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Using LiDAR slope estimates to predict the productivity of a self-levelling feller-buncher

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Introduction

Steep slopes are known to have a significant impact on both the selection and productivity of forest harvesting equipment. Self-levelling feller-bunchers have recently been introduced in parts of Australia and New Zealand for harvesting operations in steep terrain. Self-levelling feller-bunchers have advantages over conventional feller-bunchers such as reduced risk of tilting, increased lifting capacity and increased operator comfort during downhill operations.

In the past, estimation of a harvesting site's slope has been hampered by low-resolution and inaccurate topographic maps. Accurate slope estimates can be produced using LiDAR (Light Detection And Ranging). LiDAR uses laser pulses from a low-flying aircraft which can penetrate the canopy and obtain height measurements at, or close to, ground level. Accurate slope estimates from LiDAR can be combined with productivity models incorporating slope to predict the productivity of harvesting machines across a forest estate.

The objectives of the study were to:

- quantify the effect of slope on the productivity of a self-levelling feller-buncher
- evaluate the use of LiDAR-derived slope estimates to predict the productivity of a self-levelling feller-buncher.

Study description

The study site was located near Port Arthur, Tasmania. It consisted of a 1 ha area marked out within a 24-year-old unthinned radiata pine plantation of approximately 1000 trees per hectare, with little understorey. The mean merchantable volume of the study trees was 0.53 m3 with a volume range from 0.05 m3 to 1.2 m3. The study trees were felled and bunched by an experienced operator using a Valmet 475 EXL self-levelling feller-buncher fitted with a Quadco hot saw accumulating head.

LiDAR data collected over the study site were used to create a high-resolution slope map. The site's slope ranged from 7º to 27º. The study site was divided into 3 slope classes: Gentle = 6-11º (11-19%), Moderate = 11-18º (19-32%), Steep = 18-27º (32-51%). The feller-buncher's productivity was compared in the Moderate and Steep slope areas because the area of Gentle slope was too small to be used in the study. The accuracy of the LiDAR derived slope map was compared with that of a slope map derived from 10 m contours and spot heights.

Study results

The productivity curves in Figure 1 clearly show the impact of slope on the productivity of the feller-buncher for a range of merchantable tree volumes in the Moderate and Steep slope areas. At the mean tree volume for both slope classes (0.53 m3), the feller-buncher's productivity was 97 m3/Productive Machine Hour (excluding delays) (PMH0) for the Moderate slope class (11-18°) and 73 m3/PMH0 for the Steep slope class (18-27°). The productivity curves were tested in moderate slope class and steep slope class areas not used to develop the curves, using LiDAR estimates of slope and field measured tree sizes and were able to accurately predict the feller-buncher's productivity in those areas.

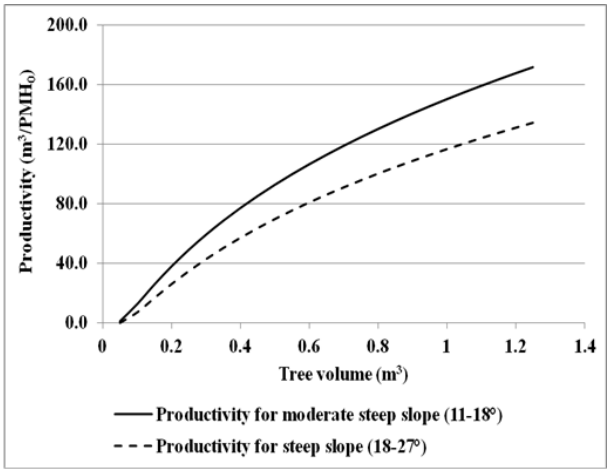

Figure 1: .Productivity of the feller-buncher against tree volume when operating in Moderate slope (11-18°) and Steep slope (18-27°) areas

The main cause of the difference in the feller-buncher's productivity when operating in each slope class, was found to be differences in the operator's working technique. In the Moderate slope area the operator worked uphill felling and bunching trees. In this area, the high density of trees frequently allowed him to fell and bunch several trees without moving the machine. In contrast, when working on the Steep slope areas, the operator worked downhill and moved each tree after felling back up hill to less steep areas that were accessible by the processor and forwarder.

The slope map derived from 10 m contours and spot heights identified less than half of the steep slope areas identified using the LiDAR derived slope map. The most likely reasons for this were:

- The lower resolution achievable using 10 m contours compared with LiDAR pulses with approximately 2 m spacing
- Difficulties in delineating ground surface contours through the canopy using aerial photography

Take-home messages

- The study results indicated that operating a feller-buncher on a Steep slope (18-27°) can reduce its mean productivity by 25% compared to operating it on a Moderate slope (11-18°) if it is required to move trees to less steep areas accessible to other machines.
- The productivity of the feller-buncher on another part of the study site was accurately predicted using LiDAR-derived slope classes
- The LiDAR derived slope map was considerably more accurate than the slope map derived from 10 m contours and spot heights

Acknowledgements

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More information

AFORA website:
http://www.usc.edu.au/research/research-partnerships/australian-forest-operations-research-alliance-afora

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