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Muhammad Azhar Iqbal



Digital Agriculture

An Introduction

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Muhammad Azhar Iqbal

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Muhammad Azhar Iqbal
University of Leeds
Leeds, UK

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With profound gratitude, to all individuals, from diligent farmers to cherished family members, who steadfastly engage in the noble tasks of cultivating, packaging, supplying, and presenting food, from the bountiful fields to the dining tables.

Preface

Through discussions with academicians and undergraduate students rooted in agricultural disciplines, it is observed that instructors and students alike (particularly in developing nations) have little knowledge about the availability and utilization of Information and Communication Technologies (ICT) in agriculture. Therefore, I discerned a dire need to introduce them the fundamental principles, underlying concepts, and benefits regarding the availability and utilization of advanced digital technologies and techniques that are practiced in developed countries and ensure environmental sustainability with higher agricultural yields at lower cost. This book aims to provide a foundational resource for instructors and undergraduate students devoid of prior exposure to digital technologies in agriculture. The key feature of this book is its elucidation of the significance and utilization of digital technologies and methodologies in managing the flow of agricultural information from the data acquisition phase to the data analysis phase while offering a user-friendly approach to understanding the design of modern digital agriculture systems. Each chapter concludes with some case study questions designed to assess readers' comprehension of the discussed concepts in that chapter. To the best of my knowledge, this book marks the first endeavor to explain the impact of advanced technologies on the digitalization of agricultural operations while considering all phases of an ICT-based digital agriculture ecosystem. Therefore, it can be considered a foundational textbook at the undergraduate level, especially in universities where dedicated modules on agricultural digitalization are still not part of the curriculum. To address the issues related to the understanding of digital agriculture fundamentals, this book is structured as follows:

Chapter 1 serves as an introduction while delineating the evolution, revolutions, driving factors, vision, definition, types, and framework of digital agriculture systems. Chapter 2 delves into the placement of enabling digital technologies essential for automating the monitoring and management of agricultural operations with a focus on the fundamental aspects of agricultural data digitalization across various phases of agricultural production. The discussion extends to the

layered architecture of IoT-based Agricultural Ecosystems, laying the groundwork for subsequent chapters.

Chapter 3 revolves around data acquisition in agricultural settings, explicating the roles of various digital acquisition technologies such as RFID (Radio Frequency Identification), sensors, RFID-based sensors, smartphones, remote sensing platforms, and development boards.

Chapter 4 explores the role of short-range, long-range, cellular, satellite, and broadband communication technologies in transmitting data from agricultural fields to cloud servers.

Chapter 5 sheds light on the concept of agricultural Big Data, introducing key enabling technologies for its storage and processing on edge, fog, and cloud servers.

Chapter 6 outlines basic analytical techniques, both statistical and machine learning-based, and visualization technologies crucial for analyzing agricultural Big Data.

Chapter 7 underscores the benefits of Digital Agriculture and delineates future directions in this domain.

Leeds, UK

Muhammad Azhar Iqbal

Contents

1	Fundamentals of Digital Agriculture	1
1.1	Learning Objectives	1
1.2	Agriculture	1
1.3	Evolution of Agricultural Systems/Farming	2
1.3.1	Brief History of Farming Systems	2
1.3.2	Agricultural Revolutions	6
1.4	Digital Agriculture	8
1.4.1	Driving Factors for Digital Agriculture	9
1.4.2	Types of Digital Agriculture	10
1.5	Digital Agriculture Framework	11
	References	13
2	Digital Agriculture Ecosystem	15
2.1	Learning Objectives	15
2.2	Ecosystem	15
2.3	Agricultural Ecosystem	16
2.4	Digital Ecosystem	16
2.5	Digital Agricultural Ecosystem	17
2.6	Data Processing in Digital Agriculture Ecosystem	19
2.6.1	Data Acquisition	20
2.6.2	Data Transmission	20
2.6.3	Data Storage	21
2.6.4	Data Analytics	21
2.7	Layered Architecture of IoT-Based Agricultural Ecosystem	22
	References	25

3	Data Acquisition in Digital Agriculture	27
3.1	Learning Objectives	27
3.2	Agricultural Data Acquisition	27
3.3	RFID Systems	28
3.4	Sensing Technology and Sensors	30
3.5	Sensor Networks	30
3.6	RFID-Based Sensor Networks	35
3.6.1	Soil Monitoring with RFID-Based Sensors	36
3.6.2	Plant Growth Monitoring with RFID-Based Sensors	36
3.6.3	Environmental Monitoring with RFID-Based Sensors	36
3.7	Smart Phone Technology	37
3.8	Remote Sensing	39
3.9	Development Boards and Data Acquisition	39
3.9.1	Single-Board Microcontroller (SBM)	40
3.9.2	Single-Board Computer (SBC)	40
3.9.3	SBM and SBC Comparison	41
3.9.4	Role of Development Boards in Agricultural Data Acquisition	43
	References	45
4	Data Communication in Digital Agriculture	47
4.1	Learning Objectives	47
4.2	Agricultural Field Data Transmission	47
4.3	Wireless Communication	48
4.3.1	Short-Range Communication Technologies	48
4.3.2	Long-Range Communication Technologies	52
4.3.3	Wireless Local Area Communication Technologies	54
4.3.4	Cellular Communications	55
4.3.5	Satellite Communications	56
4.4	Broadband Networks	56
	References	59
5	Data Storage in Digital Agriculture	63
5.1	Learning Objectives	63
5.2	BigData and Agricultural BigData	63
5.3	Driving Factors and Challenges of BigData Implication in Digital Agriculture	64
5.4	Types of Agricultural BigData	67
5.4.1	Structured Data	67
5.4.2	Semi-structured Data	70
5.4.3	Unstructured Data	73
5.5	The Cloud	73
5.5.1	Cloud Storage	74
5.5.2	Cloud Computing	77
5.6	Edge Computing and Fog Computing	79
5.6.1	Agricultural Use Cases of Edge/Fog Computing	80

- 5.6.2 Example of Fog Computing Advantage Over Cloud Computing 81
- References 84
- 6 Data Analytics in Digital Agriculture 87**
 - 6.1 Learning Objectives 87
 - 6.2 Data Analytics and Digital Agriculture 87
 - 6.3 BigData Analytics Categories and Digital Agriculture 89
 - 6.3.1 Descriptive Analytics 89
 - 6.3.2 Diagnostic Analytics 91
 - 6.3.3 Predictive Analytics 91
 - 6.3.4 Prescriptive Analytics 92
 - 6.4 Data Mining and Digital Agriculture 93
 - 6.4.1 Data Mining 93
 - 6.4.2 Text Mining 93
 - 6.5 Statistical Approaches and Agricultural BigData Analytics 97
 - 6.5.1 Descriptive Statistics 97
 - 6.5.2 Inferential Statistics 98
 - 6.6 Role of Machine Learning and NLP for Agricultural BigData Analytics 100
 - 6.7 Data Visualization in Digital Agriculture 102
 - References 106
- 7 Impacts and Future Directions of Digital Agriculture 109**
 - 7.1 Learning Objectives 109
 - 7.2 Impacts of Digital Agriculture 109
 - 7.3 Human–Computer Interaction (HCI) 110
 - 7.4 Web Technology and Web Service 111
 - 7.5 Agricultural Expert Systems and Decision Support Systems 112
 - 7.6 Benefits of Digital Agriculture 114
 - 7.6.1 Increased Production 114
 - 7.6.2 Expedite Communication 115
 - 7.6.3 Effective Remote Monitoring 115
 - 7.6.4 Real-Time Visualization 115
 - 7.6.5 Community Farming 115
 - 7.6.6 Automation of Agricultural Farm Management System 115
 - 7.6.7 High-Quality Production 116
 - 7.6.8 Safety and Fraud Prevention 116
 - 7.6.9 Agility 116
 - 7.6.10 Equipment Monitoring 117
 - 7.6.11 Security and Management of Farm Assets 117
 - 7.6.12 Livestock Monitoring and Management 117
 - 7.6.13 Support Closed-Cycle Agricultural Systems 117
 - 7.6.14 Market Price Awareness and Profit Creation 118
 - 7.6.15 Cost Reduction 118

7.6.16	Decision-Making Efficiency	118
7.6.17	Recognition and Classification of Plant Species	118
7.6.18	Monitoring of Indoor Farming	118
7.6.19	Sustainable and Resource-Efficient Practice	119
7.7	Future Directions in Digital Agriculture	120
	References	123
Appendix: Answers to Questions Given at the End of Each Chapter		125
Index		149

About the Author

Muhammad Azhar Iqbal completed his Ph.D. in Communication and Information Systems in 2012 from Huazhong University of Science and Technology (HUST), China. Later, he worked in different universities on different positions. Prior to his current tenure as Assistant Professor at the University of Leeds, he held significant roles (as Teaching Fellow) at Lancaster University (LU, United Kingdom), (as Associate Professor) at Southwest Jiaotong University (SWJTU, China), and (as Associate Professor) at Capital University of Science and Technology (CUST, Pakistan). He has received senior membership IEEE and fellowship of the Higher Education Academy. He has authored several international conferences/journal publications and leading author of two books on the topic of Network Simulations and Internet of Things (IoT). His current research interest is at the cutting edge of agriculture digitalization, and he is dedicated to developing artificial intelligence-based solutions aimed at improving sustainable crop/animal production systems. e-mail: m.a.iqbal@leeds.ac.uk

Chapter 1

Fundamentals of Digital Agriculture



1.1 Learning Objectives

After studying this chapter, students will be able to

- articulate the definition of Agriculture
- describe the brief history and evolution of agricultural farming systems
- indicate the correspondence of agricultural revolutions with industrial revolutions
- explain the concept of Digital Agriculture
- elaborate the types of Digital Agriculture
- point out the components of the Digital Agriculture Framework

1.2 Agriculture

Agriculture serves the fundamental demands and necessities of humans with the provisioning of food (i.e., crops, vegetables, fruits, herbs, spices, beverages, plants, meat, milk, eggs, honey, oil, etc.), clothing (i.e., cotton, wool, silk, leather, etc.), and sheltering (i.e., lumber, carpeting, plastics, etc.). Likewise, it helps humans with medicine, household items, fuel, and recreation. The word Agriculture is derived from the Latin word *Agricultura*, which is ultimately a combination of two Latin words *Ager* (means land or field) and *Cultura* (means cultivation or growing). Thus, in the literal sense, the word Agriculture means the cultivation of land. However, the agriculture study is not only concerned with crop cultivation and planting trees but also with rearing livestock (Harris and Fuller 2014; Chandrasekaran et al. 2010). Consequently, Agriculture can be defined as “the art and science of cultivating soil, growing crops, and rearing livestock for economic purposes” (Oxford lexico dictionary. <https://www.lexico.com/en/definition/agriculture>; National geographic society. <https://education.nationalgeographic.org/resource/the-art-and-science-of-agriculture/>). As an Art, agriculture emphasizes the utilization of the knowledge and skills to perform

cultivation and farming of crops and livestock to attain optimum yield. From this perspective, it includes the applicability of prior knowledge with physical (i.e., sowing, plowing, spraying of pesticide and fertilizer, etc.) and mental (i.e., crop selection, plowing method, sowing technique, spatial and temporal aspects of cropping system, etc.) skills. On the other hand, as a *Science*, agriculture promises to employ advanced technologies (based on scientific principles) for the production, management, and protection of crops/plants/trees and livestock to obtain optimum yield while considering the climatic and geographical conditions of a certain area. From a scientific perspective, it includes the adoption of modern techniques for all essential agricultural practices i.e., land management, crop cultivation, crop production, crop protection, fertilization, breeding, hybridization, etc. In recent times, these modern techniques rely heavily on digital and computing technologies e.g. sensing technology, wireless communication, and broadband (Internet) technology for data collection and transmission, fog and cloud computing models for systematic storage of collected data, use of artificial intelligence to improve data analysis efficiency and accuracy, etc. This trend of agricultural digitalization brings innovations to all branches of agriculture (mainly classified into five categories i.e., Crop/Plant/Tree Production and Management, Crop/Plant/Tree Improvement, Crop/Plant/Tree Protection, Animal/Livestock Farming, Allied Disciplines (Chandrasekaran et al. 2010) as shown in Fig. 1.1) and helps agriculturists to work more precisely, efficiently, and sustainably. Before delving into the details of all the innovations determining the current era of “agricultural digitalization”, it is important to discuss the evolutionary process of agriculture that supports the adoption of different tools, techniques, and technologies to fulfill the domestic and global demands of food production in different eras of time.

1.3 Evolution of Agricultural Systems/Farming

Since its inception, agriculture has been an evolutionary process and people adopted different approaches to cultivating land and livestock rearing. Below, the history of different farming systems and agricultural revolutions provides a brief overview to help you understand the patterns and characteristics of different farming systems.

1.3.1 *Brief History of Farming Systems*

Around 12,000 years ago, mankind started agriculture with the collection of grains and the hunting of wild animals for food. Later, human beings took the initiative to cultivate crops and domestication of animals to satisfy the demand for growing families. Since then, a plethora of organized and systematic ways have been adopted to increase the agricultural yield that was ultimately required to satisfy the food demands of the growing human population (Chandrasekaran et al. 2010; Thrall et al.