Simulated Productivity of Conceptual, Multi-Headed Tree Planting Devices

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Extended abstract:
The demand for mechanized tree planting has been growing steadily in southern Sweden over the last five years. This demand growth is mainly because seedlings on typical southern Swedish clearcuts survive better and grow faster when planted mechanically compared to operational manual planting after mechanical disc trenching. Today, planting machines in the Nordic countries consist of an ordinary tracked excavator with a crane-mounted planting device. Current boom-tip planting devices can be one- or two-headed, and prepare the soil via mounding, plant deeply, and are especially suitable on mesic and moist sites.

Practical experience has shown that two-headed devices are more productive than one-headed, especially on clearcuts with easy to moderate terrain. However, it is not known whether three- or four-headed planting devices could further increase planting machine productivity. Moreover, would such multi-headed planting devices remain more productive even on obstacle-rich terrain? To answer these questions, we used a discrete-event simulation tool to compare planting devices with one to four heads on clearcuts with varying frequencies of obstacles (ie. stones, stumps, roots) and different thicknesses of humus layer. The obstacles could hinder the planting heads from both mounding and planting, thus causing queuing delays for multi-headed devices on which the planting heads were linearly oriented perpendicular to the crane (Figure 1).

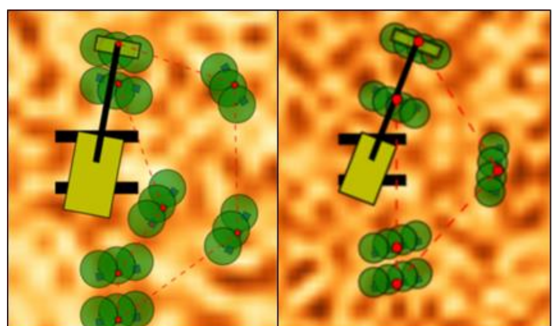

Figure 1. The ideal planting pattern of the three- (left) and four-headed (right) planting device models as depicted in the discrete-event simulation tool .

The results showed that productivity increased significantly with increasing numbers of planting heads on terrain with sparse or moderately many obstacles (Figure 2), regardless of using faster or slower soil preparation methods or seedling reloading systems. For example, tray-wise-loaded seedling carousels that were faster to reload increased the simulated productivity

by 3-13% depending on terrain and type of device. However, on obstacle-rich terrain, three-headed planting devices were more productive than four-headed, while one-headed were as equally productive as two-headed devices. Many obstacles slowed down the task of finding acceptably large microsites for the two- to four-headed devices, and also caused frequent queuing delays. Being over 3 m wide, four-headed devices were especially impeded by many obstacles. Indeed, the largeness of the four-headed devices sometimes inhibited the model from finding a large enough microsite to plant even one seedling at a machine stationary point. Meanwhile, on the same obstacle-rich terrain, three-headed devices planted significantly more seedlings per ha than both four- and two-headed devices since the four-headed devices were so large and the two-headed devices were modelled as being today's M-Planter device. The M-Planter is a relatively large planting device with the same total width as our three-headed device model had.

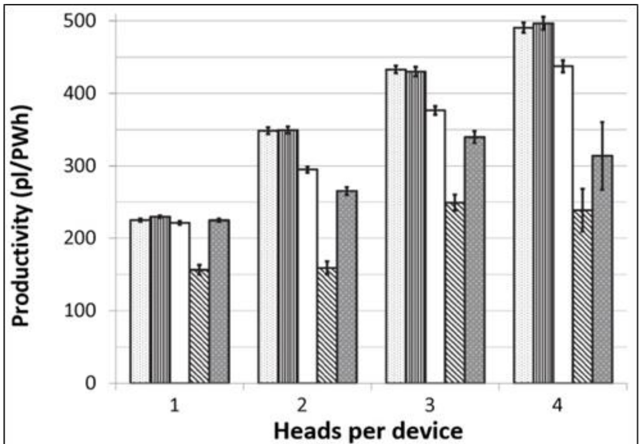

Figure 2. The mean productivity (planted seedlings per productive work hour) and 95% confidence intervals for one- to four-headed planting devices when mounding on five terrain models. The two leftmost bars of each group: obstacle-spare terrain; white bars: moderate terrain; the two rightmost bars of each group: obstacle-rich terrain.

The overall high performance of three-headed devices suggests that three heads per planting device (Figure 3) is the most realistic configuration for combining high productivity with good silvicultural results on all the terrain types that a planting machine might work on in Fennoscandia. Given the questionable silvicultural result of four-headed devices on obstacle-rich terrain, we conclude that even more heads per device, e.g. five or six heads, are not relevant. Future studies should investigate the silvicultural effects of different tree spacing geometries and the corresponding suitable geometrical design of three-headed crane-mounted planting devices.

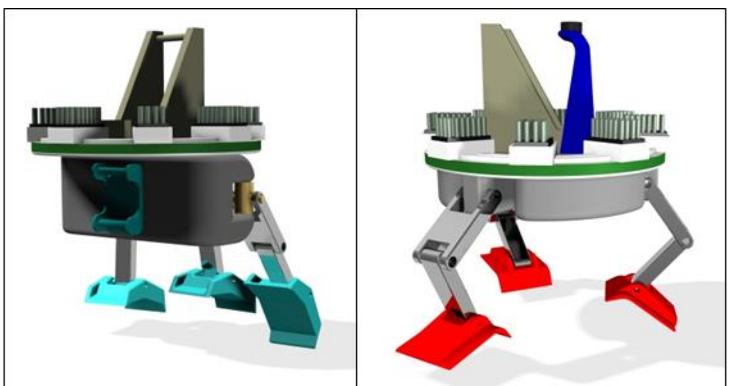

Figure 3. Examples of potential geometrical designs of three-headed planting devices: linearly (left) and triangularly (right) arranged heads .

Keywords: planting machine, mechanized tree planting, boom-tip planting head, discrete-event simulation, terrain model, mounding, site preparation, silviculture, forestry