BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Precision agriculture for sustainability

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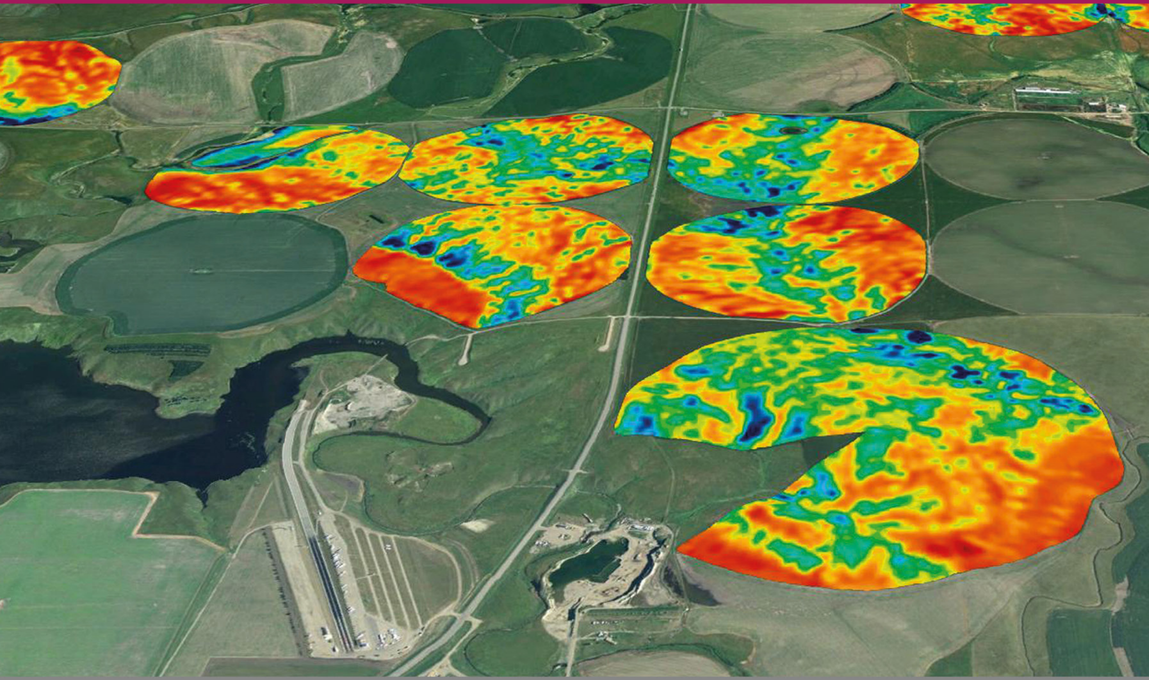

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Introduction

Precision agriculture is based on the ability to identify within-field spatial variability and to use this information for more targeted crop management. By using resources more efficiently, precision agriculture can make agriculture more productive, sustainable and reduce its environmental impact. This volume reviews the key advances in precision agriculture technology and its range of applications. It offers a comprehensive review of key technologies in precision agriculture, from proximal and remote sensing to decision support systems and variable rate technologies The volume surveys key applications of precision agriculture from controlled traffic farming to site-specific nutrient and water management, and includes discussion of the economics of precision agriculture.

Part 1 Information gathering and processing

The chapters in the first part of the volume look at monitoring techniques, including proximal soil and crop sensors and remote sensing technologies. Today's farmers are increasingly reliant on sensors in their farming operations. The theme of Chapter 1 is the use of proximal crop sensor technologies to evaluate a crop during the growing season. After briefly discussing crop properties, the chapter reviews the evolution of crop sensors and then examines three issues in current sensor development: the limitations of current crop canopy sensors; sensing for stresses other than nitrogen; and sensor fusion and high-throughput phenotyping. The chapter includes three detailed case studies showing crop sensing in practice.

Complementing the previous chapter's focus on proximal crop sensor technologies, Chapter 2 looks at proximal soil surveying and monitoring techniques. Understanding soil fertility is fundamental to agricultural production. However, soils can show great variation both spatially and temporally. The chapter outlines the key challenges faced in monitoring such variation and the solutions that have been developed to aid in optimizing crop production. The chapter focuses on proximal soil sensing where a sensor is placed at a very short distance from the soil surface and contact sensors where the sensor is in contact with or buried in the soil. These types of sensors provide information which is particularly useful in developing high resolution soil maps for use in precision agriculture. After discussing sampling methods, the chapter reviews a wide array of sensors, focusing on how such sensors may be integrated into agricultural management.

Moving from proximal to remote sensing systems, Chapter 3 considers airborne and satellite remote sensors for precision agriculture. An overview of airborne imaging systems and multispectral systems based on industrial and consumer-grade cameras is offered, before going on to consider airborne hyperspectral sensors. Examples of the application of airborne imaging systems are reviewed. The chapter offers an overview of high-resolution satellite sensors and the variety of systems available, as well as examples of the application of satellite sensors.

Chapter 4 continues the theme of remote sensing systems by considering the use of unmanned aerial vehicles (UAVs) in precision agriculture. The rapid development of small unmanned aerial vehicles (UAVs) in recent years has triggered considerable interest in their application for precision agriculture. Decreasing cost, ultra-high spatial resolution, and the increased flexibility of image acquisition have made UAS remote sensing an ideal tool for identifying field patterns in close-to-real-time. The chapter provides an overview of UAV platforms and sensors, and flight planning and imagery acquisition, before moving on to consider stitching and ortho-rectification in UAV image processing. The chapter reviews the applications of UAV imagery and methods of image analysis, and includes a detailed case study of practical applications.

The subject of Chapter 5 is the key challenges and methods in identifying management zones. Management zones are sub-regions in a field with relatively homogeneous characteristics which allow targeted treatment (e.g. with fertilizers or pesticides). The chapter examines methods to delineate management zones, including empirical, geostatistical and clustering methods. The chapter offers three detailed case studies, focusing on the delineation of management zones in wine grapes, table grapes and olive oil tree plantations which then allow the use of variable-rate and other delivery systems. The section's final chapter, Chapter 6, looks at modelling and decision support systems (DSSs) in precision agriculture. The chapter examines the key issues associated with deploying DSS in precision agriculture before moving on to consider the human and social aspects of DSS. The chapter provides a number of detailed case studies of the application of DSS, with an emphasis on nitrogen management. Finally, the chapter considers research options for decision support systems to improve productivity in a precision agriculture framework.

Part 2 Delivery systems

The focus of the second part of the volume is the delivery systems required in precision agriculture. Chapter 7 considers variable rate application (VRA) technologies using GNSS (global navigation satellite systems) for accurate location. The application of precision agriculture can be viewed as cyclical in nature, involving data collection, development of management plans, implementing those plans in the field and evaluation of their effectiveness. The chapter examines the characteristics of variable-rate application (VRA) control systems (both liquid and dry), before going on to consider the implementation of both liquid and dry VRA systems. The chapter reviews a number of detailed VRA case studies and summarises the current status of research in this field.

Chapter 8 moves on to examine the deployment of spray technologies in precision agriculture. The application of plant protection products plays a key role in the production of most crops. Equipment designed to operate with field crops are examined (although many of the principles discussed also relate to other application systems). The chapter describes features of field crop sprayers for precision agriculture, including control of delivered dose, spatial resolution, matching physical characteristics of sprays to target requirements, and minimising drift and exposure of systems outside the treatment area. Two detailed case studies are included which focus on designing and developing a system for spot treatment of volunteer potatoes and implementing a patch spraying system for applying herbicides to field crops.

Complementing the themes of the preceding chapters, Chapter 9 looks at the use of intelligent machinery for precision agriculture. The innovative core of modern precision agriculture is the use of agricultural machinery to perform precise, responsive field operations in large-scale mechanized precision crop production. Integration of autonomous functions into such machinery endows it with capabilities which could be described as 'intelligent'. These include perception, reasoning and control of operations in the field with the flexibility to achieve predetermined operational goals without human supervision. The chapter reviews the current state-of-the-art in intelligent agricultural machinery and discusses automated guidance systems based on GNSS (global navigation satellite systems), as well as path planning, automated actuation systems and implement controls. Finally, the chapter discusses the prospects for creating increasingly autonomous systems and considers the potential implications of such technology.

The concluding chapter of the section, Chapter 10, looks at controlled traffic farming (CTF) in precision agriculture. In the past few decades, there has been a continuous drive towards the development and adoption of larger, and more powerful, agricultural machinery. Larger machinery is often related with timeliness, higher work rates and lower labour requirements, which has led to significant improvements both in efficiency and productivity but with the serious drawback of damage to soil structure. The chapter defines and outlines the requirements of controlled traffic farming systems based on GNSS (global navigation satellite systems), examines the sustainability of controlled traffic farming and looks at the feasibility of coupling controlled traffic farming with precision agriculture.

Part 3 Applications

The third and final section of the volume examines applications for precision agriculture technologies, beginning with a consideration of precision tillage systems in Chapter 11. The commercial development of information-intensive precision agriculture technologies has given rise to a number of applications aimed at improving agricultural production through site-specific management, including precision tillage. The chapter describes developments in on-the-go soil strength sensing and the state of the art in sensor technology as applied to precision tillage. The chapter examines depth-prescribed tillage to control subsoil compaction, techniques of soil sensing to enable precision tillage, and how to extract information from soil sensors. Finally, the chapter looks at the challenge of implementing depth control and tractor/implement guidance technology.

Chapter 12 moves from precision tillage to consider variable seeding systems for precision agriculture. Variable-rate seeding (VRS) is the practice of adjusting the seeding rate or amount across a field in order to maximise yield and profit. This method of precision agriculture relies on site-specific data such as soil type, landscape position and yield maps. In the last decade, adoption of this method has dramatically increased as new planter technologies have emerged. The chapter summarises current practices in VRS, reviewing the available technology and discussing the key strategies in its implementation. It also discusses the economic value of VRS and the conditions in which it could produce the greatest economic return.

The theme of Chapter 13 is site-specific nutrient/fertiliser management systems. The chapter describes the processes that inform site-specific nutrient management, including grid sampling, construction of management zones, in-season crop sensing and grain quality sensing. The chapter considers regional perspectives on nutrient/fertiliser management systems, including case studies taken from both the sub-humid US Midwest and semi-arid US West.

Continuing with the theme of site-specific systems, Chapter 14 considers site-specific irrigation systems. Conventional irrigation management is based on uniform application of water across a field, which may result in both over- and under-irrigation. The chapter focuses on site-specific variable rate irrigation (SS-VRI) using center pivot and lateral move irrigation systems, which are mainly used for row-crop irrigation. Via detailed case studies, the chapter examines site-specific data acquisition and mining approaches, soil mapping, zone delineation, site-specific yield estimation and irrigation scheduling. The chapter also looks ahead to new forms of irrigation that may become available in the future for fixed sprinkler, drip and surface irrigation systems, as well as potential applications in nursery and urban irrigation settings.

The theme of Chapter 15 is precision crop protection systems. The spatial distribution of plant pests within crops is often heterogeneous particularly during growth periods. Within-field heterogeneity implies that plants at some sites may need pest control while plants at other sites do not. Automated detection, identification and quantification of diseases and invertebrate pests on a small scale are the prerequisites for a site-specific pest management strategy. The chapter reviews how sensor technologies in combination with informatics and modern application technologies may enable pest control where and when it is actually needed. The chapter summarizes and discusses the potential of aerial and proximal remote sensing using various types of sensors for applications ranging from quarantine, to the production of speciality crops and crop loss assessment.

Complementing the preceding chapter's focus on crop protection, Chapter 16 looks specifically at precision weed management systems. Weed populations in arable fields are often spatially and temporally heterogeneous, and high-density weed patches require intensive weed management. In areas with no or few weeds, input for weed control can be reduced. Manual and GIS-based weed mapping approaches and sensor-based weed identification technologies and their application to create weed maps are described. The chapter also discusses the adoption of patch sprayers based on two alternative approaches; application maps and real-time sensor information. It is shown that site-specific weed control in cereals, oil-seed rape, sugar beet and maize using GNSS-controlled patch sprayers can reduce herbicide input by 20–60%. Looking ahead, the development of precision farming technologies for mechanical weeding, including automatic steering systems for intra-row hoeing and robotic inter-row weeding are considered.

Chapter 17 examines precision livestock farming and pasture management systems. Animal management seeks to first measure the variability of animal production, disease or welfare and then prescribe targeted management strategies and treatments. The chapter reviews a range of technologies currently applied or in development which facilitate this individual animal management across the spectrum of extensive grazing production systems using GNSS (global navigation satellite systems). The challenges facing the livestock industry and the potential solutions offered by precision management, focussing particularly on precision pasture management, are examined. The chapter includes detailed case studies on using a basic farm GIS to determine sustainable long term stocking rates, and integrating satellite multispectral imaging with plant growth modelling to manage livestock rotations.

The final chapter of the volume, Chapter 18, focuses on the economics of precision agriculture. Topics reviewed include data on use of precision agriculture in the production of agronomic crops, whether economic research has correctly predicted adoption of precision agriculture technologies by farmers. Several precision agriculture technologies that recent economic research has identified as having profit and adoption potential are discussed. The chapter examines the adoption of precision agriculture technology, the economics of precision agriculture adoption, and seeks to predict future trends based on recent studies of precision agriculture profitability.

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