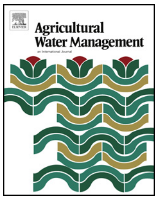
Agricultural Water Management 153 (2015) 9–19

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat



Review

UAVs challenge to assess water stress for sustainable agriculture

J. Gago[a,*], C. Douthe[b], R.E. Coopman[c], P.P. Gallego[a], M. Ribas-Carbo[b], J. Flexas[b], J. Escalona[b], H. Medrano[b]

[a] Applied Plant & Soil Biology, Department of Plant Biology and Soil Science, Faculty of Biology, Vigo University, Campus Universitario das Lagoas-Marcosende, 36310 Vigo, Galicia, Spain
[b] Research Group on Plant Biology under Mediterranean Conditions, Departament de Biologia, Universitat de les Illes Balears, Carretera de Valldemossa Km 7.5, 07122 Palma de Mallorca, Illes Balears, Spain
[c] Laboratorio de Ecofisiología para la Conservación de Bosques, Instituto de Conservación, Biodiversidad y Territorio, Universidad Austral de Chile, Casilla 567, Valdivia, Chile

ARTICLE INFO

Article history:
Received 26 May 2014
Accepted 21 January 2015
Available online 19 February 2015

Keywords:
UAVs
Remote sensing
Water stress
Precision agriculture
Multicopters
Thermography

ABSTRACT

Unmanned aerial vehicles (UAVs) present an exciting opportunity to monitor crop fields with high spatial and temporal resolution remote sensing capable of improving water stress management in agriculture. In this study, we reviewed the application of different types of UAVs using different remote sensors and compared their performance with ground-truth plant data. Several reflectance indices, such as NDVI, TCARI/OSAVI and PRInorm obtained from UAVs have shown positive correlations related to water stress indicators such as water potential (Ψ) and stomatal conductance (g_s). Nevertheless, they have performed differently in diverse crops; thus, their uses and applications are also discussed in this study. Thermal imagery is also a common remote sensing technology used to assess water stress in plants, via thermal indices (calculated using artificial surfaces as references), estimates of the difference between canopy and air temperature, and even canopy conductance estimates derived from leaf energy balance models. These indices have shown a great potential to determine field stress heterogeneity using unmanned aerial platforms. It has also been proposed that chlorophyll fluorescence could be an even better indicator of plant photosynthesis and water use efficiency under water stress. Therefore, developing systems and methodologies to easily retrieve fluorescence from UAVs should be a priority for the near future. After a decade of work with UAVs, recently emerging technologies have developed more user-friendly aerial platforms, such as the multi-copters, which offer industry, science, and society new opportunities. Their use as high-throughput phenotyping platforms for real field conditions and also for water stress management increasing temporal and resolution scales could improve our capacity to determine important crop traits such as yield or stress tolerance for breeding purposes.

© 2015 Elsevier B.V. All rights reserved.

Contents

---

* Corresponding author. Tel.: +34 986812595.
E-mail address: xurxogago@gmail.com (J. Gago).

http://dx.doi.org/10.1016/j.agwat.2015.01.020
0378-3774/© 2015 Elsevier B.V. All rights reserved.

1. Introduction

In general terms, agriculture consumes most of the world's water resources (70%) (Gilbert, 2012). At the same time, other industries are also increasing their water consumption and thus competing with food production. Current climate change predictions indicate increases in the frequency and intensity of drought periods in Mediterranean and semi-arid areas (Stocker et al., 2013). Globally, it is important to note that 45% of the world's food supply is produced on irrigated lands covering only 18% of cultivated areas (Döll and Siebert, 2002). This means that irrigation management is of crucial importance to optimize water use.

Moreover, the predicted global food demand for 2050 indicates that crop production must double (Tilman et al., 2011). Increased crop production was strongly encouraged after World War II, resulting in the "Green Revolution" of the 60s. Now, a claim for a "Blue Revolution" seems to be occurring, focusing on agriculture's environmental impacts and especially on optimizing water management to obtain the desired idea of "more crop per drop" (Beer et al., 2009).

Thus, water efficiency is becoming more and more important for society. For example, the European Parliament recently introduced the requirement to sustainably "produce more with less" in agreement with the new EU research program "Horizon 2020" (Geoghegan-Quin, 2013). In this sense, precision agriculture appears to be a multidisciplinary approach capable of responding to the previous objectives. The American National Research Council defined this type of agriculture as "a management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with crop production." In fact, it involves all of the techniques and methods available in the new ICT (Information and Communications Technology) era, which can be used to retrieve useful information for managing crops while accounting for landscape heterogeneity and variability within and between fields (Lelong et al., 2008; Anderson and Gaston, 2013).

However, interdisciplinary approaches will not be so easily realized; multi-disciplinary teams (experimental and computational scientists) will be required to integrate diverse data from multiple plant levels. Thus, a plant systems biology view will have to be used to scale this data up to an agricultural level (Fernie, 2012). For instance, most of the measurements used to characterize plant status are developed at the leaf level, while the improvement of agricultural management requires an up-scaling of this information to the canopy/field level. The characterization of one single plant is a time consuming, costly process; to carry out these types of characterizations for complete agricultural fields would be even more so (Berni et al., 2009a, 2009b; González-Dugo et al., 2012).

Traditional remote sensing approaches place remote sensors on towers over crop fields (thermal imagery, multi and hyper-spectral cameras, fluorometers, etc.) where the main limitation is the fixed position from which data is collected. Another traditional remote sensing technique is the use of aircrafts or satellites where the temporal and spatial resolution significantly limits their usefulness for agricultural assessments (it is important to consider the highly dynamic changes in vegetation in relation to the environment) (Moya et al., 2004; Louis et al., 2005; Berni et al., 2009a; Anderson and Gaston, 2013; Jones, 2014). In this context, UAVs (unmanned aerial vehicles) and remote sensing come into play as useful tools because they are able to fill this important gap, coupled with aerial imagery and adequate computational efforts. Some studies have also been developed using different ground manned vehicles equipped with remote sensors at affordable costs, but these also present constraints since transporting the equipment to the monitoring areas reduces the swath mapping capability, and in some cases, their use is only available during crop harvesting (Lelong et al., 2008).

In recent years, the use of UAVs for civilian purposes has begun to increase thanks to technological advances, cost reductions and the size of sensors related to the Global Position System (GPS), pre-programmed flights, IMUs (inertial movement units) and autopilots. In this sense, UAV technology can fill the gap of knowledge between the leaf and the canopy by improving both the spatial and the temporal resolution of the most common current remote sensing systems. Thirty years ago, a fleet of airborne imagery thermal scanners was envisioned to map thermal stress for water management purposes (Jackson et al., 1977; Berni et al., 2009b); now it seems like we are finally achieving this idea thanks to the emergence of UAV technologies.

This review considers the latest remote sensing experiences obtained from different types of UAVs applied to agriculture and their potential ability to assess plant water status at the crop-scale. Additionally, it highlights the different remote sensing indices obtained from UAV technology and their ability to estimate plant physiological parameters. Finally, the future perspectives and potentials of UAVs are addressed.

2. UAVs applied to precision agriculture

UAVs have historically been used principally for military purposes. After World War II they began to be used as targets or weapon reconnaissance platforms. Recently, other civilian purposes, such as agricultural management, have created an increased interest in them. In Table 1 we compiled all of the agronomy studies that have been published up until now which employed UAVs and remote sensing technologies compared with plant-truth data measurements. Types of UAVs and flight characteristics are also briefly mentioned (Table 1). Previously, the pioneering works of Herwitz et al. (2002a, 2002b, 2004) described the usefulness of UAVs to detect irrigation and fertilization abnormalities and fruit maturation of crops in agricultural fields. These NASA-funded projects used UAVs like the solar-powered Pathfinder-Plus (with a wing span of 36.3 m and a weight of 318 kg), with a flying capacity of several hours, equipped with visible and multi-spectral cameras to acquire images (0.5 and 1 m/pixel, respectively) of a coffee plantation in Hawaii at 6400 m altitude. Another example of large fixed wing UAVs is the RCATS/APV-3 (also developed by NASA), which has been used to study vineyards in California (Johnson et al., 2003) (Table 1). In the last decade, technological advances have led to the development of micro-UAVs (less than 5 kg) mostly due to the reduction in weight and size of the sensors, and considerable increases in precision, such as inertial measurement units (IMUs) and the auto-pilots using GPS (Global Positioning Systems) (Berni et al., 2009a; Turner et al., 2012).

Mainly two types of UAVs have been employed for agricultural management: helicopters and fixed wing airplanes (Sugiura et al., 2005; Berni et al., 2009a, 2009b; Xiang and Tian, 2011; Zarco-Tejada et al., 2012, 2013a) (Table 1). Both aerial platforms have several advantages and limitations. While unmanned helicopters have more complex flight systems, they offer lower flight altitudes and hover capacities (ability to maintain a stable position in flight) or low-speed flights. However, they are also able to cruise in any direction in the field and have no special requirements for take-off and landing, which could be critical in standard agricultural fields. Recently, it was published that the Pheno-copter UAV, a gas-based helicopter with a payload of 1.5 kg can fly for 30 min considerably improving the number of remote sensors able to equip at the same time and the length of the area studied (Chapman et al., 2014).

The fixed-wing aircrafts offer more simple flight systems and longer durations, increasing their capacity to cover wider areas. However, their flight altitude is higher, thus reducing the image

Download English Version:

https://daneshyari.com/en/article/4478449

Download Persian Version:

https://daneshyari.com/article/4478449

Daneshyari.com