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A REVIEW ON PRECISION AGRICULTURE WITH UNMANNED AERIAL VEHICLES FOR SOIL MOISTURE CONTENT ESTIMATION

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ABSTRACT
Poor agricultural practices are major contributors to climate change and environmental destruction. Precision agriculture evolves and grows the potential and opportunities of the new field of unmanned aerial systems which demonstrates how to mitigate the impacts of climate change and variability. There are several sectors the unmanned aerial vehicles are being welcomed within the agricultural sector; they have shown to be of great value for crop yield and biomass estimation. It takes little energy to run and operate and it can be from a green power source. Since the clarion call is to move towards a more sustainable and eco-friendly lifestyle, industries, businesses and corporations are no exceptions. Modern, exciting new technological innovations are also presented along with the sustainable aspect of conventional agriculture with more precise agricultural practices. By increasing the precision and applying inputs like artificial fertilizer and pesticides/herbicides at a correctly variable amount and time, a reduction of the inputs and the environmental disruption should follow, which result in an increase in the profitability for the farmers, and less environmental damages. Therefore, the objective of this paper is to review published research on remote sensing technology in the agricultural sector, for soil moisture estimations and other unmanned aerial systems (UAS) towards a more sustainable precision agriculture. The synergy between unmanned aerial vehicle (UAV), soil moisture content estimation (SMC) and sustainability are main focus of this paper, as the possibilities and opportunities this can open for us can be of significant advancement in profitability and precision agriculture.
Keywords: Climate change, Soil moisture content, Sustainable agriculture and unmanned aerial systems

INTRODUCTION
Precision agriculture
Since the beginning of agriculture, the big paradigm shifts are caused by newly developed techniques and tools to cultivate arable land with. To mention a few, the hard plough and the tractors have changed the way we cultivate our land (Chambers *et al*., 1990). We are constantly improving and changing our methods of farming according to new studies and technologies. In the last two decades, we have seen an exponential growth in these two fields. The rapid improvement with the increasing exploration of applied science and the large-scale team-based research; the development of new tools in agriculture is happening rapidly. Precision agricultural technology has and will still shape the way we are moving into this new paradigm of precision agriculture. By improving the surveillance and application of inputs on the field, we are shifting from a traditional conventional, uniformed treatment of each agricultural field to a tailor-made treatment for as small as possible areas.

Precision agriculture had its beginning in the middle of 1980´s with sensors for soil organic matter and is currently developing exponentially. It has quickly evolved to include satellite, aerial and tractor mounted or handheld sensors. It was not before the 1990s that precision agriculture became commercially available. Precision agriculture had several milestones during its progression to where it is today. It began with farming by soil and has progressed to site-specific crop management based on grid sampling and management zones. Later, there has been increasing emphasis on real-time on-the-go monitoring with ground-based sensors. The accuracy of the images has become greater which allows evaluation of soil and crop properties at a fine spatial resolution at the expense of increased data storage and processing requirements. Precision agriculture tends to offer increased farm profitability by improving the crop production (Zhang *et al*., 2002), and through improved management of farm inputs leading to less environmental pollution (Tian, 2002).The large amount of data and information that is being collected gives us more accurate and precise application of the inputs on a farm. This leads yet again to improved crop productivity and environmental quality (Harmon *et al*., 2005). There has also been a shift from spatial data analyses and management alone to a spatial-temporal data analyses and management (Miao *et al*., 2009). The PA involves several steps of information management, processing and analyzing of the data that is collected, technological advances in computer processing, yield monitoring, field positioning as well as sensor design and remote sensing (Mulla *et al*., 1997) Precision agriculture involves several different new technologies and spreads over many management inputs for the farmers. Sensors and cameras can be mounted to any platform that can carry them such as tractors, equipment's and satellites, which are commonly used. Following the rapid development of technology; cameras and sensors are getting smaller and lighter, with higher resolution. Along with these advancements, the introduction and development of unmanned aerial vehicles give us the possibilities of combining these to an unmanned aerial system (Sánchez *et al*., 2014). This thesis will give an introduction to the field of precision agriculture (PA) and surface soil monitoring methods. The sustainable aspect of this technology and the opportunities for application will also be discussed. Also, the alternative use of UAS and potential advances will be discussed which may help facilitate their use and attract farmers' interest in their application within PA.

This review will outline the established methods of remote sensing technology with a UAV in the agricultural sector. Different research areas and theories will be discussed and reviewed. Soil moisture estimation methods with remote sensing is suggested that a successful application of UAS supported image capture could reduce the time frame needed for agricultural practice adjustment and that the results of this remote sensing monitoring could exceed those from traditional control treatments (Beeri and Peled, 2009). As artificial neural networks and more user- friendly software's are becoming more and more popular, some are offering these services commercially like Dronedeploy (Van Rees, 2015).nsing technologies will be examined. The sustainability in general around these topics will also be described, to shine the light on a more sustainable farming practice. Also, the potential advances and alternative uses of UAS will be discussed. As well as recommendations for further research and usage of the UAS technology. My hypothesis is that these fields of agricultural technology have great potential for further development and make precision agriculture more.

DISCUSSION

Unmanned aerial systems have in recent years been available to the environmental and agricultural application (Laliberte and Rango, 2011). The advantages with a drone up in the air, it the shift of perspective it gives us. We can by getting a birds-view look precisely down at the wanted objects, whether it is biomass or soil. Today there are several different UAS and they can be grouped in fixed wing aircraft, helicopters, and the most recent one is aquadrocopter with vertical take-off and landing (VTOL). The fixed wing aircraft usually have longer fly time and it can cover more acres. However, they are less user-friendly. The development of aquadrocopter with attached cameras in the last five years has been progressed a lot. The cameras can detect light waves, which are invisible to the human eye. This enables researchers and scientists to explore the possibilities of these new spectra in agriculture. There are several established methods of using UAS in the agricultural sector, such as finding potentially yield- limiting problems in a timely fashion, reduction of time on scouting the crops, crop health image, integrated Geographic Information System (GIS) mapping. Currently, the use of UAS is mostly to support some of the farm operations where it is utilized. It is used across the world. In Japan, China and North America there are commercial players who offer this technology. While in Europe, the UAS are mainly used for research purposes. There has been an increase in the use of UAS technology around the world and it is becoming an important part of the agricultural practice, whereas in Norway there is little or no use of this technology except some research projects. One project that has contributed to the field of PA is on the mineralization patterns from NIR spectroscopy, by the Nordic Joint Committee for Agricultural Research. They found that using NIR to predict the C and N in plants is a much less laborious and cheaper analytical method compared to the traditional stepwise chemical digestion (SCD) or C/N ratios (Bruun *et al*., 2005). There are some limitations that come along with the UAS application to agriculture. The drone and sensors are sensitive to precipitation but on the other side, they can retrieve higher pixel quality and operate under the clouds without the restrictions that satellites have.

Soil moisture

This thesis presents and reviews the established methods for estimating soil moisture
content. The development of new methodologies and analytic methods are increasing and improving in accuracy, leads us towards a more detail knowledge based agriculture. SMC can provide us with valuable information on the growing conditions. By knowing the SMC and the plants needs, we have the knowledge to apply more precisely inputs, like minerals. The more we know, the better we can supplement the needs. SMC estimations are increasing in accuracy as the development of sensors is enhancing. By generating an informative image about the soil moisture content and other valuable factors for a grow bed, we can move towards a more tailored and detailed growing managing practises. The importance of soil physical properties and the effect it has on the plants is well established, but monitoring them has been expensive, time-consuming and laborious, until now. A remote sensing system today is almost able to provide near-laboratory-quality information from every pixel in an image very quickly. The use of machine learning approach for soil moisture estimation from remote sensing data was successfully demonstrated by Ali et al., (2015). However, with only one input, the thermal imagery is proven to be the most relevant information in surface soil moisture estimations (Hassan-Esfahani et al., 2015). The effect of precise knowledge about SMC in an agricultural field, have demonstrated its improvements in irrigation fields and will increase doing so in other areas of agriculture. This is contributing to a more detailed and informative base for agricultural practices, like,

irrigation, artificial fertiliser, pest and herbicide application, which again leads to a more sustainable agriculture. Some limitations to this are the gap between SMC and operational management. The acquired data need to be transformed and processed for the next step, for this, the knowledge gaps between different technologies need to be reduced. Further research should be focused on more detailed and precisely estimations of SMC from UAS technology, and transforming this new knowledge to farm operation management decisions and applications.

UAV Technology

The UAS technology is modern and experiencing exponential growth in development and marked. The physical parts such as the UAV and the payload (camera/sensors) are steadily becoming lighter and cheaper. This is not only creating better aircraft's but also increasing the user market. Another essential part of the UAS technology is that there is an exponential growth of possibilities as the data-driven methods for analyzing the data are explored. This method is where most of the previous research in this field has been focused on. All the analyses, processes and calculations that a UAS needs to operate are executed in the data driven models. The technology becomes more sustainable and brings new areas of usage. However, the rate of users is still low. With the development and improvements that we see today and the opportunities that this offer us, is, and can be life changing for many people. This technology can save time and improve productivity on certain operations, like input management. An open-source community sometimes develops UAS, this crowdsourcing and communal approach will continue to develop in a highly efficient and low-cost manner. There are a few factors that will determine the widespread usage like, the cost, user-friendly, flight abilities sensors technology, pixel resolution and more accurate and time- consuming analyzing methods.

Sensors and cameras

The UAS have sensors and cameras that can capture images and other inputs, like temperature, depending on the sensor and its purpose. Some sensors specifically look at certain areas of the electromagnetic spectrum, out of the human eyes capability. The area of infrared light rays is widely used for different purposes, like measuring temperature and biomass. The visible light that humans can detect is also used, and this is called the visible light rays. An area that some believe holds a great potential is the ultraviolet light rays. This provides a large set of data and a 3D-model, which can be hard to interpret. Combining the different specters and sensors have become more and more common as better results and estimations are made, like Zhan, Dongjian, and Yongliang (2013) demonstrated in their report. Sensors and cameras are becoming smaller and lighter, and this allows for more stability in the air and longer flight time. The pixel size is also improving and an essential part of a precise reflection of the reality. Sensors that are commonly used for agricultural purposes are capturing light in different areas like Red/Green/Blue, near-infrared, red-edge, multispectral, thermal infrared.

Agricultural application of UAS

The established methods of using UAS for agricultural practices are diverse and they depend on the area and the desired outcome. There are several different lightweight multi-spectral cameras that can be attached, for the particular desired result. This gives the operator a wide range of aerial imagery to choose from. These images will be analysed and processed for further use. The cost and availability of high-resolution satellite imagery often limits the application in PA (Wu *et al*, 2007).

The research that has been published on PA for agricultural application is diverse and spreads across a variety of agricultural production systems. Most areas of use can be put in these categories for an organized and structured overview (Stark e*t al*., 2015). The application of UAS in agriculture has had an exponential growth in the last years and has focused on a broad range of endeavors (Adamchuk *et al*., 2004). The application of hyper resolution vineyard mapping based on visible, multispectral and thermal images has been demonstrated (Turner *et al*.,, 2011).

Estimation of vegetation indices derivation, vegetation canopy mapping, soil and crop temperature, crop nitrogen estimation among others have shown to be affordable, precise and feasible (Al-Ara *et al*., 2013). There are still few problems that continue to challenge us such as the sensor capacity, platform reliability, and image processing and final products dissemination. It is suggested that a successful application of UAS supported image capture could reduce the time frame needed for agricultural practice adjustment and that the results of this remote sensing monitoring could exceed those from traditional control treatments (Beeri and Peled, 2009).

As artificial neural networks and moreuser-friendly software's are becoming more and more popular, some are offering these services commercially like Dronedeploy (Van Rees, 2015). Even though the technology of UAV has been around for approximately thirty years, the development and opportunities are continually expanding. The result of this is an exponential growth in the field of use for UAV. There are several different methods an unmanned aerial vehicle system (Sánchez et al., 2014) can be implemented in the farm operations. The following section describes the most shared and relevant methods that soil

Sustainability

Farming is and has always been an interaction between humankind and natural processes. We can tweak and turn some of these processes to the likings of our desired direction. By doing this, we are also affecting the surrounding and connected ecosystems, altering their natural state. Unfortunately, this has resulted in a negative and sometimes directly destructive on the environment. As we depend on upon them, their downfall and destruction will eventually bite us in the back. Therefore, it is important to have an agricultural practice that takes this into considerations and preservation. Soil organisms are considerably affected by mineral fertilizers, organic amendments, microbial inoculants, and pesticides (Bünemann *et al*., 2006).

Precise and accurate application of inputs could contribute to moderating unfavorable effects on the soil organisms. Remote sensing technology is playing a key role through precision agriculture. The application of UAS in farm operation is demonstrated by Zhang et al., (2014), the issues related to post-processing of images along with cost and training to operate and analyze were still present. With reduced inputs in fields by more precise and variable application of artificial fertilizers and pesticides, would boost the productivity and not at least the sustainability. For this to take place, the gap between researchers, end-users, and different technological innovations need to diminish the opportunities that recent technological innovations offers, was almost unimaginable a few years ago.

CONCLUSION

Soil moisture estimation methods are developing rapidly with great complexity. By building on previous research and with newly innovations of technology, smarter and more accurate methods are created. Farmers and other potential users should be more aware of the opportunities that UAS technology offers. It has been demonstrated that estimating the soil moisture in an agricultural field can help with the input decisions of some farm operations. It can also have a positive impact on the environment such as reduced fertilizer and pesticide runoff from agricultural fields. More organized "toolbox" of inputs and user-friendlier approaches, would improve the user-friendliness and attract more consumers. Networks of modern technology acquiring key information and collaborating with others have great potential to improve the precision in precision farming. It is concluded from the above that technological application like remote sensing holds a great potential for a more sustainable agriculture.

RECOMMENDATIONS

Further research is needed to acquire more knowledge about the web of agricultural life, and the implementation of UAS towards a more sustainable agriculture.

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