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Technical Note

Forest Industry Applications of UAVs

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Summary
A recent project at Scion explored the use of unmanned aerial vehicles (UAVs) to support a range of forest industry applications. Topics explored included the cost efficacy of UAVs compared to other sources of data and use of UAV data for 1) identification and mapping of wind-damaged forest to plan for value recovery; 2) identification and mapping of cutover areas; 3) assessment of post-planting stocking and survival; 4) post-harvest waste assessment. This technical note summarises the key results from this work and suggests that UAVs are likely to fill a niche for the provision of data that can support several practical industry applications

Introduction
Remotely sensed data are widely used in the forestry sector. These data have largely been sourced from satellite or airborne sensors. Recently, unmanned aerial vehicles (UAVs) have emerged as a new platform for acquiring remotely sensed data. In contrast to satellites and aircraft, UAVs are relatively inexpensive and can be rapidly deployed to collect data with high frequency. These craft have restricted flight times and payload capacity, limiting the potential range of applications and the type of sensors that can be carried. These attributes are likely to see UAVs fill a niche for the collection of remote sensing data to serve a variety of novel applications. This technical note presents a summary of the findings from a study conducted by Scion (Pearse and Watt, 2017) investigating the roles and cost efficacy of UAVs for data collection as well as four potential applications highlighted by the forest industry. The applications for UAV imagery investigated were: 1) identification and mapping of wind-damaged forest to plan for value recovery; 2) identification and mapping of cutover areas; 3) assessment of post-planting stocking and survival; 4) post-harvest waste assessment.

Cost Efficacy of UAVs
A survey of commercial providers was conducted to contrast costs for airborne, satellite, and UAV remote sensing data. Aircraft was the only practical and cost-effective means of collecting LiDAR data for forestry. Costs were strongly impacted by the area and pulse density required, with prices varying from $2-5/ha for large, low-density campaigns up to $15-20/ha for small or specialist campaigns (Table 1).

Table 1: Indicative costs for imagery and LiDAR acquired from aircraft.

Aerial data product	Minimum area (ha)	$ / ha @ minimum area	Maximum area (ha)	$ / ha @ maximum area
Imagery	100 - 500	$10 - 20	No limit	$<1 - 3
LiDAR	500	$15 - 20	No limit	$2 - 5

Satellites were the most cost effective for imagery, providing 100 ha for as little at $1.50; however, large minimum order areas and the coarse spatial resolution limited the range of applications for these data (Table 2). Aerial imagery with higher spatial resolution cost from $10-20/ha (Table 1) but also required minimum areas and both platforms could require significant delays between order and collection.

Table 2: Indicative prices for different satellite imagery products. Costs may also vary for archive imagery, reduced cloud cover, and urgent acquisitions.

Satellite	Resolution	Bands	Cost (per km^2)	Minimum Order (tasked)
RapidEye	5 m	5	$1.50	3500 km^2
SPOT 6, 7/Azersky	5 m	4	$1.70	500 km^2
SPOT 6, 7/Azersky	1.5 m	4	$4	500 km^2
Kompsat	0.50 m	4	$17	100 km^2
Pléides	0.50 m	4	$30	100 km^2
WorldView-3	0.30 m	4/8	$47	100 km^2

UAVs offered acquisition of RGB and multispectral data with very high spatial and temporal resolution. Prices varied significantly depending on the data, craft, and processing required (Table 3). Fixed wing craft could capture RGB imagery for $3-10/ha over areas of up to 100 ha or even 2000 ha for some larger fixed-wing craft. Multirotors offered very high resolution imagery, easy deployment, and moderate payload capacity at the expense of range. UAVs had no minimum order area and could be deployed within hours to capture data. Basic craft and sensors could be purchased and operated for under $5000 or crews and craft could be hired for a fixed rate of $2500-$3000 per day. UAVs serve a niche for rapid and cost-effective collection of imagery over small to moderate areas using less-sophisticated sensors.

Table 3: Indicative costs for UAV services in New Zealand.

General contractors	Notes	Cost (NZ$/ha)	Minimum area	Maximum area
RGB + Multispec	Fixed wing, raw data	$3 - 10	Min 1 hr charge @ NZ$250-350	100 - 2000 ha/day (craft dependent)
RGB + Multispec (RAW) Multirotor	Multi-rotor, raw data	$5 - 10		50 - 100 ha/day (typical multirotor)
Processing		Plus $1 – 5	1 - 2 day turnaround	1 - 2 week turnaround
Forestry Specific				
RGB + Multispec	No ground control	$10 - 25	None, but few jobs < 30 ha	100 - 2000 ha (craft dependent)
RGB + Multispec	Ground control	$50 - 125	30 - 40 ha	60 - 100 ha (2000-4000 ha if RTK/PPK only)
LiDAR	Incl. survey and processing to DTM	$110		

Wind damage

Wind damage is a major risk to planted and natural forests in New Zealand and effective mapping and planning can assist with damage assessment and value recovery. A fixed wing UAV was used to collect RGB imagery over a wind-damaged forest in the Nelson region. The data were also used to compare orthomosaics (the product of image stitching and 'draping' over the terrain) produced by two competing software packages – Agisoft Photoscan (Agisoft, St. Petersburg, Russia) and Pix4D Mapper (Pix4D SA, Lausanne, Switzerland). The RGB data could be accurately classified into affected / unaffected areas using simple methods available in e.g. ArcGIS (ESRI, Redlands, California) such as Mahalanobis classification. This approach produced similar estimates to manual mapping (10.8 ha cf. 9 ha) with the error largely attributable to misclassification of sunlit roads (Fig. 1.). The process correctly identified wind-damaged areas missed during manual mapping and provided finer detail for updating stand records. Pix4D was much simpler to use and could generate results in a shorter amount of time; however, Agisoft achieved noticeably improved levels of canopy detail and produced fewer image artefacts in forested areas. Overall, UAV imagery appeared useful for rapid assessment of post-storm wind damage in forests. A multirotor craft provided much higher resolution RGB imagery to test stem detection over the same site. An object-based image analysis performed on a filtered and transformed version of the scene was largely successful in delineating stems on the ground and appeared to show promise for obtaining stem counts with further refinements. The results showed that image classification need not be complex to be useful and RGB orthomosaics were also suitable for manual digitisation to update stand records and assist in planning for recovery.

Fig. 1. Results from Mahalanobis classification of standing and wind-thrown forest. Approximately 10 ha of damaged forest was identified.

Automated cutover detection

Cutover assessment is important for monitoring progress during harvest operations and for updating stand records after harvesting is complete. A series of images showing forested and recently harvested areas were used to develop methods for detecting the boundary between forest and cutover. A computationally simple colour space transformation provided mean classification accuracy of 83.2%; however, more complex classification using support vector machines (machine learning) provided superior accuracy of 90.2%. The edge-detection and tracking algorithm showed a mean deviation of 2.4 m from the actual boundary when applied to pre-recorded test data with known boundary coordinates (Fig. 2.). A collaborative project with the University of Canterbury led to the development of an affordable custom UAV equipped with a video camera and programmable navigation system. The UAV was successfully programmed to apply the edge-detection algorithm in real-time to detect and follow the edge of a recently harvested site in Canterbury. The results showed that imagery from inexpensive UAVs could be used to accurately map forest cutover and the UAV system developed showed potential for regular, automated updating of the cutover boundary using inexpensive UAVs. Results also showed that georectified imagery collected from the UAV and manually digitised in a GIS would provide similar accuracy to area estimates generated from e.g. aircraft or satellite imagery. High elevation flights using fixed-wing UAVs are particularly well suited to this task.

Post-planting assessment

Post-planting assessment is important to ensure initial planting has reached the target stocking and to assess survival in order to fill areas with high mortality during the next planting season. RGB imagery was acquired at a test site to trial a range of methods for counting seedlings younger than 1 year. Object-based approaches using the spectral properties of seedlings in combination with contrast features had a precision of 83% and sensitivity of 86%. A second method based on the normalised cross-correlation coefficient between image windows and a template derived from a large training sample improved on these results. A combination of software tools were used to develop this approach but the commercial package MATLAB (MathWorks, Natick, MA, USA) and the open source alternative SciLab (Scilab.org) are capable of sophisticated pattern matching for image recognition. The method had a sensitivity of 89% while the precision of the classifier was 92%. Both methods used only RGB data, but the addition of multispectral imagery from higher-resolution sensors is likely to significantly improve these approaches. Survival was high at the chosen site, but the few dead seedlings present could be excluded using the differences in foliage colour and seedlings with little to no remaining foliage were correctly rejected by the algorithm during matching.

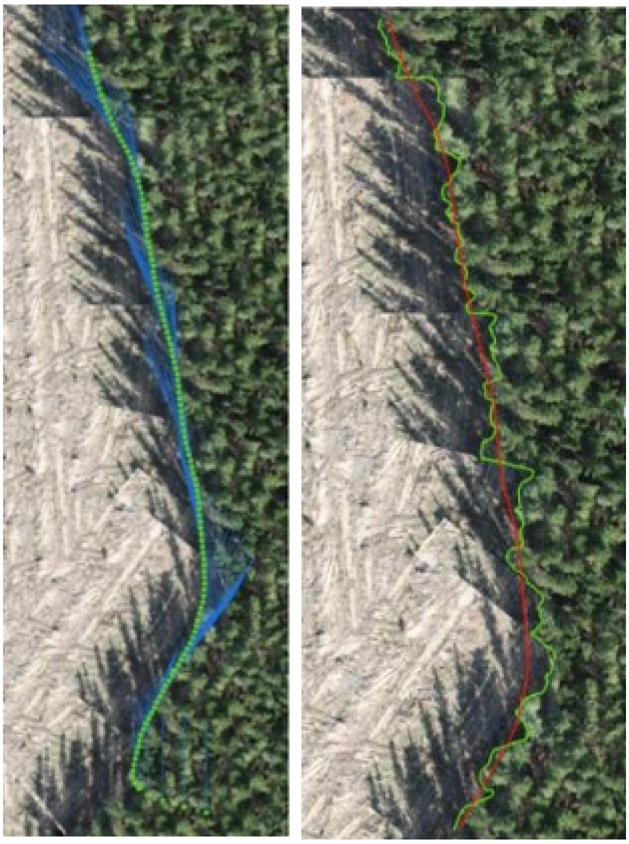

Fig. 2. Left panel shows the UAV flight path (dotted green) and heading (blue lines) determined by edge detection. Right panel shows the smoothed flight path (red) compared to the actual edge determined from ground-truth mapping (green).

Post-harvest waste assessment

Post-harvest waste assessment is traditionally conducted using the line intersect method (LIM) to compute a residual volume of timber left unrecovered on the site. RGB imagery from a UAV was acquired over a recently harvested area and used to develop a very high resolution orthomosaic. Measurements obtained from 60 waste pieces using traditional ground-based LIM methods and digitised measurements obtained from the UAV imagery were compared (Fig. 3.). The length, intercept diameter, and large and small end diameters all showed strong agreement. Measuring length using imagery produced the highest error (mean difference of 9.9 cm). Volumes calculated from the field and image-based measurements agreed strongly (R^2 = 0.95) with a mean difference of 0.02 m^3. Traditional LIM methods computed using the cross-sectional diameters extracted from the field and image-based measurement of pieces along 16 transects showed strong agreement. Overall, UAV-derived imagery appeared well suited to the estimation of post-harvest waste volumes. A disadvantage of the image-based approach was the inability to identify rot using the imagery. Pieces obstructed by slash were also difficult to measure; however, sweep could be accurately assessed. Further testing may validate several apparent advantages offered by this approach such as identifying the orientation of waste pieces and arranging digital transects as equilateral triangles to account for the substantial errors in volume estimates that arise from use of the LIM on sites with non-random orientation of waste pieces.

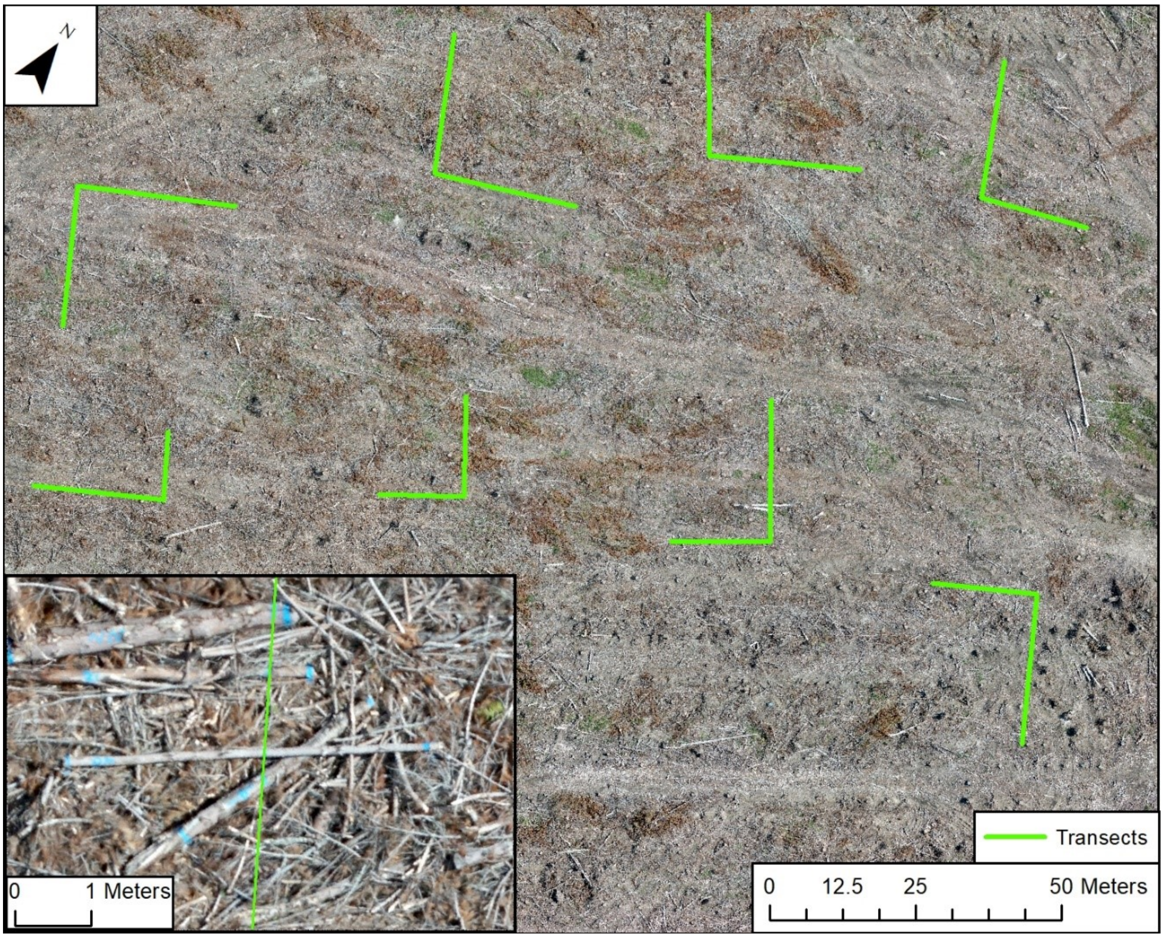

Fig. 3. Study site and layout for post-harvest waste assessment based on the line intersect method. Blue paint indicated the locations where field measurements were collected.

Overall, the results from this study showed that UAVs fill a niche in terms of remote sensing data that is not currently served by other platforms. As such, UAVs are likely to complement rather than replace traditional remote sensing methods. The results from this study showed UAV imagery to be useful at the proof of concept level for all of the potential applications highlighted for investigation. External factors such as the availability of a satellite based augmentation system (SBAS) for New Zealand are likely to further improve the usefulness of UAV-derived data. The SBAS system proposed by LINZ will allow capable commercial GPS receivers such as those used on UAVs to obtain sub-meter positional accuracy in real-time. Many of these technologies are still young and are therefore likely to see large improvements. The rapid development of methods, craft, and sensors are likely to see greatly expanded uses for UAVs within the forest industry in the future.

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References

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