Preface

Mixed-species stands are widely thought to provide many forest functions and services to a higher level than monocultures. However, the scientific foundations of forest management, from analyses and measurements to modelling and knowledge application, have been largely derived from monocultures. More recently, there has been a growing body of evidence showing that the effects of mixing different tree species on ecosystem functions are not simply a combination of the effects of each participating species in monoculture. It is precisely this question, how the performance of polycultures compares with that of monocultures or more simple forests, that determines whether forest owners decide for or against establishing and maintaining mixed-species stands. However, the available knowledge was so far rather fragmented and could not provide a holistic picture of mixed-species forests. Until now, a textbook has been missing to synthesise the existing knowledge and provide answers to questions such as:

Which concepts of the dynamics and management of mixed-species stands are available, how generalisable are they, and what kind of experiments are necessary to develop them further?

How do mixed-species stands compare with monocultures in relation to productivity, ecological stability, and wood quality?

How do mixing effects on ecosystem functioning depend on the species composition, site conditions, and stand structure?

How does any over- or underyielding at the level of forest stands emerge from the tree and organ level, and what are the main mechanisms behind the mixing effects?

How can any facts, findings, and models in mixed-species stands be efficiently integrated in silviculture, management, and planning in forest practice?

Do ecological characteristics of mixed-species stands also translate into economic differences compared with monocultures?

These and other questions are in the focus of this book. In addition, it will address experimental designs and analytical approaches required to study mixed-species forests and provide empirical facts and findings, general relationships, models, and management tools. These differ in many ways from established

concepts developed for monocultures. However, our work for this book has also identified many open questions. To better understand, model, and manage mixed-species forests, many additional measurements of resources and environmental factors, tree and stand structures, and growth and allocation are required. The ambition is to measure and quantify as many relevant system attributes as possible. Those variables which are not yet sufficiently measured or accessible are often replaced by nonspecific proxies such as site index, growing space, real niche, or crown volume. We hope that these gaps can be filled in the future to develop a more process-based understanding of mixed-species forests.

The content of this book is meant for students, scientists, lecturers, forest planners, forest managers, forest experts, and consultants.

The editors and main authors of the book Hans Pretzsch (HP), David Forrester (DF), and Jürgen Bauhus (JB) could not have completed the book without their co-authors Thomas Knoke (TK) and Thomas Rötzer (TR) from the Technical University of Munich, Germany. Several others have provided valuable contributions to individual chapters, where this is indicated.

The first seven chapters of the book synthesise the existing empirical knowledge about mixed-species forest and its theoretical underpinning development. Chapter 1 (Mixed-Species Forests: The Development of a Forest Management Paradigm. JB, DF, and HP) summarises the background and approaches of research in mixed-species stands. Chapter 2 (From Observations to Evidence About Effects of Mixed-Species Stands. JB, DF, and HP) presents theoretical concepts and hypotheses related to mixed-species and diverse forests and discusses approaches to study their ecological functioning and dynamics. Chapter 3 (Ecological and Physiological Processes in Mixed Versus Monospecific Stands. DF) introduces the basic processes behind any emergent properties of mixed-species stands compared with monocultures. Chapter 4 (Stand Dynamics of Mixed-Species Stands Compared with Monocultures. HP and DF), Chap. 5 (Size-Structure Dynamics in Mixed Versus Monospecific Stands. HP), and Chap. 6 (Individual Tree Structure and Growth in Mixed Compared with Monospecific Stands. HP) trace mixing effects from the stand level to community, population, tree, and organ level. The overview of mixed-species stand development is completed by Chap. 7 (Ecological Stability of Mixed-Species Forests. JB, DF, HP, and others) which analyses whether mixtures are more resistant and resilient in relation to abiotic and biotic stress and disturbance.

Chapter 8 (Modelling Mixed-Species Forest Stands. HP, TR, and DF) describes common models for monospecific stands and discusses the environmental conditions, processes, and structures that need to be included in forest growth models to be applied to mixed-species forests. The focus is on how these different processes are incorporated into models and the strengths and weaknesses of tree-level and stand-level approaches.

The next three chapters are dedicated to the integration of biophysical knowledge into silvicultural practice, forest management planning, and economic analyses. Chapter 9 (Silvicultural Options for Mixed-Species Stands. JB, DF, HP, and others) discusses approaches and guidelines for natural and artificial

establishment, tending, thinning, and regeneration of mixed-species stands. Whereas the focus of the first chapters is at the stand level, application of the results in forest planning and management, in contrast, requires extension to the enterprise or landscape level, which is discussed in Chaps. 10 and 11 (Forest Management Planning in Mixed-Species Forests. HP and TK. Economics of Mixed Forests. TK). The book ends with Chap. 12 (Perspectives for Future Research Directions on Mixed-Species Systems. HP, DF, JB, TK, and Carola Paul) which presents identified knowledge gaps and perspectives for future research. A glossary including the key terms complements this first textbook on mixed-species forests.

When writing this book, Hans Pretzsch, Thomas Knoke, and Thomas Rötzer could build on their research and lectures at the Ludwig Maximilian University and Technical University of Munich. Jürgen Bauhus and David Forrester based their contributions on their research and teaching at the Albert-Ludwigs-University of Freiburg. This book is dedicated to all students, researchers, and colleagues at the above-mentioned institutions who have contributed to the realisation of this book. In addition, we are grateful to Hervé Jactel, Ramón Vallejo, Barry Gardiner, Adam Felton, Patrick Pyttel, Adam Benneter, and Carola Paul who made specific contributions to Chaps. 7, 9, and 12.

For the review of substantial parts and individual chapters of the manuscript, we are deeply indebted to Dan Binkley of Colorado State University, USA; Jette Bredahl Jacobsen of the University of Copenhagen, Denmark; Hubert Sterba and Manfred Josef Lexer both of the University of Natural Resources and Life Sciences, Vienna, Austria; Jerry Vanclay of Southern Cross University, Lismore, Australia; and Charles Nock of the University of Freiburg.

We further thank many students for prereviewing the manuscripts, Gerhard Schütze for data analyses, Ulrich Kern for the graphical artwork, Emily Kilham and Astrid Moser for language revision of some chapters, and Germar Csapek and Beate Felsl for proofreading and assistance with the glossary.

Finally, we also extend our thanks to the editor at Springer Publishing, Christine Eckey, for her reliable and congenial assistance and great patience.

Freising-Weihenstephan and Freiburg	Hans Pretzsch
Germany	David I. Forrester
Spring 2017	Jürgen Bauhus