Unmanned aerial vehicles in forestry – reaching for a new perspective

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Abstract

Because of the scale involved in forestry, both time and area, mathematics has always been heavily employed so foresters can take samples and calculate averages or make predictions on the growth or yield of their crop. With the advent of increasingly usable and accessible aerial remote sensing techniques, in particular UAV (unmanned aerial vehicle) technology, it is becoming possible to greatly increase the size and speed of the samples that are taken and perhaps even generate 100% samples for stock-taking or growth modelling. However, it is not just the possibilities of increased sampling density in forest modelling, but also the range of applications that they can be used for, which is starting to arouse the interest of many industries.

In this paper some background into UAVs is given followed by a discussion about the benefits they can bring to the forest industry, and the range of applications that we can hope to deploy them in over the coming years. Legislation governing UAVs will also be touched on in an attempt to increase airspace awareness for those wishing to pursue this innovative technology.

Example of the tiny size of the latest UAVs in the form of the DJI Mavic Pro. Source: Interpine

Brief history of UAVs

The concept of taking aerial imagery to help inform decision-making in forestry is not a new one. In New Zealand alone people have been using aerial photography since 1919 when the chief instructor for the New Zealand Flying School took the chief photographer of the *Auckland Weekly News* up in the air to take pictures over Auckland (Lovell-Smith, 2016). The first photogrammetry was used in 1931 when the Department of Lands and Survey experimented with mapping from aerial photographs as a quick and cheap method of producing topographical maps (Lovell-Smith, 2016). It is, however, the advent of a new technology that is bringing to the forester's tool belt (sometimes quite literally) a whole new range of affordable options for managing not only their forests, but a wide variety of other aspects in the forestry, timber and native forest conservation sectors.

Smaller UAVs have been active in agricultural and environmental settings in more recent years, with their use in precision agriculture being pioneered to optimise chemical application and monitor crop health (Zhang & Kovacs, 2012). The more modern concept of a prosumer (pro-consumer) UAV has been available on the market since about 2010 (Juniper, 2015). This has brought a ready-to-fly solution to the table, as well as becoming more manoeuvrable, with the advent of the quadcopter and their VTOL (vertical take-off and landing) capabilities (Villbrandt, 2010). This is especially important for forestry, where we often have to launch our UAVs from relatively confined spaces between tall trees. Foresters are also achieving some great results with fixed-wing UAVs that can also stay up in the air for longer periods of time.

Getting the upper hand – the advantage of UAVs

As with aerial photography from fixed-wing and rotary-wing aircraft, UAVs allow forest managers the opportunity to cover vast areas of land, collecting data in a fraction of the time it would take to get it from on the ground. The platform of UAV imagery fills the void between ground-based observation and aerial or satellite remote sensing (Laliberte, Rango & Herrick, 2007).

Being able to gather more information at a greater speed is the goal for foresters, which brings us to cost. UAV operations may not always out-compete traditional aerial imagery, and probably not when we look at covering vast areas. UAVs fit nicely into mapping areas of 1 to 200 ha so therefore should be considered as an additional tool in the range of remote sensing platforms. Although some of the prosumer grade devices can be bought relatively cheaply and easily from an increasingly large range of consumer outlets in New Zealand, to have the appropriate kit for a UAV to carry out the range of work required (i.e. enough batteries, carry case, tablet/RC device) pilots have to be trained, mission planning must be taken into account, airspace regulations must be adhered to etc, so it is not quite as simple as one would at first believe. However,

UAV crew readying their craft for operations. Source: Interpine

the lower maintenance and upkeep costs of the UAV make it competitive compared to a manned aircraft.

When looking to invest in UAV technology the size of the machine and the range it can cover must be taken into consideration. Battery life, although getting better, is still a limiting factor. Even the best UAVs on the market still only boast a 40 to 50 minute battery life, but with enough batteries it is possible to cover large areas. Over a certain size though (e.g. 100 to 200 ha) it may be more economical to hire the services of a local manned aircraft.

But this begs the question, 'Why not just hire out a manned aircraft in the first place?' Well, aside from the cost-effectiveness on the smaller blocks the resolution of UAV imagery is much better. A UAV can be flown at much lower altitudes, and travelling at slower speeds it can produce clear, crisp imagery which can be excellent for identifying weed presence or regeneration in forest blocks. For the wood products industry, you would not consider hiring a helicopter for an hour to fly your chip piles for your monthly stock-take, but a UAV could do this very inexpensively.

The turnaround of data from UAV operations can also be exceptional. A flight can be planned in the morning, carried out in the afternoon, and the dataset brought back to the office and processed, ready for operational analysis by home time. The timely turnaround of data can open up many doors in forest management and this rapid turnaround is especially beneficial in forest firefighting or managing controlled burns. As a tool for a forester, UAVs also provide a great deal of flexibility. When out in a forest block, a forester may want to know what is on the other side of a gully, or what the stocking is like a few hundred metres in from a skid, or whether the recent plantings have survived well at the bottom of a slope. With a UAV it suddenly becomes possible to quickly go and check these spots while carrying out routine inspections.

Practical applications of UAVs in forestry

The UAV therefore provides a multifaceted platform for foresters to be able to accomplish a range of applications in an affordable and timely manner. UAVs allow the forester the ability to get a different view in their routine inspections and to have an eye in the sky so they can more accurately monitor their forests, or check on recent operations, covering greater areas in less time. Having discussed the benefits of UAVs, the different areas that it is possible to use them in can now be explored.

Software

One of the obvious applications is that high-definition maps of forestry blocks are possible. Using software such as Agisoft or Pix4D, it is also possible to produce an orthorectified DSM (digital surface model) or a 3D model of a site, which could be very useful in planning steep slope harvesting operations or assessing areas for their suitability for afforestation.

Survey

Mills and forestry quarries can benefit from the use of UAVs because it becomes possible to create 3D orthorectified maps from which you can take accurate measurements and calculate volumes with a precision equal to, or greater than, regular GNSS surveying techniques and equal to LiDAR (Draeyer & Strecha, 2014).

Using UAVs for surveying is quickly becoming a regular option in many industries (Metcalfe, 2013) including mining, quarrying and the bulk shipment of goods, such as aggregates. The timber industry can benefit from this immensely through using UAVs in surveying wood chip piles, bark piles or hog fuel piles. The process is much quicker than traditional terrestrial survey methods (Arango & Morales, 2015). It allows a non-intrusive method of assessment, keeping the surveyor out of harm's way and allowing the chip pile to stay operational for the duration of the survey, or at least only close down for a fraction of the time taken on standard surveys. Interpine regularly survey woodchip piles and have the data processed and reports written by the end of the day so the turnaround is very fast.

Training and health and safety

UAVs can also be used to increase safety in the forest, 'taking a man off the slope' as it were. UAV imagery means that the forester no longer has to scramble across dense slash on cutover sites or climb up and down steep gully walls. It is also an excellent opportunity to aid in training and auditing, providing a safe viewing platform from which the trainer can see everything they need to. With this technology, a trainer could instruct harvester operators without having to stand next to the operating machinery, taking them out of harm's way from chain shot, falling trees or loud, moving machinery. The

Inspecting erosion and water management in steep slope sites from a UAV. Source: Interpine video feed can be played back to the operator so they can visualise what they are doing right and what they are doing wrong, which is a popular technique in sports coaching (Cassidy et al., 2006).

The clarity and accuracy of UAV imagery means they are also ideal for use in freezing the scene after an accident. The site can be flown in a matter of minutes, producing a high-definition 3D model of the site, which can later be analysed by the investigators to see what went wrong.

Being able to get that bird's eye perspective is a great way to cover greater distances in a smaller amount of time, with a superior viewpoint to being based on the ground. For example, if a forester wishes to assess a recent planting operation, or to do a basic survival assessment to work out if any blanking is required or re-work, they could find a central location and put the UAV up in the air. They could then get excellent, clear, high-definition video footage of the site, which could be used in planning future operations. This also means the forester does not have to walk across potentially hazardous terrain to make these assessments, improving the health and safety aspect.

UAV photogrammetry

From UAV imagery finely detailed, geolocated and orthorectified maps can be created. This allows for better operational planning, stock-taking of timber on skid sites, weed and regen mapping, checking stocking, nursery stock-takes, growth modelling, or carrying out quality control on forestry operations.

Stocking can be assessed by creating 'virtual plots' in UAV orthophotos, or alternatively an entire block can be evaluated by analysing the 3D point cloud derived from photogrammetry. These are both techniques that Interpine is pioneering at the moment as a means of looking at whether there is a more efficient way to accurately carry out an inventory. There are data that a UAV cannot collect remotely, such as soil samples or diameters at breast height, and therefore there are obvious benefits to collecting plot data in the field as well, compared to solely using remote sensing. The benefits to be gained from UAVs, however, are in the increased sample size and in a reduced timeframe and costing, e.g. in carrying out a tree nursery stock-take.

The orthorectified nature of UAV maps means they are ideal for producing accurate and up-to-date shape files of compartment boundaries. The ability to rapidly create these shape files would make progress reports for forestry operations, or creating a mark-up map, to pay contractors for work done up to a certain date (e.g. in site preparation) much easier than the traditional method of walking over the site with a hand-held GPS across difficult terrain very much a thing of the past. Advances in UAV technology now mean that mapping can even be carried out on-the-fly, creating spot markers or polygons live during flight using full motion video (FMV), a technique developed by the military. The implications of this, and how it can improve the speed and efficiency of data collection while also greatly increasing the health and safety aspect of not having to walk across difficult terrain, are enormous.

Using the same techniques, there is a very viable application for mapping the extent of fire damage, or wind throw, or extreme weather events. This also provides excellent documentation to present to insurance companies to aid in their investigations.

Multispectral and near infrared

As well as the traditional red, green, blue (RGB) cameras, great advances are being made in other sensors that are suitable to be operated from UAVs. Multispectral sensors are being used increasingly for assessing crops in precision agriculture, so that farmers and agronomists can tell which areas of their crops are suffering from a lack of nutrition or irrigation or are affected by disease. In a forestry setting, near infrared (NIR) imagery could be applied to weed mapping, species mapping, planning chemical applications or assessing the health of crops, e.g. in a nursery.

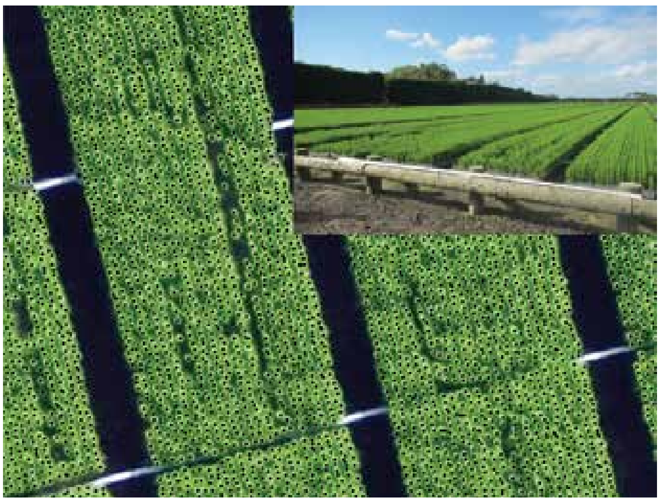

Figure 1: Section of nursery stocktake from UAV photogrammetry. Source: Interpine

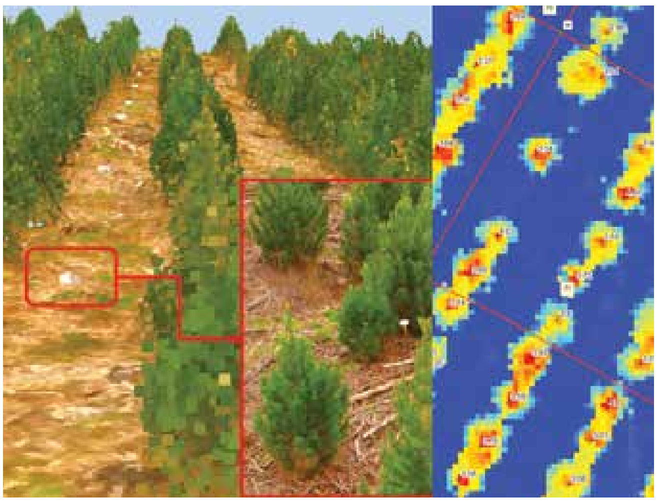

Figure 2: Heighting inventory from UAV point cloud for growth modelling of trials. Source: Interpine

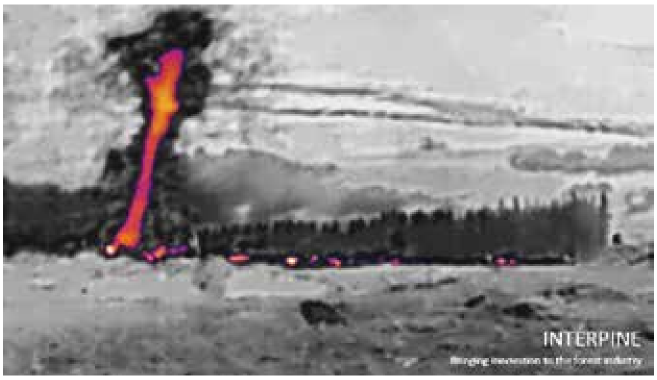

Figure 3: Fire whirl ripping across cutover site at a controlled burn. Source: Interpine

Infrared (thermal) imagery

Infrared or thermal imagery is starting to become more accessible for UAVs. However, thermography is a very technical science in itself, therefore it is strongly advised that training is undertaken and research carried out before investing in this technology. It is also advisable to ensure that suitably qualified contractors are used for thermographic work because it is not as simple as regular photography. If the cameras are not set up correctly, or the wrong camera is used for the wrong applications, inaccurate temperature readings will be recorded, which could be more dangerous than not doing thermal assessments at all.

Thermal imaging opens up many doors to foresters, especially for firefighting and fire prevention. Using the UAV's portability, manoeuvrability and generally lower cost than say helicopter hire, UAV thermal imagery can provide excellent support for monitoring fire behaviour, helping to plan firefighting operations on the front line, and providing a regular and timely stream of useful information to the Incident Management Team. UAVs are also excellent tools for ensuring that the mop-up is as clean and efficient as possible. Having thermal vision as part of a firefighting operation greatly increases safety for fire crews, and with the aid of UAV-mounted thermal sensors hidden dangers such as ash holes become less of a hazard to those on the fire line. Applications for thermal imagery in forestry are only limited by the imagination, and this could be an area of expansion in forest remote sensing over the coming years.

LiDAR

As LiDAR becomes more popular as a method for carrying out forest inventories, and also creating highly rigorous and accurate GIS for forest managers, there has been much talk about whether LiDAR units will soon be mounted on UAVs. Currently research organisations, such as Scion and the University of Tasmania, are experimenting with the use of LiDAR from UAVs and the results are quite promising. However, the limitations of the craft (i.e. the battery life) are a major drawback to commercial adoption at the moment. The technology is constantly evolving though and over the next few years it is very likely that we will see it reach maturity.

Heavy lifting and spraying

Larger craft are being kitted out with spray tanks and pesticide application is being explored by several companies. The current models on the market seem to be limited by battery power, and weight restrictions, but the precedent is set. The benefits in using UAVs for this application are that they can be programmed to carry out operations on a pre-determined flight plan. Examples include mapping an area of dothistroma and then uploading the shape file for the UAV to automatically go and apply the chemical, or being able to apply chemicals over a vast area with precision, such as spot spraying wilding conifers, as well as the health and safety benefits of using a UAV to replace knapsack spraying on steep or dangerous terrain.

Other more 'physical' applications for UAVs being explored include carrying strawlines across gullies in setting up haulers, and carrying planting boxes across steep or difficult terrain to increase productivity and reduce health and safety risks. As the technology increases, the applications become even broader.

The craft are also varying in size more, and getting smaller and more technical all the time. For instance, some have sensors to avoid collisions as well as features such as object avoidance, a high-resolution camera, multiple flight modes, etc. Some can fit into the palm of your hand, with the whole kit fitting into a case the size of a regular DSLR camera bag. This is the type of craft that should definitely be on a forester's tool belt.

UAVs in the wider aerial community

As tempting as it is to see UAVs as a novelty item that can take images from great altitudes, they are a serious piece of kit and an aircraft in their own right, whether that be a toy 'drone', a prosumer grade craft, or a large multirotor mounted with a LiDAR scanner. As such, UAVs are regulated under the CAA (Civil Aviation Authority), who are trying to ensure that everybody appreciates the seriousness of operating them. This can best be demonstrated by comparing a UAV to a large bird. Large jet aircraft have collided with birds and have crash landed. Similarly, if a manned aircraft collides with a UAV it will most likely cause a serious, potentially life-threatening incident or crash. This is why it is so important that UAV activity is heavily regulated and airspace is understood by those who use them.

Rules for UAVs in New Zealand fall into two categories: Part 101 and Part 102. Most UAV use will fall under Part 101, which covers everything from a child getting a cheap quadcopter for Christmas and flying it at the domain, up to a professional UAV business flying commercial surveying operations.

To operate with airspace awareness, it is important to understand how airspace is governed. For aircraft to operate safely a policy of isolation must be applied – aircraft cannot always see each other, owing to weather conditions, and so they use a combination of

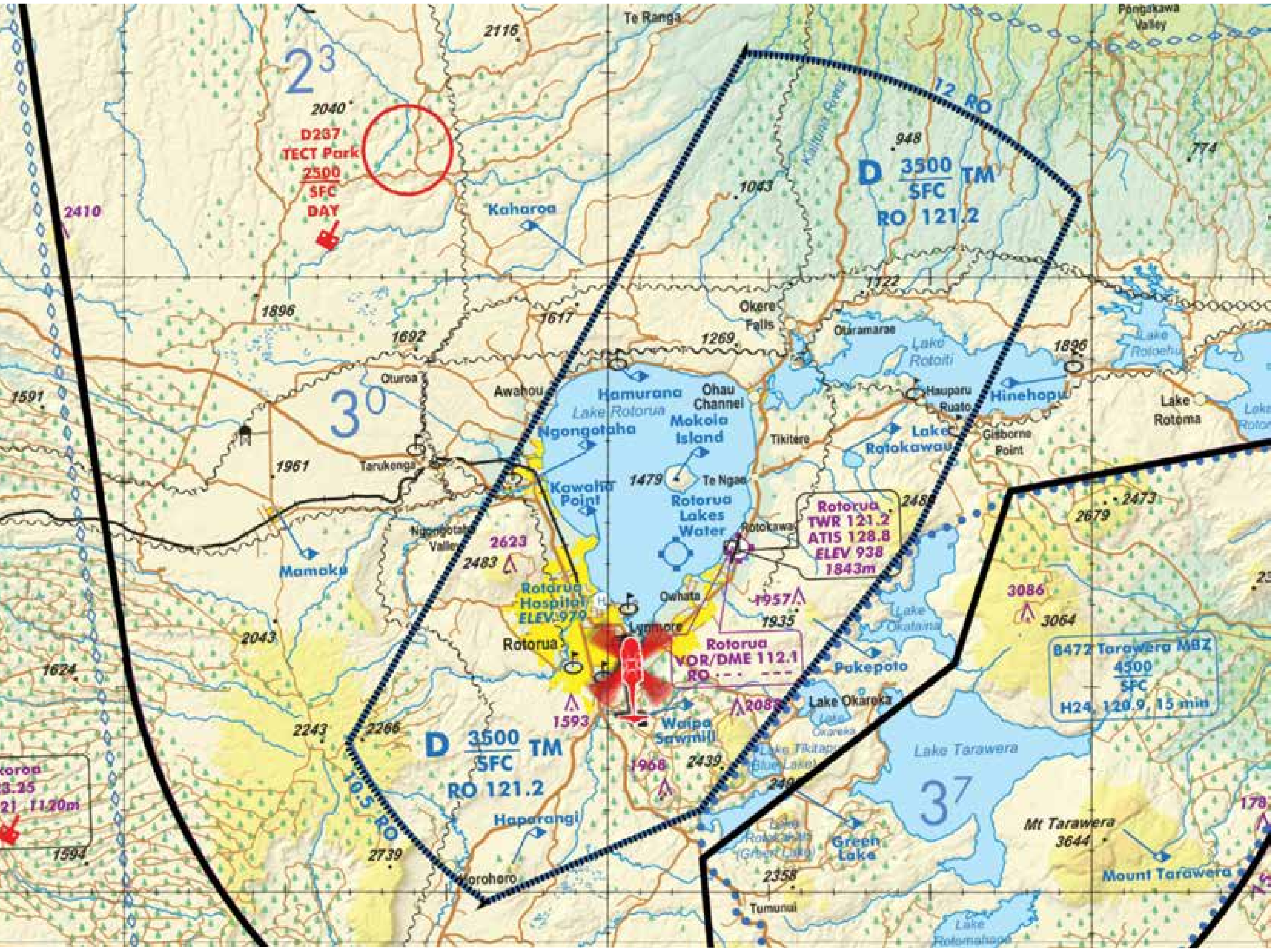

Figure 4: Visual Navigation Charts showing airspace over Rotorua. Source: Seattle Aviotronics, 2016

instruments, transponders and radio contact to locate each other and charts to ensure they remain in the correct locations. All these things help to maintain adequate space around the aircraft to ensure their safety (Murphy, Bell & Partie, 2009).

UAVs are too small to be seen within the standard 'see and avoid' distances set out in Visual Flight Rules, and often do not have any form of transponder to be picked up via the instruments of other aircraft. When a UAV is flown up into the air it enters this airspace, and unless the operator is aware of what this airspace is they could be putting their craft, or more importantly other manned aircraft, at risk.

Figure 4 shows a VNC (Visual Navigation Chart) for the airspace in the Rotorua area. The different lines on the chart indicate various levels of airspace and the correct aircraft VHF radio frequencies to operate when flying in these areas. For example, the light blue polygon with black dots that surrounds Rotorua, and makes up the central feature of this map, is actually restricted airspace. This means that from SFC to 3500' (surface to 3500 feet above mean sea level) the airspace is restricted and you must request permission from Rotorua Tower (through the proper channels) to fly within this area. This would no doubt come as a surprise to some people who got a UAV for Christmas and flew it out over Lake Rotorua to get some photographs.

There are airspace awareness courses, and good resources online, which explain all of these unfamiliar rules. The resources include the CAA website (www.caa.govt.nz/rpas) and Airshare (www.airshare.co.nz), which is a detailed database for UAV operations knowledge, powered by Airways, New Zealand's air navigation service provider. Airshare allows you to book in flights and obtain permission to fly in restricted airspace (if you are certified to do so). At the time of writing, there are currently five organisations that are certified to conduct UAV training in New Zealand and only three of them are certified to conduct training for CAA Part 102. These courses offer thorough training in airspace awareness, flight planning, aircraft VHF operation (receiving transmission only) and a flight competency test. Interpine are working with the Massey University School of Aviation to develop and deliver forestry and firefighting-specific UAV training and certification to help progress the industry into this new technology.

When considering the use of UAVs it is important to remember that they are in fact aircraft, something that is duly noted by insurance companies. UAVs are classed as an aircraft in an insurance policy, so it is advisable for any companies wishing to invest in them to check their insurance policy covers them for aircraft operation. It is also advisable to ensure contractors are covered for aerial operations before allowing them to enter the forest. LiPO (lithium polymer) batteries, which UAVs are powered by, can be very volatile when impacting with enough force, i.e. in a serious crash. It is essential that the operators are responsible, operate with rigorous health and safety, have good on-site fire procedures, and most importantly have adequate insurance. This is obviously a very unlikely situation, but it pays to be prepared.

As an industry, UAV operators are trying to adhere to the rigorous standards of other areas of the aviation community. Especially within the forest industry, we are trying to encourage people to follow these standards and fly safely so we can continue to explore the possibilities of this technology and make it work for everyone.

Limitations of UAVs

There are many benefits in using UAVs in forestry and the possibilities for their application are almost endless. However, it is also easy to get carried away about how they are the only option for many operations, and so it is important to understand their limitations. Currently, the UAVs on the market are not quite at the stage where they are robust enough to be deployed to the average crew carrying out forestry operations. Popular models are certainly small enough and user-friendly enough to be able to deploy to crews, but they are still quite fragile and would not stand up to being tossed into the back of a ute with the chainsaws on a daily basis.

UAVs are also not particularly weatherproof, with the smaller models not standing up to flying in the rain, mild winds or very dusty conditions. These statements are made with regard to the prosumer grade UAVs, although some of the larger and more advanced UAVs on the market can be made more robust in relation to weather resistance. Planning for weather is always a factor in operations, despite how robust your UAVs are, if you want to collect good data.

Advanced sensors, such as NIR and thermal imaging cameras, must be considered carefully before investing in them. The science behind multispectral, and particularly infrared, imagery is quite advanced and it begs the question whether or not an organisation would really benefit from having their staff trained in such a specialised field if this technology was only to be used occasionally. If intending to do so, it is strongly recommended to seek advice from experts or other operators in this field before investing in potentially the wrong technology for the outputs required.

It is the author's view that battery life is currently the greatest drawback for UAVs, particularly the prosumer grade UAVs, which claim to have a life of around 20 to 25 minutes. These claims do not stand up in the field. A mild breeze, a relatively large area of interest, and having additional sensors attached all contribute to perhaps half or two-thirds of the advertised battery time. There are large advances in the technology, however, with solar powered batteries, hydrogen cell and even dual petrol-electrical motors being developed. It will not be long until this filters down into the 'off-the-shelf' solutions.

The pathway for adoption

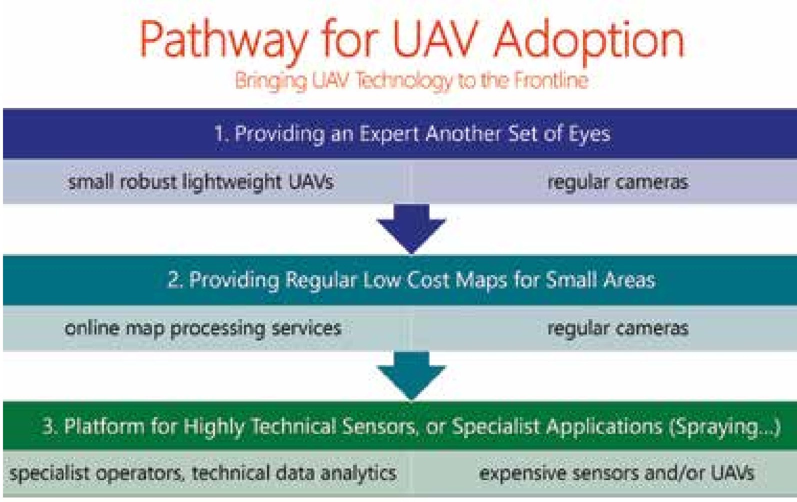

Figure 5: The pathway for UAV adoption. Source: Herries, 2016

UAVs can be seen as fitting into three categories of use, Figure 5. This three-staged approach to UAVs means that they could be adopted at multiple levels throughout the forest industry:

- Stage one would see small, robust and lightweight UAVs being kept in the back of a supervisor's ute and used to check progress on forest operations, or for foresters to take out into the field to get a better perspective in planning their operations. This is also a key element in first response forest firefighting.
- Stage two would be the more technical operations, providing a means for low cost, high-definition maps over small areas. This could still be carried out by the smaller UAVs, but would require a greater level of training and skill in being able to plan the operations to collect the desired data and then using third party mapping providers to generate the results.

- Stage three would be a much more specialist operation, which most forestry companies would probably not invest in. This would include increasingly technical sensors that give foresters a new way of looking at their forests, such as multispectral imagery to monitor crop health and to be able to treat disease before it is too late. Mapping large areas, calculating quarry or chip pile volumetrics or stocking from photogrammetry, would also fall into this category, as well as operating spray craft or LiDAR units. These more expensive and technical UAVs would be owned by a UAV service provider, who could afford to keep their UAVs up-to-date. They would have great technical expertise in planning and flying these highly technical operations and the required qualifications to operate them. The rate at which the technology is now improving means it sometimes becomes redundant after only a few months.

Getting UAVs into the frontline

For forestry companies to make the most of UAVs, it is very important for them to understand what is involved in order to maximise the benefits and avoid any pitfalls or surprises. The model for adoption can be seen as following the pathway set out in Figure 6.

Following these stages, a company can be sure that they are equipped to deal with each stage of adoption:

- First, ensuring that the company has the knowledge to understand the rules and regulations, what is involved in the operations, the potential benefits, and also the potential hazards associated with UAVs – or their improper use.
- Secondly, developing a policy to ensure this technology is used properly and effectively across the company or its estate.
- The third stage, which a few companies are starting to engage in, is to assess what UAV technology could bring to their business and to identify key areas for adoption.
- Once the technology has been trialled, the fourth stage begins to bring the technology more solidly into the company, following the first stage of the adoption pathway, as outlined in Figure 5. Interpine, alongside Massey University School of Aviation, are offering a package of vocational training, certification and a suitable craft so companies have the confidence they need to operate UAVs effectively.
- Once they are more understood within the company, the trials have been assessed, and foresters and supervisors are using them to improve their observations, the fifth and final stage is to merge the more complexed operations into existing forest management practice and engage with a UAV service provider to provide these more technical forestry-based remote sensing operations.

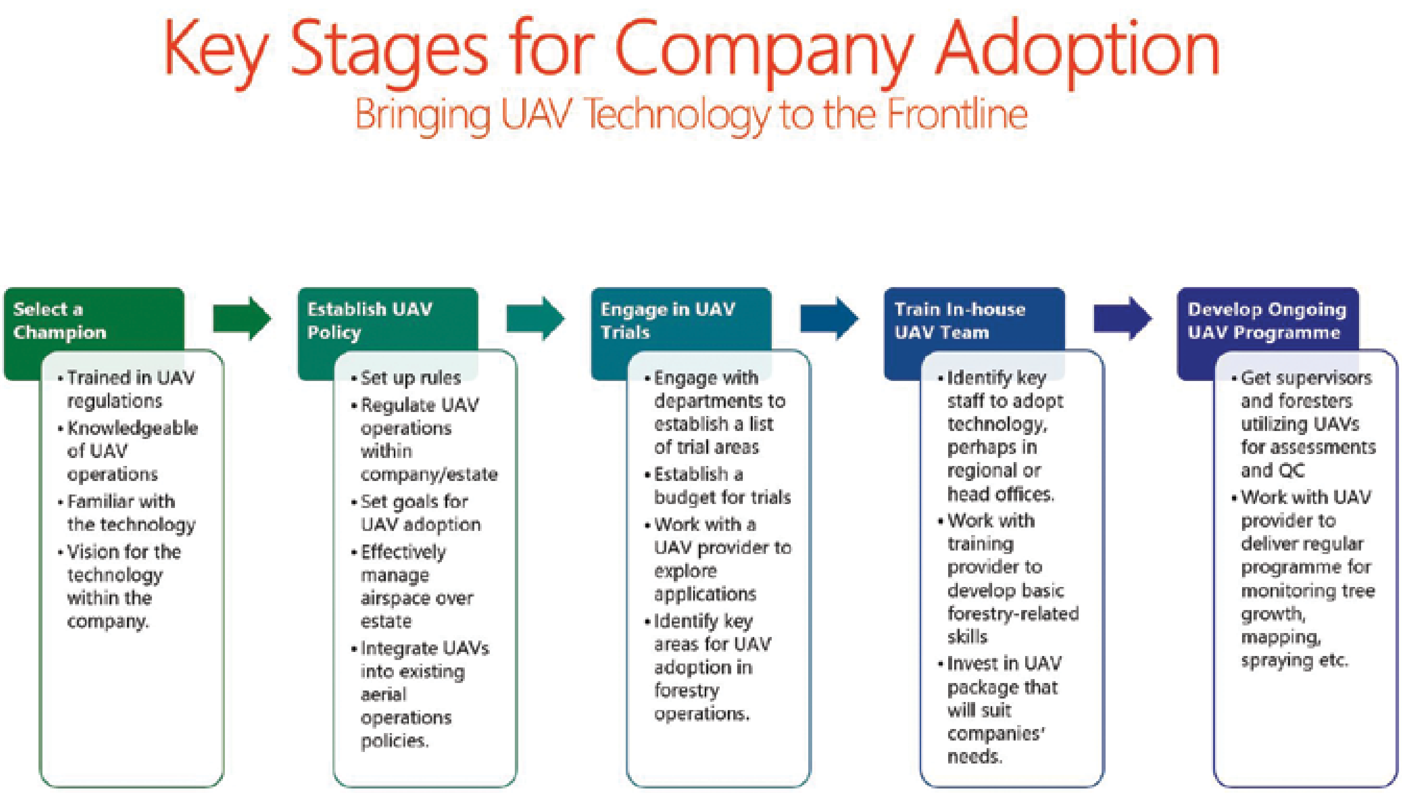

Figure 6: Key stages for company adoption of UAVs

Conclusion

UAVs provide an excellent opportunity to increase efficiency in our forestry industry if we adopt them responsibly and with an open mind. They could give us the chance to deploy sensors that have traditionally been too expensive or to gain a perspective that could only be dreamed of in the past. However, although UAVs provide opportunities many of them can be achieved equally as well from different platforms such as satellite imagery, or fixed-wing or rotary-wing aircraft, so it is useful to see them as an additional platform to aid the traditional options available to foresters. It is also important to remember that UAVs cannot do everything, and there are still some jobs where there is no substitute for heading out to the bush.

The technology is changing all the time, and the applications are increasing daily, so it is up to us as foresters to ensure our industry makes the most of it and join other forward-thinking industries doing the same. Let us embrace and adopt this new technology keenly and responsibly, and use it to grow our industry to new levels of excellence.

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