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The Use of Drones in Forestry

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Abstract: Recently, drones have found applicability in a variety of study fields, one of these being forestry, where an increasing interest is given to this segment of technology, especially due to the high-resolution data that can be collected flexibly in a short time and at a relatively low price. Also, drones have an important role in filling the gaps of common data collected using manned aircraft or satellite remote sensing, while having many advantages both in research and in various practical applications particularly in forestry as well as in land use in general. This paper aims to briefly describe the different approaches of applications of UAVs (Unmanned Aircraft Vehicles) in forestry, such as forest mapping, forest management planning, canopy height model creation or mapping forest gaps. These approaches have great potential in the near future applications and their quick implementation in a variety of situations is desirable for the sustainable management of forests.

Key words: Drones, UAV, remote sensing, forest management.

1. Introduction

The first aerial photos were acquired in 1860 using balloons, which were later replaced by aicrafts in the first and second world wars. Afterwards, the first satellites were launched into orbit around the 1960s for military purposes, and since the 1970s, once with the development of digital sensors, first civilian applications appeared.

In recent decades, remote sensing techniques applied in forestry has been given an increased attention, which leads to the ability of extracting important information for forest planning and sustainable management such as the forest structure, composition, volume or growth [1].

At the same time, with the development of sensors, computers and computational techniques, the applicability of remote sensing in forestry has evolved from aerial photography data [2] to satellite imagery data [3], which led to different calculations of forest indexes [4] and were up to estimations of forest volume and biomass [5, 6].

Satellite programs like Landsat, which is still one of the most used remote sensing worldwide program, is commonly used in forestry [7]. And the recent Sentinel 2, which has a higher revisit frequency, narrower bandwidths and finer resolution [8], is still limited and not suitable for applications where very high spatial resolution is needed, such as individual trees or even leafs, or those requiring a very short period of area revisiting.

In this context, the applicability and effectiveness of drones have a great potential in filling the gaps of other data types even if currently forest applications are still in the experimental stage [9].

Drones are UAVS (Unmanned Aerial Vehicles) which were originally developed in the early last century and after the 1950s, the main application of drones relied in the military field, through reconnaissance or surveillance. In the last decade, drones of different sizes, shapes and capabilities have grown rapidly and have acquired a growing interest (Fig. 1) in civilian applications [10], as well as precision agriculture, forestry, biodiversity, meteorology, emergency

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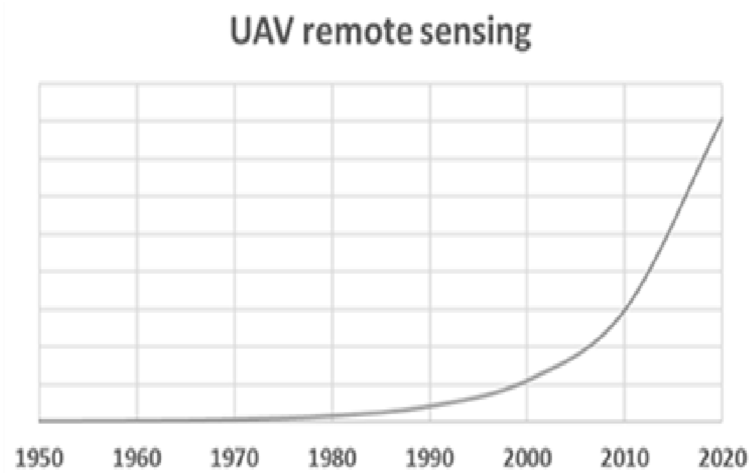

Fig. 1 Relative trend of UAW remote sensing in civilian applications.

management, wildlife research, land management, traffic monitoring and many others [9].

The most common classification of drones is made according to takeoff and landing type [11]:

• takeoff and landing horizontally, typical for fixed-wing drones (aircrafts);

• takeoff and landing vertically, typical for rotary-wing drones (helicopters, quadcopters, hexacopters etc.);

The stability of drones and the area covered per flight are key elements in applications of remote sensing. The first category of drones has the advantage of higher coverage areas per flight and the second category has the advantage of better stability which gives a higher spatial resolution, but with reduced areas that can be covered per flight [11].

Another classification of drones is based on their power supply and it directly affects the maximum flight time [12]. On this matter, UAVs can be split into two different types: electric and internal combustion. Drones with electrical power supply are recommended for remote sensing applications compared to those with internal combustion that are not so economical and have higher vibrations [11].

The drones can fly autonomously or by remote piloting using a remote control. Autonomous flight is scheduled previously and is well suited to systematic mapping.

A multitude of details for drone remote sensing can be found in the literature prepared by Anderson and Gaston [13], Colomina and Molina [10].

2 Applications of UAVS in Forestry

Remote sensing using drones has a range of benefits such as reduced costs, flexibility in time and space, high accuracy data and the advantage of no human risks.

It is important to mention that even though forest fires' monitoring and management was one of the first field in forestry that showed the importance of drones in forestry [14, 15], getting National Aeronautics and Space Administration (NASA) and the US Forest Service to present a drone that was able to fly up to 24 hours [11], at the moment the use of drones spread in other more popular forestry fields.

The following will briefly present recent examples of applications of drones in forestry.

2.1 Mapping Forests and Biodiversity

An application in order to map forest areas was made by Koh and Wich [16], where a drone was used in mapping tropical forests in Indonesia.The experiment involved a small UAV type aircraft (under 1 kg) with a flight time range of approximately 25 min per flight and a maximum distance traveled per flight of about 15 km. The acquired images were assembled after the flights and a land cover map resulted with a spatial resolution of 5.1 cm. Also, shots and videos that caught different human activities, logging, wildlife or flora species were made. Authors suggested that using UAV remote sensing can save time, costs and labor power for these purposes.

2.2 Precision Forestry and Sustainable Forest Planning Management

Parameters such as canopy cover, number of trees, volume estimation, vitality or composition of stands are important parameters in forest planning and sustainable forest management. Quick and accurate determination of canopy cover can be reached using unmanned aircraft [17], leading to fast and better decisions that improve optimal quality and productivity of stands. A study that estimated biomass volume and basal area in forests of *Pinus Taeda* was done [18] in 2014 using a drone with radar SAR (L-band - Synthetic Aperture Radar) sensor. The authors concluded that it was feasible to use L-band or shorter wavelength radar to measure these parameters only in young stands with lower BA (Basal Area) and lower AGB (Above Ground Biomass) similar to stands from their study.

Mokroš et al. [19] used a commercial low-cost quadcopter (DJI Phantom 3 Professional) to fly at an altitude of ~20 meters in order to estimate the volume of wood chips pile. After comparing the results with the volume resulted with a GNSS (Global Navigation Satellite System) device, the authors concluded that the use of UAVS does not lead to significantly different results (10.4% more volume estimated via drone method) and the time to collect data is significantly lower (12-20 times less) with the advantage of documentation through ortho mosaic [19].

Hassaan et al. [20] used a commercial quadcopter (DJI Phantom 2) with a maximum flight time of ~20 min to count trees in urban areas and successfully identified trees with a 72% accuracy. Also, a paper that consisted in detecting the number of trees using LiDAR (Light Detection And Ranging) sensors mounted on a UAV was successfully performed by Wallace et al. in 2014 [21].

Fast-growing forest plantations can have similar approaches to precision agriculture from the drone remote sensing perspective [22] and increasing their productivity is a major concern, especially nowadays when the demand for timber is highly increasing. Regarding this field, Felderhof and Gillieson [23] acquired NIR (Near-Infrared) images using drone remote sensing to map the vitality of tree canopy in a macadamia plantation, where they found significant correlations between spectral radiation of trees and the levels of nitrogen in leaves measured in-situ.

Regarding the monitoring of forest vegetation recovery in tropical areas, the work of Zahawi et al. [24] indicated that the methodology based on the use of drones is viable even for large data volumes.

Lehmann et al. [25] study showed the potential of UAVS for the detection of pest infestation (*Agrilus biguttatus*) levels in small oak forest stands. Authors used a commercial quadcopter with an estimated flight time of ~30 min and ~200 g payload used for a low-priced digital CIR-camera (Canon IXUS 100-equipped with an infrared sensor) that acquired images with a very high spatial resolution (~2 cm). Their results which were based on five classes, had an overall accuracy of over 82.5% with an estimated saving time and financial cost by more than 50% for small/medium sized stands compared to traditionally ground-based pest detection workflow [25].

In future studies, fields such as forest dynamics, forest species proportions in stands, mapping and assessing forest disturbances will grow considerably with the benefits of unmanned aircraft technology.

2.3 Mapping Canopy Gaps

Forest disturbances, especially those caused by wind and snow, directly affect regeneration, biodiversity, and productivity of the stands.And mapping the forest canopy gaps can provide an accurate situation of these types of disturbances. So far, small gaps cannot be measured accurately using satellite data [26], but it can now be achieved using drone remote sensing.

In Germany, Getzin et al. [27] made drone flights in beech-dominated deciduous and deciduous-conifers mixed forests, obtaining images with 7 cm resolution that could accurately identify gaps in the canopy down to 1 sqm size. The flights took place at an altitude of 250 m with an aircraft-type drone that weighs about 6 kg and having flight-times of up to 60 minutes. After processing the obtained images, a significant correlation between the measured gaps parameters and the biodiversity indicators was found. The paper suggested that the use of drones and their high resolution imagery can accurately measure the canopy gaps parameters which could actually be some valuable biodiversity indicators.

Also, Getzin et al. [28] used the above described equipment to successfully quantify and compare spatial gap patterns in age-class, selection-cutting and unmanaged forests. The authors also recommended that flights should be made at low altitudes and under low cloud cover conditions, without direct sunlight, in order to get very good images [27].

2.4 Measuring Forest Canopy Height and Attributes

Canopy height is a valuable parameter in forestry and is normally determined by field measurements. Currently, LiDAR technology becomes a lot more accessible and represents a new solution in canopy height measurements [29], especially now due to the fact that it can be mounted on UAVs [21, 30]. Also, drones with oblique optical sensor combined with new digital photogrammetry techniques can provide new methods for measuring canopy height [31].

In Belgium, Lisein et al. [32] used a small drone (about 2 kg), aircraft type, with 40 minutes autonomy/flight to acquire a set of near-infrared images with a spatial resolution of 7.6 cm which were used to measure canopy height. The results obtained with this equipment were similar to measurements obtained by a more expensive LiDAR crewed equipment.

In Spain, a study on a forest area of 158 ha that used an aircraft type drone with an infrared camera acquired images with 5 cm spatial resolution. Authors [33] obtained accurate canopy height measurements when comparing with classical field determinations.

In the U.S.A., Dandois and Ellis [34] used a hexacopter to fly at lower altitudes (below 130 m) over an area of 625 hectares of deciduous forest and made observations of the canopy phenology at a high temporal resolution.

Chianucci et al. [17] tested in pure beech stands if UAV digital true color photography can be used to estimate canopy attributes. A small fixed-wing UAV (~700 g) with a maximum flight time of ~50 min, equipped with a standard RGB digital camera was used to fly at an altitude of 170 m acquiring images with ~7.5 cm resolution per pixel. Authors demonstrated that in this way it is very effective to obtain cheap, rapid and useful estimates of forest canopy attributes at medium-large scales [17].

Therefore, the studies described above suggest a great potential in using drones for determination of canopy height and attributes with much lower costs compared to the solutions provided by LiDAR technology.

5. Concluding Remarks

❖Drones are unmanned aircrafts of remarkably reduced dimensions, very low energy consumption and low cost for their utilization, no human life being endangered.

❖The current use of drones in forestry applications is still at an experimental stage, but with great potential in the near future.

❖The increasing accessibility in terms of cost and size for LiDAR and infrared sensors along with data combining methodologies will highly improve the utilization of UAVS in forestry.

❖Future generations of UAVS will continually evolve and offer increased flight time and improved sensors.

❖Future applications will include studies over a large range of forestry fields, such as forest dynamics, species detection, forest disturbance evaluation and others, all these with a quick implementation requirement in the variety of situations that occur in the sustainable management of forests.

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