used in the experiment

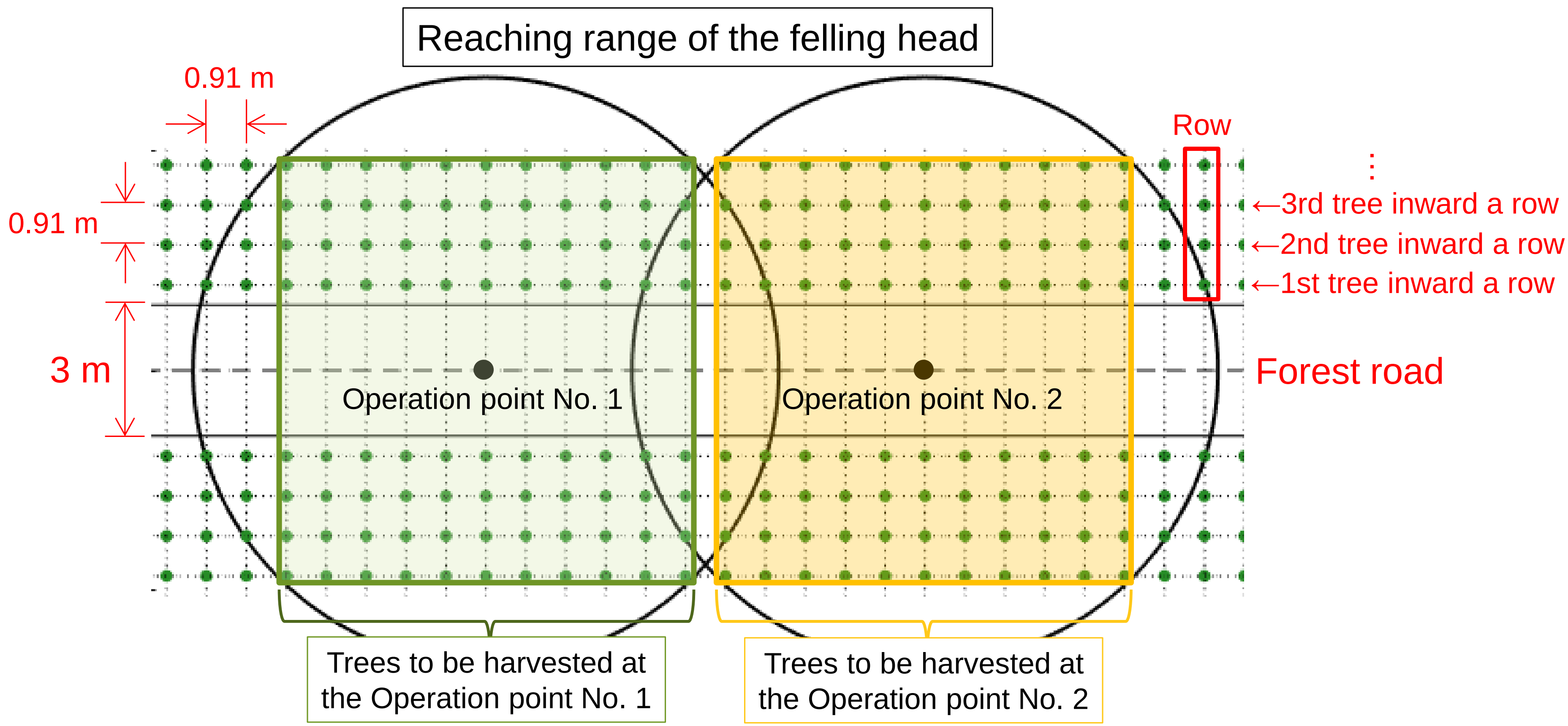
●The harvesting experiment was carried out with the multi-tree felling head (ENERGY WOOD GRAPPLE 300, Biojack, Finland; weight: 260 kg), which was utilized for the felling and accumulating of small-diameter trees in Nordic countries, as an attachment of the crane (LOGLIFT 61Z, Hiab, Sweden) mounted on a log transportation truck.

Felling and accumulating coppice trees alongside a forest road was time-studied in order to collect basic data.

Assumed simplified model forest

● A broad-leaved coppice forest was assumed to be on either side of a forest road of which width was 3 m. The stand density and the biomass per unit area were assumed to be 12,000 trees/ha (growing 0.91 m apart in a reticular pattern) and 30 BDT/ha, respectively.

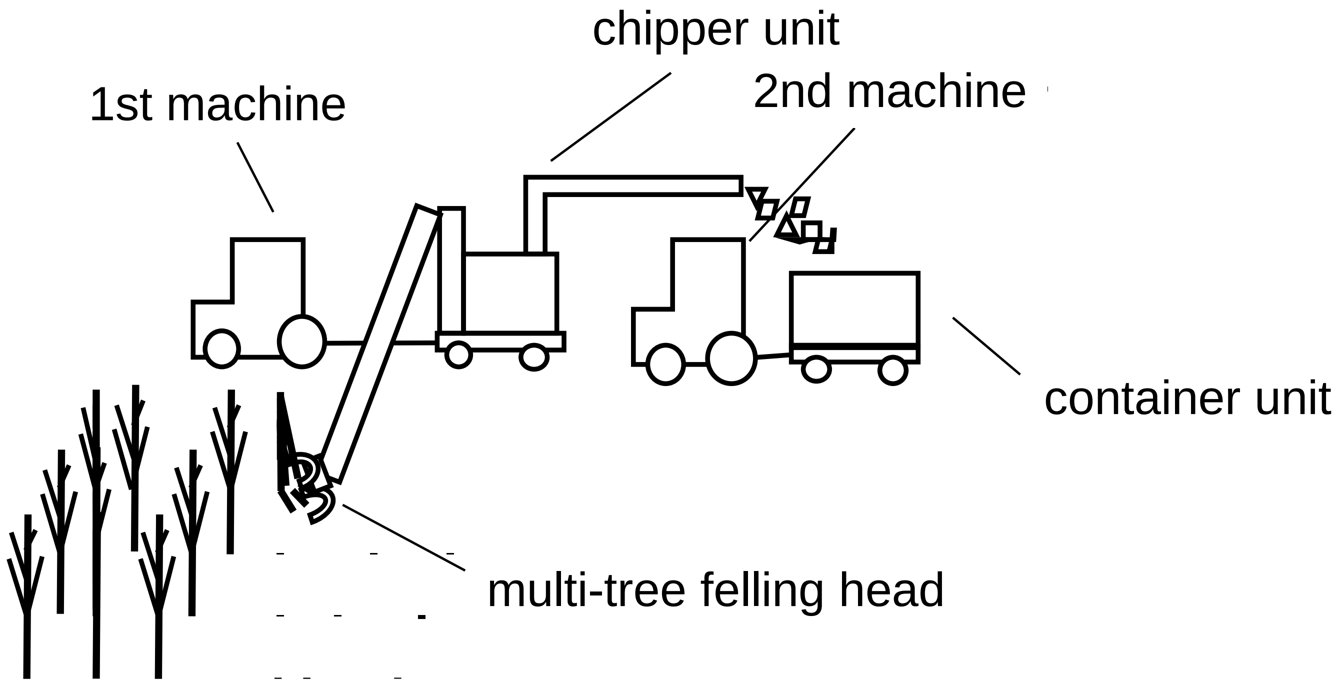




When a felling machine harvested the coppice trees repeatedly with moving each operation point in turn, the number of felled trees inward a row that minimized the harvesting cost was examined.

Assumed harvesting operations by two machines

●The first machine was a chipper that equipped with a multi-tree felling head. It felled and accumulated trees, and then the trees were comminuted. The second machine had a container, followed after the first one, and received the comminuted wood chips. This study calculated the costs taken to fell, accumulate, and chip trees, and regarded the sum as a harvesting cost.

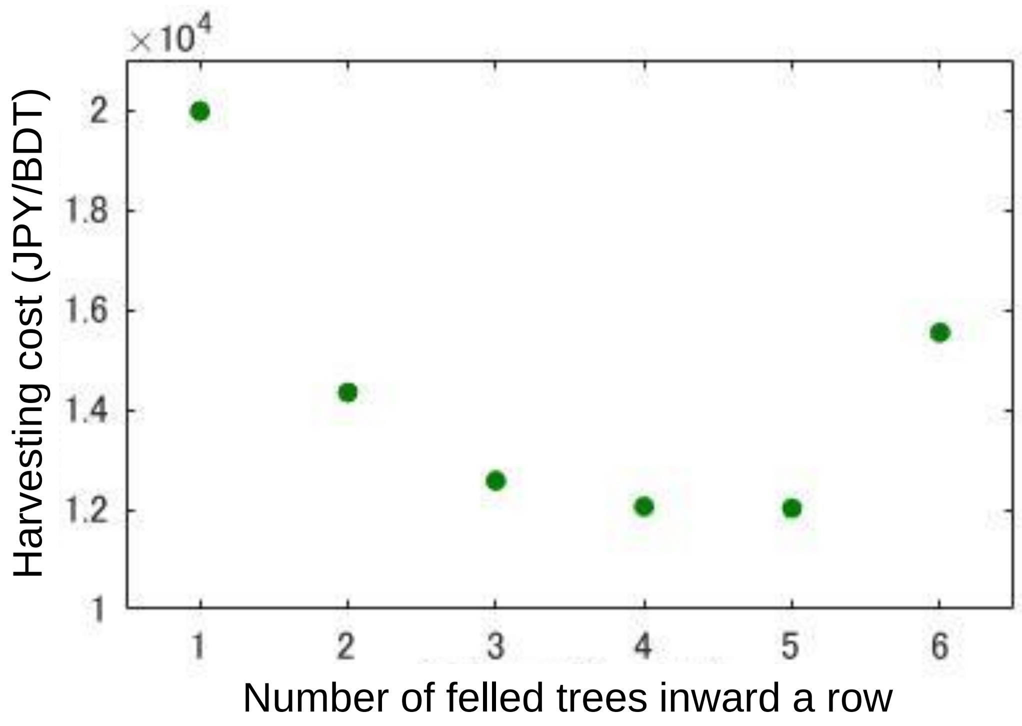


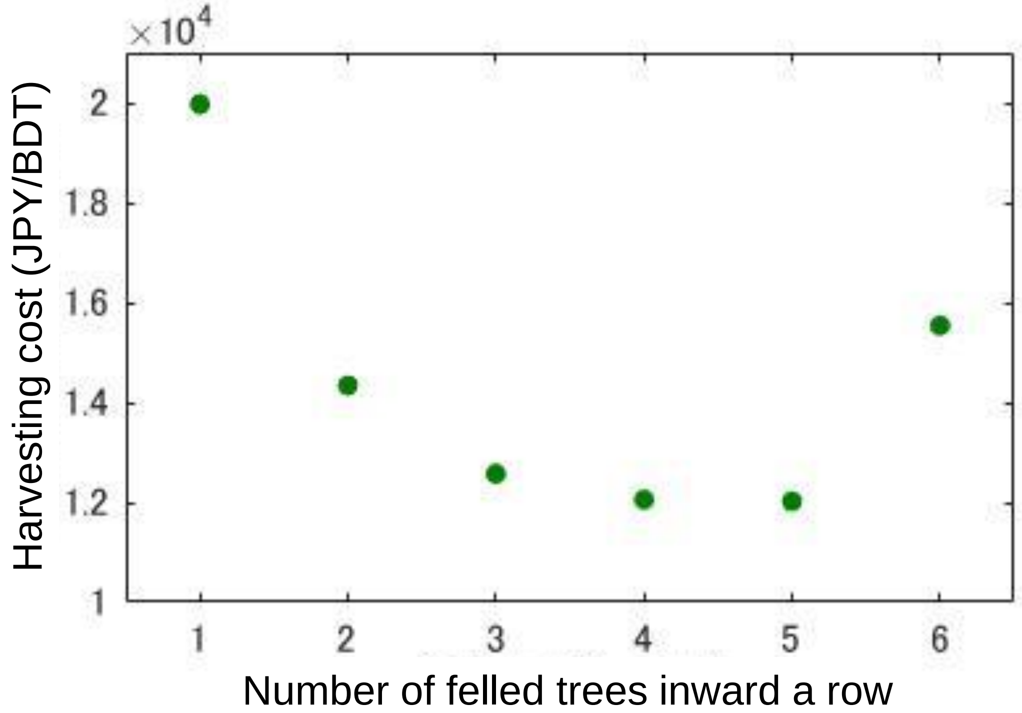
Results and Discussion

Relationship between the number of felled trees inward a row and the harvesting cost

●The maximum reach of the felling head used in the experiment was 6.7 m so that the machine could fell, in the model forest, the maximum six trees inward a row from a forest road with 3 m of road width taken into consideration.

●The harvesting cost was the cheapest when the machine felled five trees inward a row.



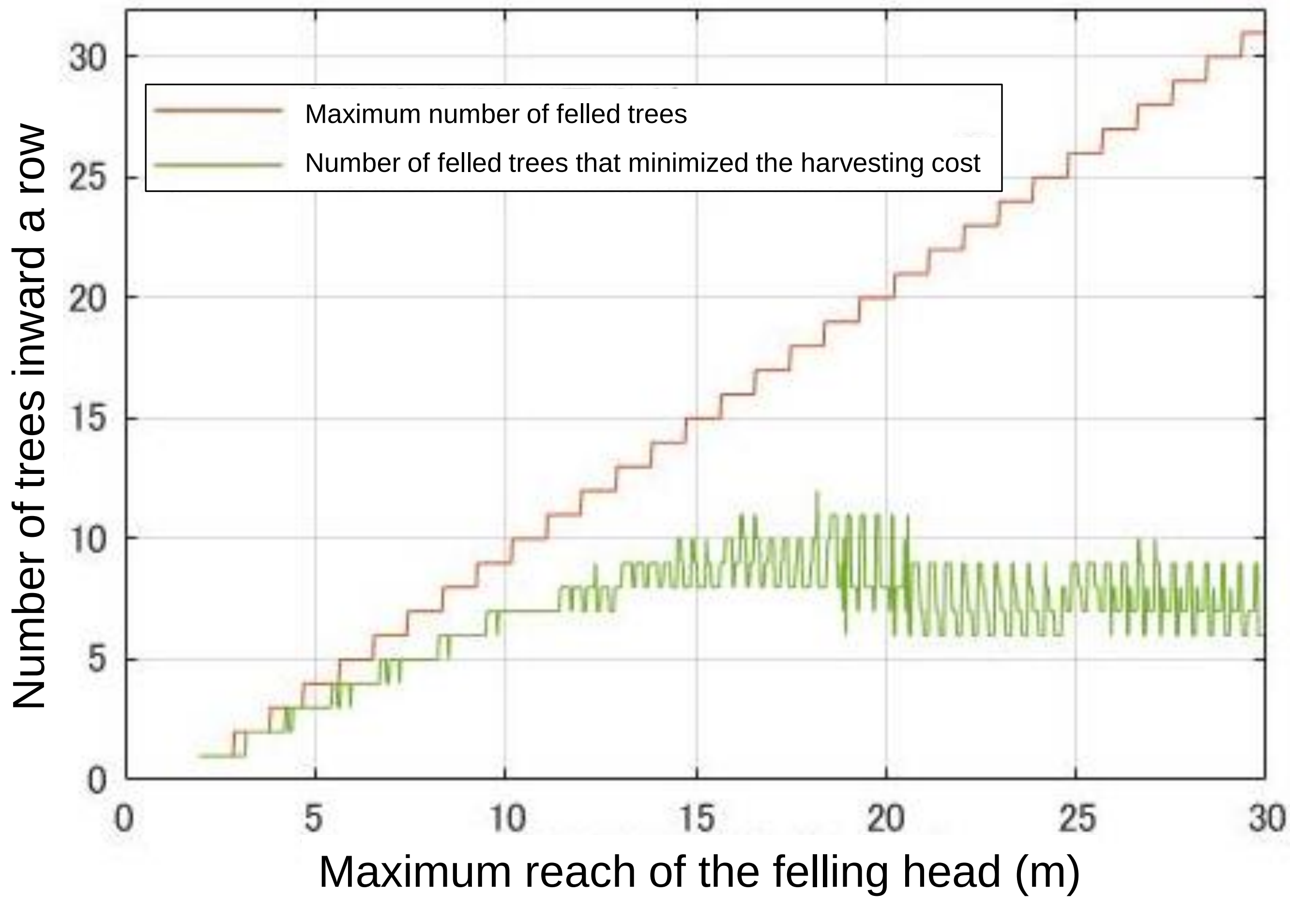


The more trees inward a row the machine felled, the more trees were harvested at one operation point. In this case, however, the machine’s total moving time markedly increased because the frequency of moving among operation points increased. Therefore, it was concluded that there was the optimum number of felled trees inward a row that could minimize the harvesting cost.

In order to increase the harvest amount of trees, it seemed to be effective to lengthen the maximum reach of a felling head and fell deeper trees inward a row; thus, the following two factors were examined in the case that the length of the maximum reach of a felling head was changed: (1) the maximum number of felled trees inward a row that minimized the harvesting cost, and (2) the minimum of the harvesting cost itself.

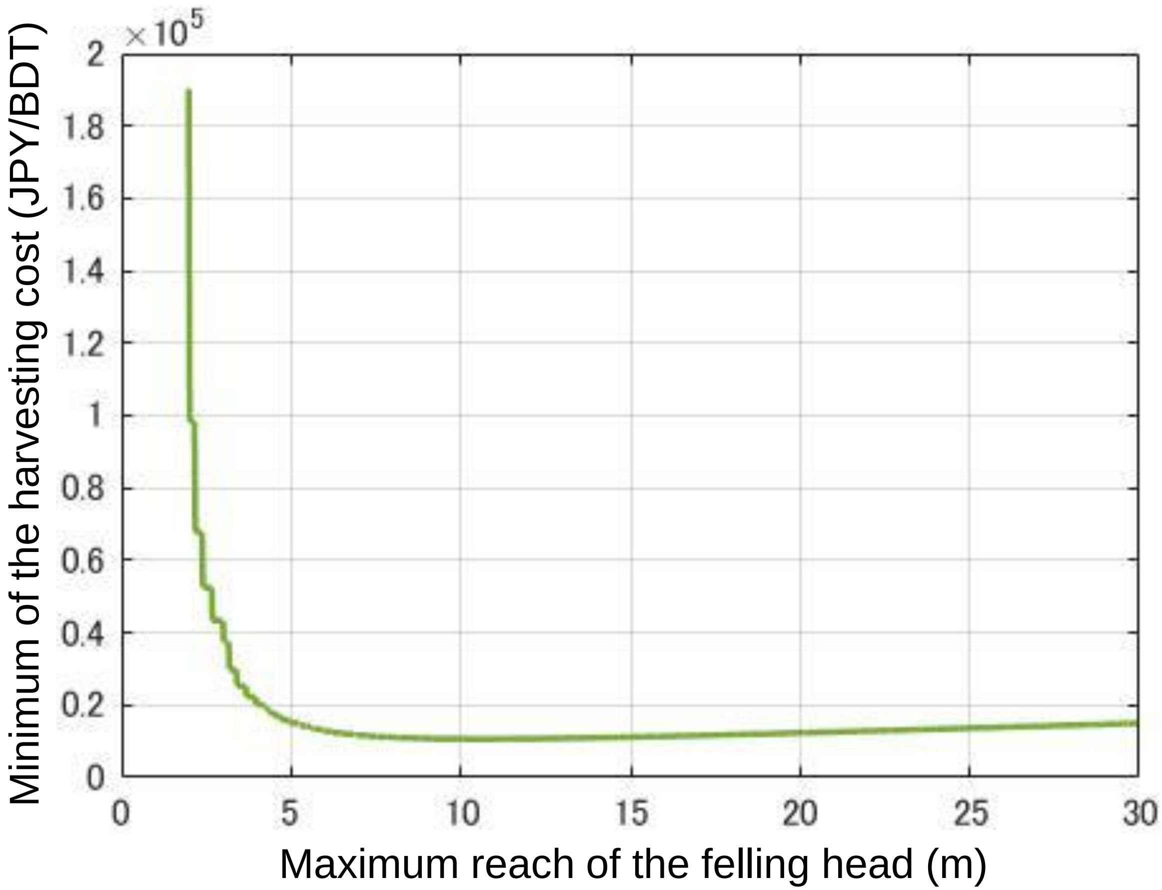
Relationship between the maximum reach of the felling head and the number of felled trees inward a row that minimized the harvesting cost

●Twelve trees inward a row from a forest road was the most when the length of the maximum reach was 18.2 m.



Relationship between the maximum reach of the felling head and the minimum of the harvesting cost

●The harvesting cost of 10,658 JPY/BDT was the cheapest when the length of the maximum reach was 10.4 m (the exchange rate was roughly 1 EUR = 125 JPY in October 2020).

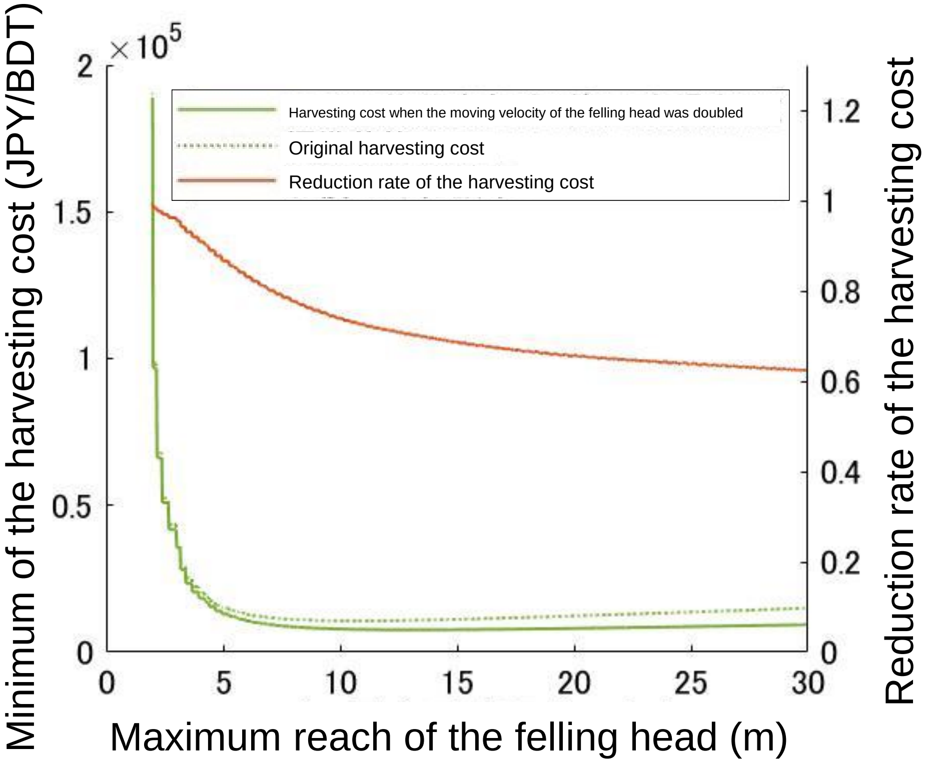


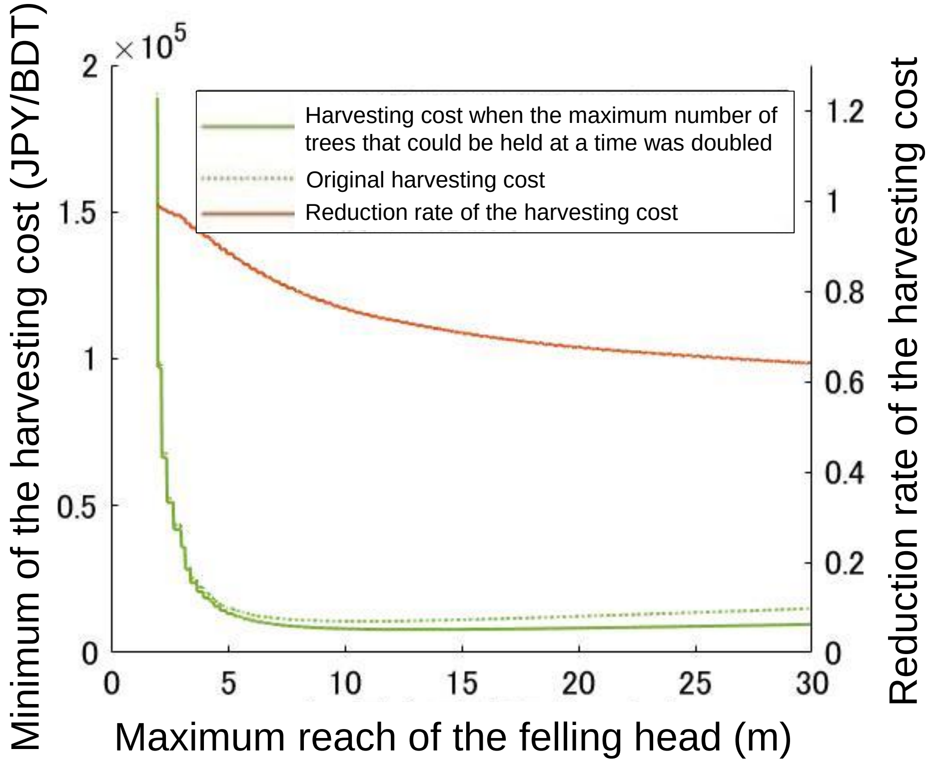
From a point of view of minimizing the harvesting cost, there were upper limits to the number of felled trees inward a row as well as the maximum reach of a felling head.

Sensitivity analysis was carried out to the acquired results to examine what kind of improvement should be necessary for the felling machine used in the experiment.

Results of the sensitivity analysis (1)

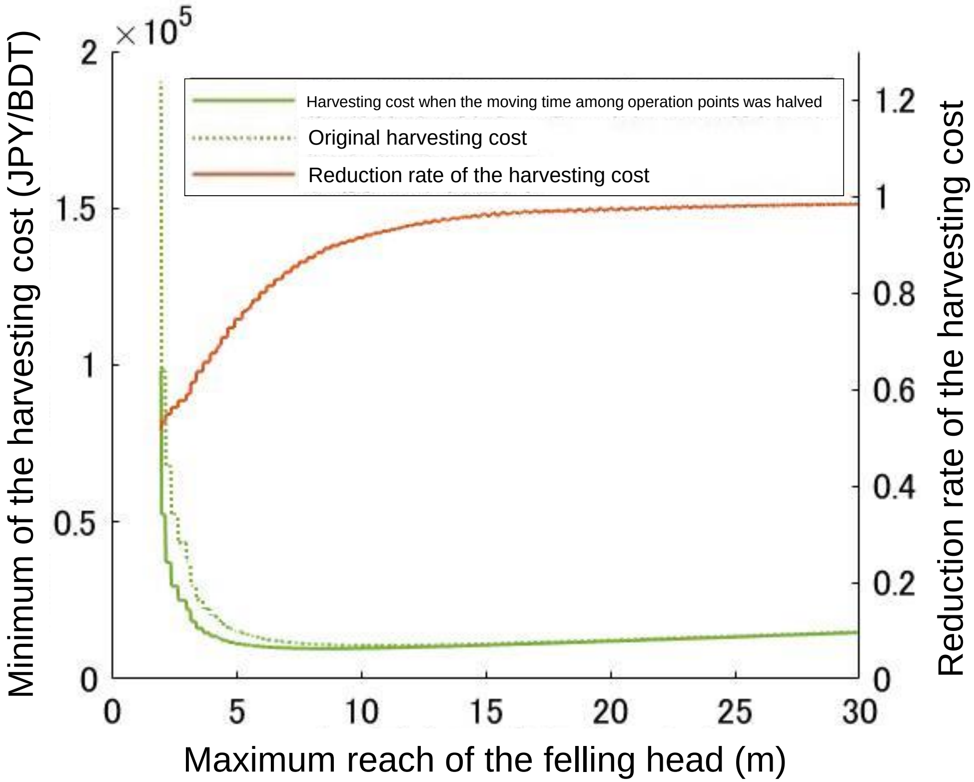
●In the cases that the moving velocity of the felling head was doubled and that the maximum number of trees that could be held at a time was doubled, the cost reduction effect was greater as the longer maximum reach of a felling head was used.





Results of the sensitivity analysis (2)

●The shorter the maximum reach of a felling head used was, the greater the cost reduction effect was when the machine's moving time among operation points was halved.



The following future policy for the machine’s improvement was suggested: Raising the moving velocity of a felling head and increasing the maximum number of trees that can be held at a time are effective if lengthening the maximum reach of a felling head is possible. In the meantime, shortening the machine’s moving time among operation points is effective unless the maximum reach of a felling head is lengthened.

Conclusions

- The machine used in the experiment could fell the maximum six trees inward a row from a forest road, but the harvesting cost was the cheapest when the machine felled five trees inward a row;
- From a point of view of minimizing the harvesting cost, there were upper limits to the number of felled trees inward a row as well as the maximum reach of a felling head;
- Raising the moving velocity of a felling head and increasing the maximum number of trees that can be held at a time are effective if lengthening the maximum reach of a felling head is possible. In the meantime, shortening the machine’s moving time among operation points is effective unless the maximum reach of a felling head is lengthened.

Conclusions (continued)

Finally, although this study was the limited examination based on various kinds of assumption, general trend concerning the procurement cost of wood chips from forest biomass in Japan was identified; that is, the cost from small-diameter trees calculated in this study was more expensive than that from logging residues but was cheaper than that from short rotation woody crops.

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Thank you very much for your attention!!