Precision agriculture for pasture, rangeland and livestock systems

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Abstract

Precision agriculture tools have potential to increase productivity and efficiency of grazing systems. Several soil sensors, initially employed in the cropping industry are available to map variability in pasture soils including electromagnetic induction and gamma ray spectrometry. Remote sensing tools for pasture assessment (quantity and quality) have been available for many years however recent application of proximal active optical sensors for pastures offer options for increased utility, both as sensors in their own right as well as for calibrating remote sensing products. Recent advances in spatial monitoring technologies for livestock offer new opportunities to quantify the spatial heterogeneity in pasture utilisation by animals. Integrating these technologies holds great potential for resource management tools such as variable rate fertiliser management, and improving livestock productivity and welfare. This paper briefly reviews current and emerging technologies for monitoring the soil, plant and animal components of a grazing system.

Key Words

Precision pastures, GPS, GNSS, precision livestock, spatial variation

Introduction

Precision agriculture (PA) tools have been in the cropping and horticultural industries for many years but are not yet widely applied to pasture and livestock systems. However, both researchers and producers can see potential benefits from increased productivity and pasture use efficiency that may arise from applying PA tools to grazing systems (Schellberg et al*.* 2008; Virgona and Hackney 2008).

Conceptual frameworks have been developed for precision livestock (Laca 2009) and precision grassland systems (Schellberg et al*.* 2008) and, to lesser extent, integrated animal-plant systems (Hacker et al*.* 2008) however these do not adequately integrate the range of contemporary and emerging PA technologies that can be used to monitor and manage the spatial variability in the soil, plant and animal components of a grazing system. This paper briefly reviews the sensors and technologies available for monitoring the soil, plant and animal components systems in a grazing enterprise with a view to integrating datasets from these sensors to better inform PA management technologies in grazing systems.

Soil monitoring technologies

Like yield monitoring and mapping systems, spatially-enabled soil survey technologies are a ubiquitous part of precision agriculture for cropping enterprises (Adamchuk et al*.* 2004). Direct contact soil sensors are restricted to tilled arable soils, although disc-electrode systems like the Veris conductivity meter (Sudduth et al. 2005) and tine compaction sensors (Gardner and Howard 2009) have some ability to physically penetrate sward covers. However, the sensor response will be influenced by the ground cover and care must be taken in calibrating data from these contact systems. ‘Virtual sensors’ like ground penetrating radar (GPR), electromagnetic induction (EMI) and gamma ray spectrometry (GRS) may be deployed over an established ground cover, provided adequate allowance is made for the effects of variable sensor-surface distance and coupling (Doolittle and Collins 1998) and subsequently hold more potential for application in pasture systems. GPR data have been correlated with soil hydrology parameters (Huisman et al*.* 2003) but its deployment in crops and pastures is constrained by the nature of the underlying soil; requiring good profile delineation to effect a meaningful sensor response (Doolittle and Collins 1998). EMI instruments have been extensively used in cropping and the derived apparent electrical conductivity (eC_a) is known to have a relationship with a number of soil properties including soil moisture, soil texture, soil depth and ion content (Corwin and Lesch 2005). The limited reports of their application in pastures demonstrated some relationships between eC_a and plant species, soil characteristics and pasture productivity (Guretzky et al. 2004; Serrano et al. 2010). GRS involves the measurement of gamma radiation from the radioisotopes of potassium, uranium and thorium (Minty 1997), all of which have been found to relate to soil the parent materials and their weathering (Dickson and Scott 1997). GRS has been found to provide a good local correlations with specific nutrients particularly Potassium along with other soil textural characteristics (Pracilio et al. 2006; Wong and Harper 1999).

Subsoil sensors based on optical reflectance (Bricklemyer and Brown 2010) require a direct view of exposed soil and have been calibrated to a number of soil characteristics. Ultimately the utility to infer soil characteristics lies in the spectral range and resolution of the instrument and these include multi-spectral colour sensors (Escadafal et al. 1989; Reeves 2010) through to visible-near-mid infrared hyperspectral sensors (Reeves 2010). Unless exposed soils can be viewed from above, the primary sensor options are restricted to penetrating probe (Kweon et al. 2008) or tyne-mounted (Bricklemyer and Brown 2010) systems.

Plant monitoring technologies

Vegetation monitoring tools are probably the most common and commercially mature PA tools available to pasture and rangeland managers. As early as the 1980's the value of remote sensing for pasture management was being recognised (Vickery et al. 1980) and commercial remote sensing products have been developed, for example the Pastures From Space (PFS) (Hill et al. 2004), which deliver estimates of forage availability and growth rate directly to graziers. Multispectral and hyperspectral imagery has been applied in precision agriculture for many years (Lamb 2000). Whilst airborne systems are regularly used in cropping (Lamb et al. 2009) it is unlikely that this platform will be widely applied to pastures unless cheaper Unmanned Aerial Vehicle (AUV) platforms are developed. A significant amount of literature is published concerning the use of satellite based remote sensing, primarily using low resolution multispectral (Boschetti et al. 2007; Hill et al. 1999b) and hyperspectral (Numata et al. 2008) systems. A good review can be found in Schellberg et al. (2008). More recently, high resolution systems (Dutkiewicz 2006) have been investigated. PFS, widely considered an exemplar of remote sensing approach, involves the integration of remotely-sensed normalised difference vegetation index measurements (NDVI) with plant growth models (Hill et al. 1999a; Vickery et al. 1999). The recent application of proximal, active optical sensors like Greenseeker™ and Crop Circle™ offer alternative ground-based platforms for deriving similar measures as PFS (Flynn et al. 2008; Trotter et al. 2010a). Other proximal plant sensors investigated for dairy pasture systems include ultrasonic and optical plant height sensors (Awty 2009; Yule et al. 2006). However these sensors developed to date are based predominantly on correlations of height to biomass and suffer from the inability to delineate green and senescent material. Digital image analysis of plant morphology is also gaining interest as a means of weed identification (Schellberg et al. 2008).

Animal monitoring technologies

In recent years there has been a rapid growth in research and development activity in monitoring the spatial behaviour of livestock, catalysed by the emergence of low-cost global navigation satellite systems (GNSS) tracking technology (Trotter et al. 2010b). Whilst simple store-on-board collar tracking units are currently used in research (Trotter et al. 2010b), a number of real-time tracking systems are known to be in development for commercial application (Stassen 2009); particularly based around an ear tag form factor (Schleppe et al. 2010). The applications of spatial livestock monitoring range from simply recording movement and grazing pressure (Trotter et al. 2009) to health and welfare monitoring. More than any other PA technology available to pasture systems, livestock tracking in its own right, or integrated with other 3rd-party, *in vivo* sensors is the key to unravelling many of the mysteries of animal-landscape interactions and has great potential for increasing production and efficiency in the grazing industry.

Other important animal-based monitoring technologies include walk-over-weigh systems (WOW) which offer an excellent tool to better understand and manage animal production (Charmley et al. 2006; Filby et al. 1979). Real-time video streaming either from static mounted cameras and associated digital image analysis is also proving of interest (Van der Stuyft et al. 1991).

Conclusion: opportunities for improved management of pasture systems

The key to success of PA technologies in grazing systems will be the integration of the information provided by the various sensors. For example, variable rate fertilizer applications have been suggested for pastures since the 1980’s (Vickery et al. 1980) however most proposed systems are based on the use of a single technology (mostly remote sensing) and traditional soil sampling. The integration of plant monitoring technologies (remote sensing and active optical sensors) with soil surveys (EM38, gamma ray spectrometry) and an understanding of the spatial utilization of pastures by livestock (GNSS tracking) along with more traditional measures of soil fertility (sampled on a spatial scale using the above technologies to locate sample sites) will enable the land manager to have a far better understanding of the flux of nutrients across his landscape and then formulate a variable rate input strategy. Another example of the potential for monitoring technologies to inform management is in rotational grazing systems where an understanding of the plant system through remote or proximal sensing along with spatial monitoring data from livestock and data from walk-over-weigh systems might enable producers to better schedule rotations to meet the needs of stock whilst maintaining biomass thresholds.

There are many other potential applications of precision agriculture tools in grazing systems and the integration of various sensors holds considerable promise for increasing production and efficiency whilst reducing environmental impacts on pasture and rangeland environments.

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