Use of LiDAR data to quantify the influence of topography on radiata pine (*Pinus radiata* D. Don) at the sub-compartment level

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Certification

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis and all sources used have been acknowledged in this thesis.

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Abstract

Accurate estimation of inventory estimates, such as aboveground tree biomass, is a fundamental aspect of studies on carbon stocks of forest ecosystems since it reflects the accumulation of organic carbon and ecosystem productivity. Diameter at Breast Height (DBH) and tree height are the two main variables used for numerous forest inventory parameters, including stand stem volume and biomass. The significant variability within these factors, however, can challenge the acceptable levels of precision and bias required for inventory estimates at the operational Planning Unit.

In Hanging Rock State Forest, New South Wales, Australia, despite the similar genetic sources, edaphic (geology and soil type) and climatic (temperature and rainfall) variables as well as similar initial stocking rate, the radiata pine (*Pinus radiata* D. Don) trees displayed significant height and DBH variation within even-aged compartments. The aim of this research was to determine the significant factors causing these variations and identify the relationships between height and DBH variables with these factors. The knowledge of intra-compartment variability in tree height and DBH is important as these small area inventories are used for operational yield predictions and facilitate local silvicultural and harvesting decisions.

Airborne Light Detection and Ranging (ALS or LiDAR) system has demonstrated the ability to provide accurate metrics from stand attribute estimates. LiDAR offers a cost-effective, operationally flexible and robust sampling tool for forest managers. With the use of LiDAR, substantial data from tree canopy structure and its surrounding spaces can be acquired. In this study, not only LiDAR was used to derive different tree structural metrics, such as height and stocking, but also different terrain information such as slope, aspect as well as solar radiation was calculated from the highly accurate Digital Elevation Model (DEM).

The results of this study demonstrated significant relationships between DBH and height of radiata trees with slope and aspect, solar radiation and stand density ($P < 0.01$ or $P < 0.001$). Overall taller trees and trees with larger diameters were common on southerly aspects and on gentle slopes (<20°). Also larger and taller trees were associated with low values of summer and winter radiation. A significant relationship was also seen between tree height and DBHs and stocking ($P < 0.001$), where taller trees were associated with high stocking while larger diameter trees were found on lower stocking sites. These results indicate initially the capacity of LiDAR to capture sub-compartment variation in these tree-level attributes and further define these factors suitable for use as a sub-compartment stratification variable as well as for possible inclusion in different *P. radiata* models for better and accurate resource predictions.

Dedications

This work is dedicated to my loving parents.

My father, Dr Hossein Saremi , whose unending love, moral character, and strength inspired my own perseverance and guided my being in this endeavour. He has been my role-model for hard work and persistence, and inspired me to set high goals and the confidence to achieve them.

My mother, Mahnaz Faghihzadeh, whose constant love, belief in me, encouragement, motherly care and support has helped realize my potential, and make this contribution to our world. She has emphasized the importance of education and given me the determination to keep going.

This work is also dedicated to my late Aunt Moazam, who passed away towards the end of second year of my research. Her words of encouragement and push for tenacity ring in my ears, I am sorry that she has not lived to see me graduate. She was like a mother to me, a source of motivation and strength during moments of despair and discouragement. I will cherish her memory with warm thoughts, laughter and tears as I reminisce of all the wonderful times that we have shared together.

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Above all, I thank GOD for helping me through this journey and making all things happen according to his will.

Note to Examiners

This thesis has been written in journal-article format. I have attempted to minimize the duplication of material between the chapters. However, some repetition remains, particularly in the methodology section. This is due to the requirements of the journals and the need for each of the papers to stand alone.

Although an effort has been made to ensure consistency in the format for the purposes of this thesis, I acknowledge that some inconsistencies remain due to the requirements of each of the journals to which the separate papers were submitted.

Publications from this thesis during Candidature

Saremi, H., Kumar, L., Turner, R., & Stone, C. (2014). Airborne LiDAR derived canopy height model reveals a significant difference in radiata pine (*Pinus radiata* D. Don) heights based on slope and aspect of sites. *Trees - Structure and Function*, *28*(3), 733-744.

Saremi, H., Kumar, L., Turner, R., Stone, C., & Melville, G. (2014). Impact of local slope and aspect assessed from LiDAR records on tree diameter in radiata pine (*Pinus radiata* D. Don) plantations. *Annals of Forest Science*, 1-10. doi: 10.1007/s13595-014-0374-4.

Saremi, H., Kumar, L., Turner, R., Stone, C., & Melville, G. (2014). DBH and height show significant correlation with incoming solar radiation: a case study of a radiata pine (*Pinus radiata* D. Don) plantation in New South Wales, Australia. *GIScience & Remote Sensing*, 1-18. doi: 10.1080/15481603.2014.937901.

Saremi, H., Kumar, L., Stone, C., Melville, G., & Turner, R. (2014). Sub-compartment variation in tree height, stem diameter and stocking in a *Pinus radiata* D. Don plantation examined using airborne LiDAR data. *Remote Sensing, 6*(8), 7592-7609.

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