Introduction to Biosystems Engineering

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Introduction to Biosystems Engineering

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Preface

The discipline of Biosystems Engineering emerged in the 1990s from the traditional strongholds of Agricultural Engineering and Food Engineering. Biosystems Engineering integrates engineering science and design with applied biological, environmental, and agricultural sciences. This book is targeted at 1st- and 2nd-year university-level students interested in Biosystems Engineering but not yet familiar with the breadth and depth of the subject. It is designed as a coherent educational resource, available as hard copy and for download as individual digital chapters.

The origins of the book date back to 2012, when a group of universities, led by University College Dublin (Ireland) in the European Union (EU) and Virginia Tech in the United States (US), began working on an EU-US Atlantis Programme project called *Trans-Atlantic Biosystems Engineering Curriculum and Mobility* (known as TABE.NET). One of the project activities was to explore the meaning of Biosystems Engineering. An important output of the work was the framework for an introductory course focused on Biosystems Engineering. This detailed how students might best be introduced to the subject and formed the basis for this textbook. The preparation of the textbook was supported by the American Society of Agricultural and Biological Engineers (ASABE) *Harold Pinches and Glenn Schwab Teaching Materials Fund*, intended for projects that "facilitate development or effective distribution of ASABE teaching materials, including textbooks," and the Virginia Tech University Libraries' Open Education Initiative (https://guides.lib.vt.edu/oer/grants). The writing and editing were provided as voluntary service by the authors and editors, and the ASABE funding supported the publication process so the online version of the book can be made freely available around the world (ASABE.org/BE).

The chapters are intended to stimulate interest and curiosity across the breadth of Biosystems Engineering and provide an international perspective. The goal of each chapter is to introduce the fundamental concepts needed to understand a specific topic within the discipline of Biosystems Engineering; it is not intended to provide complete coverage of the topic. The scope of each chapter is narrow enough to be addressed in one week.

All chapters follow the same structure: Introduction, Outcomes, Concepts, Applications, and Examples. Following a brief introduction, the learning outcomes state what the reader should be able to do after studying the chapter. The outcomes are consistent with expectations for a student engaging with the topic for the first time, and include being able to describe basic principles,

complete fundamental calculations, and explain how the concepts are used in industry or by researchers. The concepts section covers basic principles and explains terminology, referencing commonly used sources and using internationally accepted units. Once the concepts have been described they are put into the context of applications in industry and research to help bring them to life. All chapters conclude with worked examples drawing on the concepts so that the reader can see how the information provided can be used to solve basic problems in Biosystems Engineering. The chapter structure used by this textbook could also be used to develop advanced textbooks delving deep into any topic relevant to Biosystems Engineering.

The inaugural chapters are aligned with six ASABE technical communities: Energy Systems; Information Technology, Sensors, and Control Systems; Machinery Systems; Natural Resources and Environmental Systems; Plant, Animal, and Facility Systems; and Processing Systems.

The *Energy Systems* section focuses on energy from biomass. The section places emphasis on feedstock and anaerobic digestion, but considers a wider range of technologies from a systems perspective. Specific topics addressed in this edition are densification of biomass; energy from organic wastes, fats and oils; and bioenergy systems analysis. There is scope for future chapters on other topics relevant to this community such as electrotechnology, feedstocks, and renewable power.

The *Information Technology, Sensors, and Control Systems* section focuses on processing optical sensor data and basic control. The section places emphasis on statistical methods as well as practical applications. Specific topics include use of optical sensors, multivariate data processing, and microcontrollers. Future chapters in this area could focus on topics such as automation, biosensors, robotics, sensors, and wireless technology.

The *Machinery Systems* section features agricultural technologies used for field crops, placing emphasis on the fundamental principles of equipment design. Current chapters focus on traction and mechatronics, which are topics that are relevant to multiple machinery systems, and on machinery systems for crop establishment and grain harvesting. Topics for future chapters could include automation, hydraulics, ISO bus, precision agriculture, and other machinery systems.

The *Natural Resources and Environmental Systems* section highlights the management, protection, and improvement of environmental resources including soil, water, and air. This section places emphasis on field, laboratory, and modeling studies related to environmental systems. Specific topics addressed are the measurement of gaseous emissions, water budgeting, water quality, soil erosion, and management of agri-food by-products using anaerobic digestion. Examples of technical areas for future chapters relevant to this community are drainage, irrigation, soil and water remediation, wetlands restoration, and sustainable land management.

The *Plant, Animal, and Facility Systems* section focuses on indoor plant and animal production. The current chapters emphasize mass and heat transfer for design and operation of agricultural buildings. Specific topics include plant production in controlled environments and energy efficiency for livestock

housing. Future chapters relevant to this community could include topics such as grain handling, design of animal production structures, milk handling, manure management, feed storage and management, and aquaculture.

The *Processing Systems* section focuses on the safe processing and distribution of foods. This section places emphasis on heat and mass transfer and delivery of safe food to consumers. Specific topics addressed are food packaging, frying, and preservation by freezing, thermal processing, and irradiation. There is scope for future chapters on other topics relevant to this community such as food engineering, bioprocessing, bioconversion, drying, and unit operations.

While each chapter is placed in a single section, many of the topics are relevant to more than one section, or technical community. The "Anaerobic Digestion of Agri-Food By-Products" chapter in the *Natural Resources and Environmental Systems* section nicely illustrates the overlap between technical communities. Anaerobic digestion is both an environmental technology for the management of wastes and an energy technology for the provision of renewable energy. The chapters in the *Plant, Animal, and Facility Systems* section also overlap with the *Energy Systems* technical community because of the role of energy, or heat transfer, management in indoor plant and livestock production. The mechatronics chapter in *Machinery Systems* overlaps with the *Information Technology, Sensors, and Control Systems* community.

There is scope for contribution of introductory level chapters from the other ASABE technical communities, *Applied Science and Engineering* (e.g., forest engineering, fermentation, engineering and biological fundamentals), *Education, Outreach, and Professional Development* (e.g., ethics and professional conduct), and *Ergonomics, Safety, and Health* (e.g., vibration, farm safety, ergonomic design, health and safety training) for the ongoing development of the ASABE digital education resources.

Our ambition is for this textbook to continually evolve, with the addition of new online chapters every year and periodic publication of hard copy volumes. Each new chapter will follow the standard structure described above and focus on a specific topic. We believe that in time the textbook will provide a foundational resource used all over the world by students learning about Biosystems Engineering for the first time.

In parallel with the preparation of this book, the editors, with the support of the ASABE *Initiative Fund*, have been developing the *Biosystems Engineering Digital Library (BEDL)*. This resource will support instructors by providing additional teaching and learning materials for use in the classroom and for assignments. While the library will not be limited to the scope of this book, from the outset it will be used to support both instructors and students who use this book. We believe this textbook combined with the BEDL will provide a global digital teaching resource for Biosystems Engineering for many years (ASABE.org/BE).

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The editors-in-chief have overall responsibility for the book, including approval of content and editing. They established the team of technical community editors (listed below).

Nicholas M. Holden is Professor of Biosystems Engineering and Head of Teaching and Learning in the School of Biosystems and Food Engineering at University College Dublin, where he has worked for the last 25 years. His research is focused on the environmental impact and sustainability of agriculture, and food systems. He teaches life cycle assessment, precision agriculture, and green technology project modules and is the Programme Director of the BAgrSc Agricultural Systems Technology programme. He has been an ASABE member for over 20 years.

Mary Leigh Wolfe is Professor in the Department of Biological Systems Engineering (BSE) at Virginia Tech. After serving on the faculty at Texas A&M University for over six years, she moved to Virginia Tech in 1992. Recently, she served as head of the BSE department for over eight years. Her research and teaching has focused on hydrologic modeling, nonpoint source (NPS) pollution control strategies, and decision support tools for NPS pollution control and watershed management. She has also conducted research related to engineering education. She is a Fellow, past president, and life member of ASABE.

Jactone A. Ogejo is an Associate Professor in the Department of Biological Systems Engineering (BSE) at Virginia Tech. His research and extension programs focus on improving the management and use of bioresidues from production agriculture and food processing. His work encompasses recovering value-added products from bioresidues, agricultural air quality, and, more importantly, advancing knowledge to increase the acceptance and adoption of technology for manure management on animal production farms. He has been an ASABE member since 1992.

Enda J. Cummins is a Professor and Head of Research, Innovation and Impact in the School of Biosystems and Food Engineering at University College Dublin. His main research area is food safety, risk assessment, and predictive modelling, with a particular focus on implications for human health and environmental contamination. He teaches quantitative risk assessment, food physics, and research and teaching methods. He is Programme Director for the Masters of Engineering Science in Food Engineering at UCD. He has been an ASABE member since 2002.

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