Harvest equipment and soil erosion in a macadamia orchard

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Abstract
Soil erosion, in macadamia orchards in the high rainfall area of northern New South Wales (NSW), Australia, is exacerbated by mechanical harvest practices. Effects of harvest machinery (blower and sweeper) on soil under macadamia trees were measured in a mature orchard at the Centre for Tropical Research (CTH), Alstonville, NSW. Transects were set up across the tree row and inter-row to measure changes in soil elevation. Soil loss from the within tree row area occurred on the blower-treated plots. Soil was also removed by the sweeper but some soil was redistributed within the plot area. Orchard harvest practices that include sweeping and blowing will substantially remove soil over time and result in soil erosion in the vulnerable under tree region.

Key Words
Orchard-management practice, soil elevation, mechanical harvester, blower, sweeper.

Introduction
Soil erosion, exacerbated by orchard management practices, is an issue in northern NSW. Intense tropical rainfall and storms in the area can cause soil erosion from runoff, overland flow and also from water flowing down the trunk (stemflow) of a macadamia tree. Steep slopes and limited ground cover (grass and mulch) can accelerate erosion from water. Management practices, particularly the use of heavy mechanical harvest equipment, can disrupt the surface of the soil and vehicle tracks can promote erosion channels.

In a mature macadamia orchard, tree canopies shade the orchard floor limiting the growth of vegetative ground cover. Routine harvest practice in a macadamia orchard includes blowing or sweeping fallen nuts from within the tree row to the area between the tree rows, the inter row. Within the tree row, tree trunks, low branches, tree roots or irrigation pipes interfere with the harvest machinery while the inter-row area is generally free from obstructions. Thus macadamia nuts are moved to the inter row to facilitate their collection by a mechanical harvester. Sweepers and blowers have been designed to move macadamia nuts but inappropriate use can move soil and extensive root exposure has been observed. Blowers have a pipe diameter range of between 100 mm to 500 mm with an air flow velocity of up to 300 m/s. Sweepers comprise bunches of plastic bristles, up to 5 mm thick, set on a high-speed rotating circular frame.

While studies have measured the volume of dust resulting from mechanical harvesting practices (Downey *et al.* 2008), assessed particulate matter emissions and harvester improvements (Faulkner *et al.* 2009; Southard *et al.* 1997) or the effects of machinery on soil compaction and soil health (Van Zwieten *et al.* 2003; Jenkins 2004) there exists a dearth of information on actual soil loss from these practices. Studies that assessed soil condition in macadamias have not directly analysed the effects of harvest machinery on soil but they have shown distinct inferior soil conditions in the bare row where blowers and sweepers are concentrated, compared with a grassed inter row (Van Zwieten *et al.* 2003; Stephenson *et al.* 2004). To assess soil movement from mechanical harvesting, experimental plots were set up in the orchard and each plot was treated with a blower, sweeper or not treated.

Methods
The orchard was situated on an Acidic, Dystrophic, Red Ferrosol (Isbell 2002) at the Centre for Tropical Research (CTH), Alstonville, NSW. The soil can also be classified as a Nitisol (IUSS WRB 2006) or Oxisol (Soil Survey Staff 1999). The experimental site comprised nine plots, three blocks across by three blocks long in an orthogonal row column (Latin Square) design with three treatments, including the control, and three replicates. The plots, which ran along the tree lines across the slope, had five trees. Buffer trees were left between plots and between each row. Each treatment was represented within a block along a tree row across the slope. Each treatment was also represented within a block or "column" down slope.

Three replicated treatments were used:
1. Control that was not blown or swept
2. Blower (100 mm diameter pipe, velocity ~ 30 m/s measured 1 m from pipe outlet)
3. Sweeper (1.5 m diameter deck with bunches of 5 mm bristles)

Treatments were at seven day intervals in two sets over three months to represent two harvest years.

Field measurements

After each treatment, the soil surface topography along set transects was measured using an electronic fluid, or elevation, level (Technidea *ZIPLEVEL*^{TM}). Measurements were taken within 48 hours after treatments. Measurements were at 20 cm intervals, along each of two 7 m long transects, one either side of the centre tree of each plot. For each plot the two transects were parallel to each other and set 5 m apart. A tape measure between two permanently fixed pins one in each buffer row either side of the plot row delineated a transect line. At two times, before treatments started and after treatments finished, four extra transects were set up between the two regular transects. The additional transects were parallel to the regular transects and set at 1 m intervals. Measurements for all six transects were completed at 20 cm intervals using the same procedure as for the weekly measurements. For this paper, soil loss between the start and completion of the treatments was assessed.

Data analysis

Outcome of interest was declared to be the difference between final and initial elevation (final – initial) at each observation point. This put the response on an intuitive scale; values less than zero implied a soil loss while values greater than zero implied soil gain. Change in elevation was modelled as a linear response to treatment, distance and plot plus a cubic spline smoothed response to distance. The model was used to estimate the expected change in elevation along a typical transect under each treatment. Model parameters were estimated according to the methods outlined in Verbyla *et al.* (1996) through use of the asreml package (Butler *et al.* 2007) in the R environment (R Development Core Team 2008).

Results

Raw observations are shown in Figure 1. The control plots suggest consistent and small loss of elevation along transects while the observations from the blower and sweeper plots indicate relatively high disturbance at the transect centres.

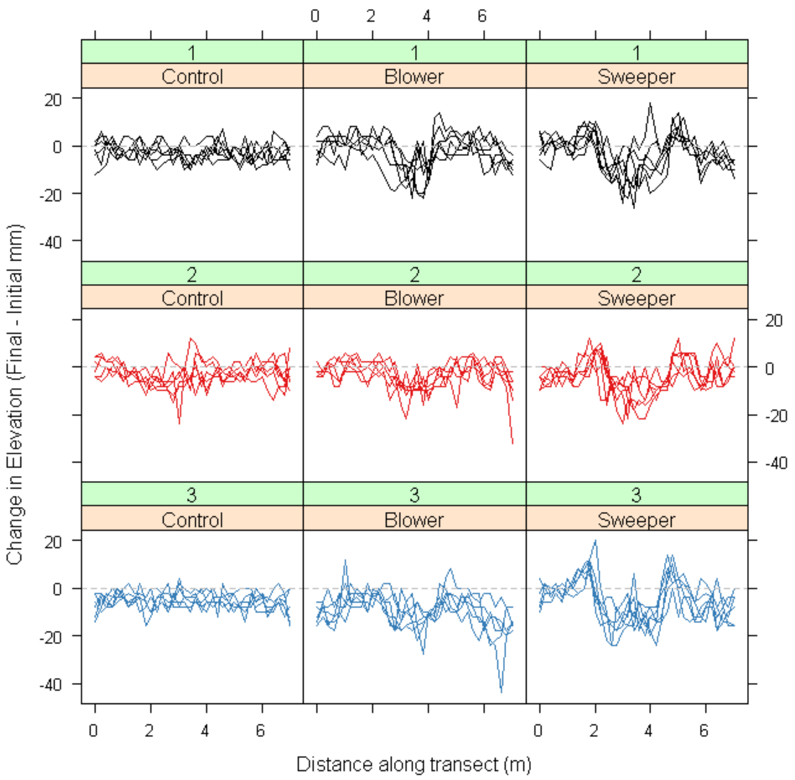

Figure 1. Observed changes in elevation along each transect showing variability within and between each plot.

The raw observations were supported by the model which indicated a statistically important movement of soil from the plot centres to the plot edges under the blower and sweeper treatments relative to the control (Figure 2).

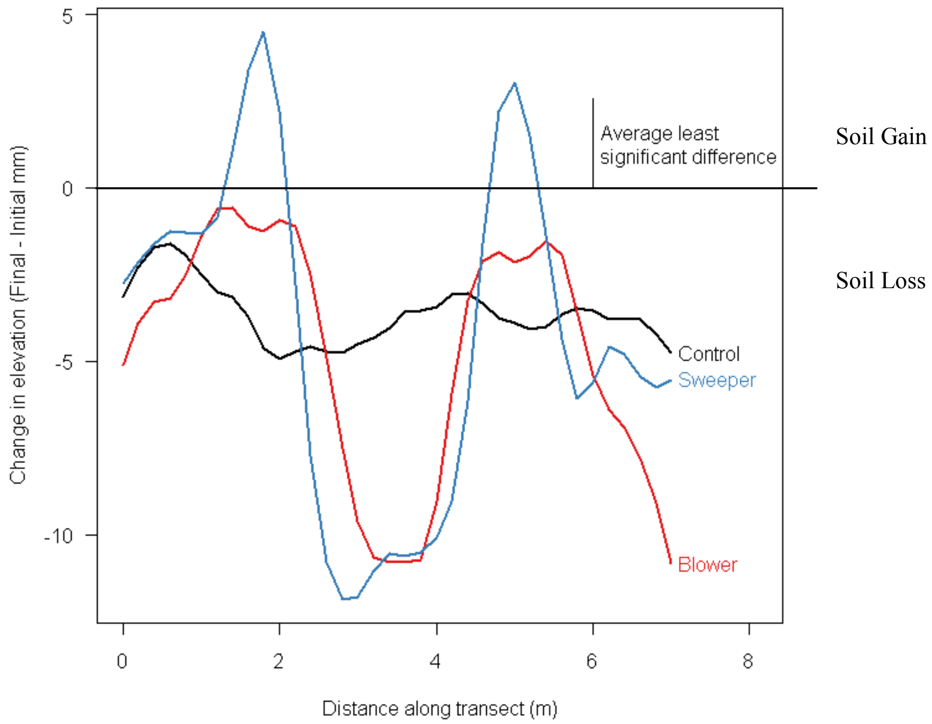

Figure 2. Predicted change in elevation under each treatment showing final observation less initial observation. Negative values indicate a loss in elevation while positive figures show a gain in elevation.

Soil loss was obvious on the blower-treated plots particularly in the centres of the plots where up to 20 mm depth of soil had been lost. This observation is reflected by the model, which shows that soil was lost from across those plots with more soil lost from the centre of the plots. Soil movement was noted on the swept plots following treatment. Here, the response predicted by the model shows that soil was moved from the centre of the plot outwards, a distance of only 1 m to 2 m. It was shown that soil accumulated in this area. For the control plots, the model shows a slight decrease in elevation. This could be explained by soil loss resulting from inherent movement of soil from wind and rainfall.

Conclusion

The harvest equipment used in this experiment moved more soil from the tree-row area than expected. Blowing removed soil from the crucial tree row and roots were exposed. While soil was also removed by sweeping, some soil was redistributed within that area. Both blower and sweeper actions produced small linear hollows, potential new erosion zones, along the tree rows. Water flow from large rainfall events will concentrate in these areas and the level of erosion that will occur will depend on the force of the water, the slope and the length of the slope. Continued orchard management practices that include sweeping and blowing will remove substantial soil volumes over time. This will result in soil erosion in the vulnerable under tree region. Not only will root exposure endanger the health of macadamia trees but soil sediments in runoff and overland flow in this high rainfall area will exacerbate water quality down stream.

The soil moved in the experiment was detached and thus at a higher risk from further erosion from rain drop, overland flow and other erosion processes (Rose 1994). Ground cover (grass or mulch) in both the tree row and inter row on the steep slope of macadamia orchards is very important in helping alleviate soil erosion from these regions (Cox *et al.* 2004; Jenkins 2004). This study has identified that the current harvest practices in macadamia orchards move large volumes of soil and this is unsustainable in the long term. Modification in the design and use of blowers and sweepers needs to be addressed to reduce the impact of soil loss.

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