How Farmer Can Utilize Drone Mapping?

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SUMMARY

During the last few years, drone technology has evolved tremendously. At the same time, the weights of miniaturized multi- and hyperspectral sensors have decreased to a level of 100 - 1000 g, allowing their use in small drones. This provides completely new possibilities to carry out high resolution remote sensing of the environment. Agriculture is one of the most promising applications of the drone remote sensing. Traditional RGB cameras can already provide valuable information about the state of the environment. For example, a farmer can have a quick general view of the crop condition. In addition, almost automated service chains are available, utilizing this technology for farmers. However, the improved availability of drone systems with spectral sensors enables even more possibilities of the technology practical use. In this case, farmers can plan crop management and input use (e.g. nutrient application and crop protection) depending on yield capacity. Although many demonstrations with drone mapping have shown the potential of the technology, the usability of the service is still a critical aspect to be incorporated in farmers every days use.

In the context of EU-LIFE Climate Change Mitigation Project "Optimising Agricultural Land Use to Mitigate Climate Change" (OPAL-Life; www.opal.fi) we are investigating feasibility of drones in aiding farmers in optimizing their land use and farming practices. We carried out 34 flights with drones for 16 different agricultural field parcels during summer 2016, in real farms in Finland. The same parcels were measured by drones several times during the summer to acquire multitemporal data during different phases of the growing season. We used in each flight a low-cost RGB camera and a hyperspectral sensor were used. The collected data covered different plants such as grass, wheat, barley, oat, rapeseed and pea. The spatial resolution of data is high, for example 4 cm for RGB and 15 cm for spectral sensor, when using flying height of 140 m. 3D-pointclouds, digital surface models, RGB orthomosaics, hyperspectral reflectance mosaics and various vegetation indices maps were generated from the data collected. Using the data, analysis of the vegetation status and growing will be studied. Based on these experiences, the aim of this work is to study the potential of novel drone based technologies in precision farming and to show for farmers practical examples on how to utilize novel drone mapping technologies in agriculture. Also aspects of integrating drone data to open Sentinel 2 satellite data sets was demonstrated.

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1. INTRODUCTION

Remote sensing based on drones (alternative terms: UAV; Unmanned Aerial Vehicle or RPAS; Remotely Piloted Aircraft System) is a rapidly developing field of technology, which allows new possibilities for monitoring of the environment. Due to technological innovations lightweight multi- and hyperspectral sensors have become available which may be carried by small drones.
The applications for UAV can comprise, for instance, precision agriculture (Honkavaara et al., 2013; Bareth et al., 2015; Bendig et al., 2015), vegetation monitoring (Aasen et al., 2015) and forest monitoring (Torresan et. al., 2016; Nevalainen et al., 2017; Näsi et al., 2015).

Drone based mapping enables to map agricultural lands with a very high spatial resolution, which enables to monitor even small anomalies in vegetation inside the parcel. Such uneven growth of plant stand may be caused by, for instance, drought induced uneven germination and growth, seedling loss caused by flooding and anoxia, disease outbreak, pest invasion, unbalanced nutrient availability and uptake, and overwintering damages. In addition, by monitoring variation of vegetation inside a parcel, drone can facilitate monitoring of differences between field parcels in their production capacities at farm-scale. Drone may also provide additional high-resolution information, which is valuable for interpretation of satellite data when assessing variation in productivity or determining yield gaps (i.e., difference between potential and attained yields) of fields from landscape up to national scale. All these opportunities provided by drone support optimization of land use and farming practices in the future as a part of targeted sustainable intensification actions in Finland that will be pushed through with the on-going OPAL-Life project (www.opal.fi), which aims at mitigating greenhouse gas emissions from agriculture following the principle of sustainable intensification. This means combining environmental benefits, profitability of the farm and social aspects.

2. EQUIPMENT

The FGI's DroneFinland research group has been developing drone based remote sensing tools since 2008 and for agriculture applications since 2011. The major drone since 2014 has been a hexacopter with Tarot 960 foldable frame. Diameter of the rotors is 450 mm and KDE4014XF-380 electric motors were used. Autopilot is Pixhawk equipped with Arducopter 3.15 firmware. Payload of the system is 3-4 kg and flight time 15-30 min (depending on payload, battery and weather conditions).

The central components of system in the remote sensing use are cameras. The other main components are on-board GPS (RasPiGNSS, NV08C-CSM) for collecting UAV position trajectory. Additionally Raspberry Pi2 on-board computer was used for collecting timing data for all devices and logging the GPS. The predominant instrument used in hyperspectral imaging was the FPI

(Fabry-Pérot interferometer) based hyperspectral camera (Saari et al., 2011; Mäkynen et al., 2011; Honkavaara et al., 2013, Oliveira et al., 2016). This technology provides spectral data cubes (spectral range 500-900 nm) with frame format and enables stereoscopic measurements when overlapping images are used. The field of view (FOV) is ±18° in the flight direction, ±27° in the cross-flight direction, and ±31° at the format corner. This technology has shown already potential for various environmental mapping applications, such as forestry (Näsi et al., 2015, Näsi et al., 2016, Nevalainen et al., 2017), peat production (Honkavaara et al., 2016) and precision agriculture (Honkavaara et al., 2013; Pölönen et al., 2013; Kaivosoja et al., 2013). An off-the-shelf RGB camera (Samsung NX500) was also used for capturing high spatial resolution stereoscopic images that can be used for stereoscopic 3D measurements to provide the 3D geometrical structure of the object.

In addition to the drone, equipment in ground is necessary. The ground station is composed of reference panels for determining the reflectance level and equipment for irradiance measurements. The equipment of ground station are important to calibrate the data values of the hyperspectral camera to reflectance also during variable illumination conditions, which is usually caused by clouds. For ensure geometrically accurate and compatible measurements with coordinate system, ground control points (GCPs) were used. The targets are white circles with a diameter of 30 cm. Typically, five GCPs for each parcel are measured, using the virtual reference station real-time kinematic GNSS method (Trimble R10 VRS-RTK- GNSS system).

Figure 1. The drone and ground station ready for flight campaign (left) and the drone in action (right)

3. FLIGHT CAMPAINGS

The first step of flight campaigns with drones is planning. Flights should be planed considering safety and legislative issues. The current legislation in Finland requires for example that pilot or observer have visual contact with drone and possible to handle it if something unexpected occurs. Operating of drones outside the densely populated areas, within visual line of sight (VLOS) and under 150 m from ground does not need additional permissions. Mainly because of these limitations, flight campaigns of this study were carried out using 140 m flying height to maximize the size of mapped area. This produced 14 cm ground sample distance (GSD) for FPI camera and 3.2 cm for RGB camera. The flights need to be planned such that overlaps (side and forward) are high enough for strong image block geometry to enable stereo measurements. In addition to flying height, camera parameters (field of view), flying speed and distance between flight lines affect to overlaps. The flying speed used in these experiments were 4 m/s, flying time 18 min and the distance between flight lines were 40 m, which produced 90% forward overlap and 65% side overlap for FPI camera and for RGB camera 93% and 75% overlaps, respectively. The same flying parameters, which allow coverage of 30 ha/flight, were used in every flight in this study.

During summer 2016, 34 flights with drones were carried out for 16 different agricultural field parcels, in three real farms of Finland. The same parcels were measured by drones several times during the summer to acquire multitemporal data of different phases of the growing season. The overview of the campaigns, with flying dates, number of flights and parcels is shown in Table 1. A low-cost RGB camera and a hyperspectral sensor were used in each flight. The collected data covered different plants such as grass, wheat, barley, oat, rapeseed and pea.

Table 1. The overview of collected data

	Farm 1	**Farm 2**	**Farm 3**
Flying date	2016-06-02	2016-06-07	2016-06-15
N of flights	3	5	4
N of parcels	5	6	4
Flying date	2016-06-22	2016-06-21	
N of flights	4	6	
N of parcels	5	6	
Flying date	2016-07-21	2016-07-26	
N of flights	4	4	
N of parcels	5	3	
Flying date		2016-03-03	
N of flights		4	
N of parcels		2	

4. DATA PROCESSING

Modern photogrammetry and computer vision techniques provide suitable algorithms and tools to handle huge numbers of frame images and to generate products, like digital surface models (DSM) and orthomosaics. Orthomosaics, which are composition of geometrically oriented aerial images, enable accurate 2D measurements. DSMs provide information about 3D structure of the object. During the last years, software based on structure from motion (SfM) (Wu, 2013) and semi-global matching (SGM) (Hirschmüller, 2008) algorithms have developed a powerful and user-friendly tool to process drone data sets, allowing incorporate more users for this technology. Agisoft Photoscan (agisoft.com) and Pix4D (pix4d.com) are examples of these software. However, even with user-friendly software, it is important to have the perception to theory of photogrammetry to understand geometrical accuracy of the end products.

For optical remote sensing tasks, aspects of radiometry need to be consider. Radiometry means the measurement of radiance. A digital imaging sensor measures the incoming radiance and stores the result of the measurement as digital number (DN). Radiometric corrections are needed in order to create comparable values, such as reflectance values, for the analysis.

Honkavaara et al. (2013) has developed a processing chain for frame-format hyperspectral cameras, like FPI camera, to generate uniform reflectance mosaics. This method includes radiometric block adjustment method to handle aspects caused by variable illumination conditions.

The data of this study was processed geometrically using Agisoft Photoscan software which provides orientations of images, DSMs with hundreds of millions of 3d points, and orthomosaics. The spectral data cubes of 36 bands from FPI sensor was then processed, using the method proposed by Honkavaara et al. (2013) to reflectance mosaics.

5. RESULTS

5.1. Visual analysis based on expertise of farmer

The farmer can quickly have a general view about the situation of the field only by looking orthomosaics. The farmer may know that there are weeds in the parcel, however, the visual analysis of orthomosaics (Fig 2) can allow detecting more detailed information about problems, like infestations, comparing the perspective from ground level. Thus, the farmer can plan possible plant protection tasks and their timing based on the orthomosaics.

Figure 2. Parts of orthomosaics where farmer can identify weeds.

A farmer who knows his fields can also see quickly the scope of ice encasement from winter wheat parcel (Fig 3, left). Occasionally, farmer does not know exactly the history of the parcels, but he may have observations based on growth from ground level. For such situations, drone based orthomosaic can ensure the doubts of farmer. This was the case when the farmer saw the orthomosaic (Fig 3, right) and was then sure that there were to locate old sub-surface drainages in the field, which cause horizontal strips to orthomosaic.

Figure 3. Parts of orthomosaics where the farmer can identify areas of ice encasements (left) and old sub-surface drainages (right)

In addition to detect old sub-surface drainages, drone based orthomosaics are a useful tool to map freshly made drainages. From orthomosaic based on FPI camera (fig 4, left) it is easy to detect drainage lines and to map them (yellow lines). The green square area had not sub-surface drainages during flight. After two weeks of constructions, they had progressed and could be noticed in the RGB based orthomosaic (fig 4, right). The orthomosaics are excellent documentation of sub-surface drainages and based on mapped coordinates, they can be located after decades.

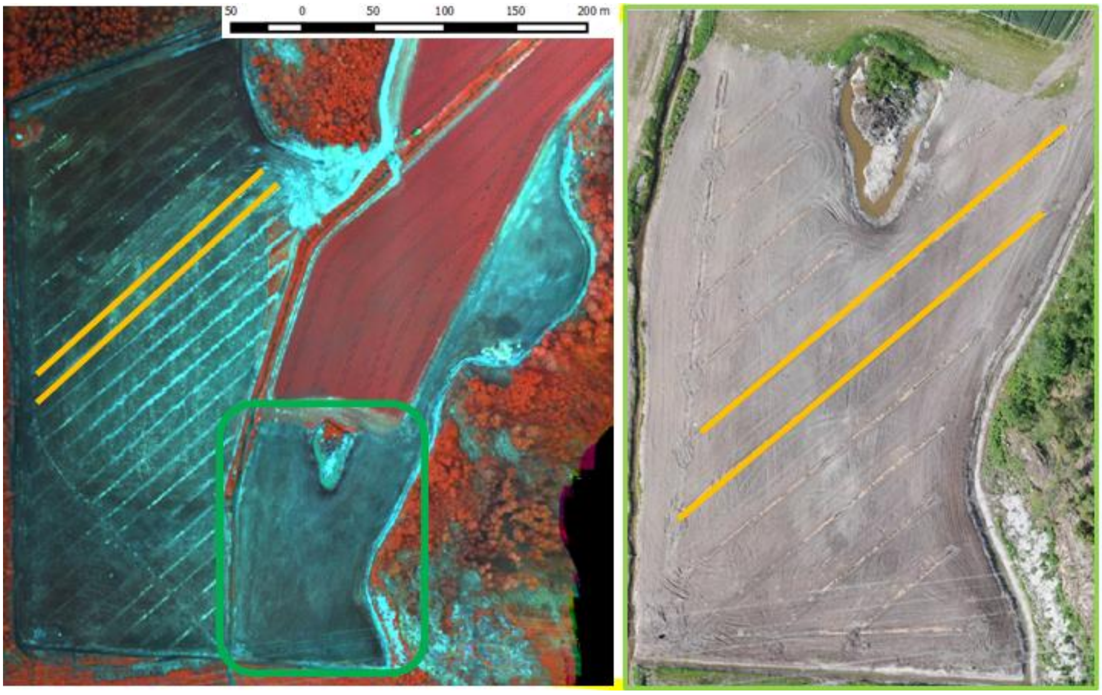

Figure 4. Orthomosaics are excellent tool for documentation of sub-surface drainages

5.2 Analysis of time series

Multitemporal data collection enables to create time series, which are a valuable tool to recognize plants during the growing season. The time series presented in Fig. 5 shows the development of a pea parcel. The first data set (left) was collected during the beginning of growing season (June 2), the second one (middle) was collected three weeks later (June 22) and the last one (right), one week after the previous one (July 21). The upper row shows RGB based orthomosaics; the next one shows orthomosaics based on bands of FPI camera and the third row shows the Normalized Difference Vegetation Index (NDVI) map, based on FPI data. NDVI is commonly used index in remote sensing, due to the strong correlation between the NDVI and plants biomass. Low values of NDVI (marked on the map) indicate low level of biomass. On the other hand, high values (green) indicate high level of biomass. Especially from the last data set, it is possible to identify areas, which were not developing as well asother parts of the parcel. The reason for these anomalies is probably drowning of plants caused by heavy rains and the topology of parcel. The growth of pea and increasing biomass is also visible in average reflectance spectra of the parcel (fig. 6, the lowest row).

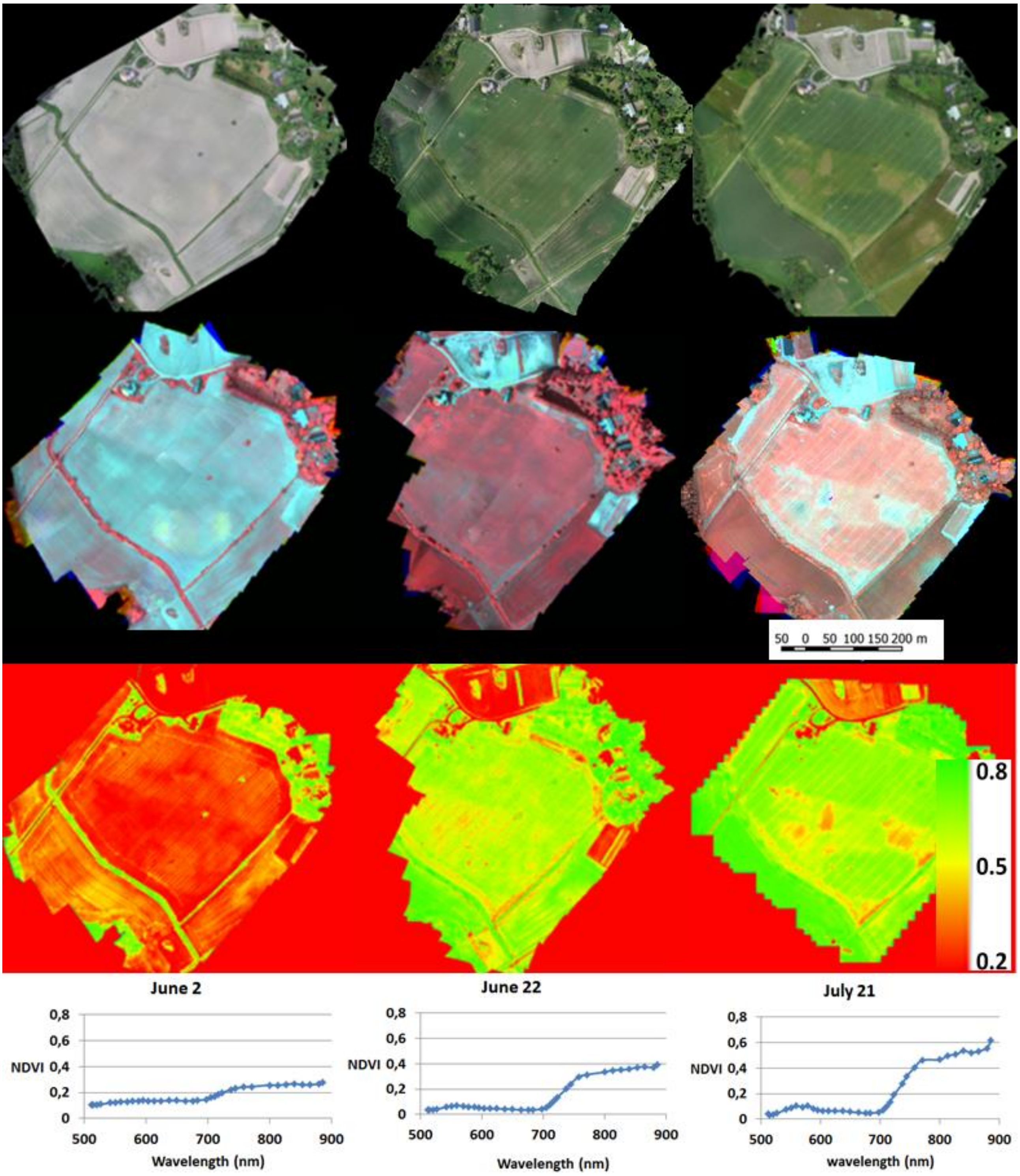

Figure. 5. Time series with RGB, FPI orthomosaics, NDVI maps and average reflectance spectra for a pea parcel for three different dates.

As can be seen from the maps in fig 5, NDVI is a good indicator of biomass, during the growing season. Statistics of the parcel are also a tool for growth monitoring. An example is the average of

NDVI values (fig 6). Data from Sentinel 2 satellite is complementary statistic data (fig 6). Even if the GSD of satellite images are huge (10 m) comparing to drones (3-20 cm), this type of parcel based statistics are compatible, if the radiometric processing is reliable for both products.

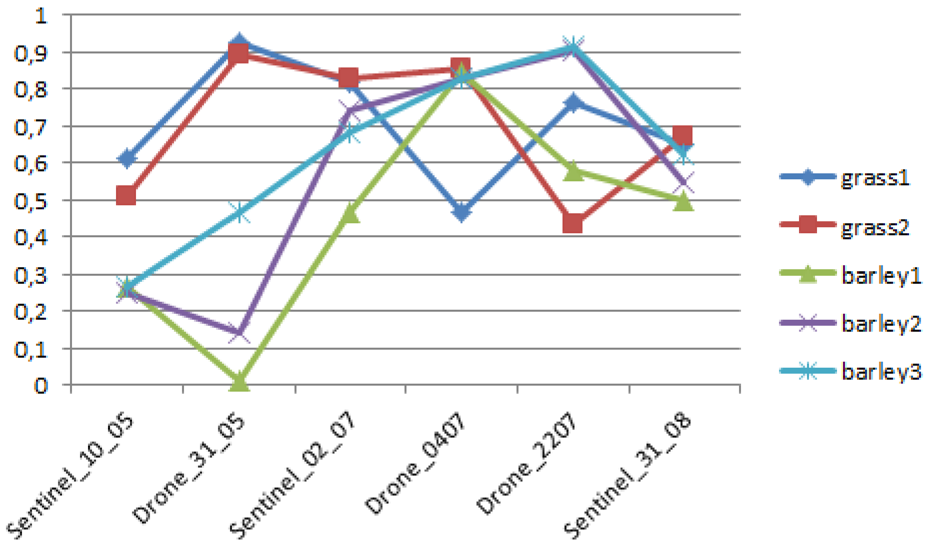

Figure 6. Average NDVI time series based on data from drone and Sentinel 2 satellite for different parcels from May to August

The difference between GSD of drone (fig 7, left) and satellite data (fig 7, right) can be seen in the analysis of anomaly detection. The aim of anomaly detection is to detect areas which are not developing in the same way of the most parts of the area. In this case (fig 7), the anomaly detection is based on comparison between NDVI value of pixel and average of NDVI of parcel. The anomalous areas (marked on red) are quite similar in both data sets. The FPI dataset has indicated more anomalies than Sentinel dataset, which is mainly caused by the GSD difference.

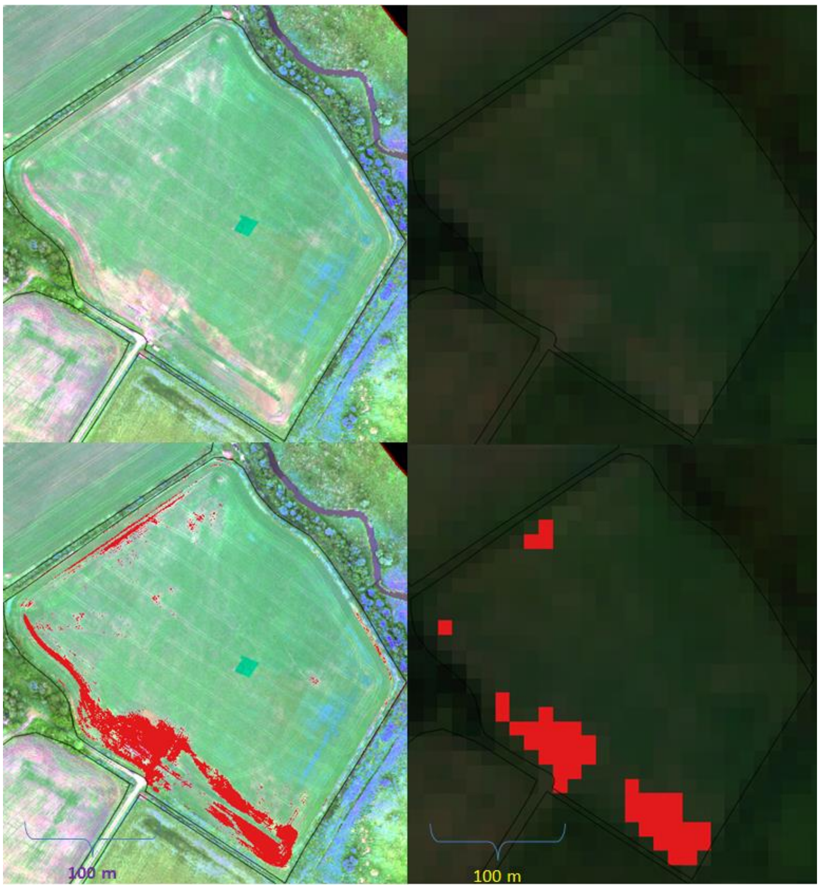

Figure 7. Anomaly detection from drone based FPI and Sentine satellite datasets

Satellite images are covering large areas, which is an advantage comparing to drones. Satellite images have been exploited already during decades for agricultural applications. Nevertheless, it is expected that high resolution drone mapping will improve also satellite based yield estimation, like the experiments presented by Laurila et al. (2010), who used optical and radar satellite data for cereal yield modelling. Drone based remote sensing enables novel methods to monitor agricultural fields. For example, photogrammetric canopy height models (CHMs) are used successfully for biomass estimation (Bendig et al., 2015). In addition, using drone based spectral information for estimation of agronomic parameters, like biomass and nitrogen, are showing promising results (Pölönen et al., 2013; Honkavaara et al., 2013; Caturegli et al., 2016; Schirrmann et al., 2016).

6. CONCLUSION AND OUTLOOK

The FGI's DroneFinland research group (www.dronefinland.fi) has been developing drone based remote sensing tools for precision agriculture since 2011. The major focus has been to develop reliable and automated methods based on 3D object structure and spectral data.

In the present Opal Life project led by the Natural Resources Institute Finland (www.luke.fi), the novel remote sensing data sets are taken to the farmers and potential approaches to utilize the data sets are explored. Visual analysis of drone based orthomosaics can already provide valuable information for farmers, but computational analyses are independent of human knowledge and necessary for automatic methods.

The rapidly evolving drone remote sensing tools provide new possibilities to automate and accelerate the remote sensing procedures for precision agriculture. Nowadays, hyper- and multispectral sensors are utilized to provide accurate information of crops. The novel drone based internet services (like www.dronedeploy.com) are also available and they can produce reflectance data sets and even interpreted results rapidly. In the future, even near real-time response is expected. This provides a possibility for autonomous precision farming, where the system gives suggestions for the farmer about farming tasks and their timing. Integration of different remote sensing data, like satellite and drones as well as other relevant sources, for instance, weather, soil type and its condition, will improve the systems to work reliably. This kind of systems have a great potential to support optimization of land use and farming practices in the future as a part of targeted economic and environmental sustainable intensification actions.

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