Agroforestry in Europe

Current Status and Future Prospects

Advances in Agroforestry

Volume 6

Series Editor:
P.K.R. Nair
School of Forest Resources and Conservation,
University of Florida, Gainesville, Florida, U.S.A.

Aims and Scope

Agroforestry, the purposeful growing of trees and crops in interacting combinations, began to attain prominence in the late 1970s, when the international scientific community embraced its potentials in the tropics and recognized it as a practice in search of science. During the 1990s, the relevance of agroforestry for solving problems related to deterioration of family farms, increased soil erosion, surface and ground water pollution, and decreased biodiversity was recognized in the industrialized nations too. Thus, agroforestry is now receiving increasing attention as a sustainable land-management option the world over because of its ecological, economic, and social attributes. Consequently, the knowledge-base of agroforestry is being expanded at a rapid rate as illustrated by the increasing number and quality of scientific publications of various forms on different aspects of agroforestry.

Making full and efficient use of this upsurge in scientific agroforestry is both a challenge and an opportunity to the agroforestry scientific community. In order to help prepare themselves better for facing the challenge and seizing the opportunity, agoroforestry scientists need access to synthesized information on multi-dimensional aspects of scientific agroforesty.

The aim of this new book-series, *Advances in Agroforestry*, is to offer state-of-the art synthesis of research results and evaluations relating to different aspects of agroforestry. Its scope is broad enough to encompass any and all aspects of agroforestry research and development. Contributions are welcome as well as solicited from competent authors on any aspect of agroforestry. Volumes in the series will consist of reference books, subject-specific monographs, peer-reviewed publications out of conferences, comprehensive evaluations of specific projects, and other book-length compilations of scientific and professional merit and relevance to the science and practice of agroforestry worldwide.

For other titles published in this series, go to
www.springer.com/series/6904

Antonio Rigueiro-Rodríguez • Jim McAdam
María Rosa Mosquera-Losada
Editors

Agroforestry in Europe

Current Status and Future Prospects

Springer

Dr. Antonio Rigueiro-Rodríguez
University of Santiago de Compostela
Lugo, Spain

Dr. María Rosa Mosquera-Losada
University of Santiago de Compostela
Book Coordinator
Lugo, Spain

Dr. Jim McAdam
Agri-Food and Biosciences Institute
and Queen's University
Belfast, UK

ISBN: 978-1-4020-8271-9 e-ISBN: 978-1-4020-8272-6

Library of Congress Control Number: 2008928525

Cover photograph by José Javier Santiago Freijanes.

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

Foreword

Agroforestry has come of age during the past three decades. The age-old practice of growing trees and crops and sometimes animals in interacting combinations – that has been ignored in the single-commodity-oriented agricultural and forestry development paradigms – has been brought into the realm of modern land-use. Today agroforestry is well on its way to becoming a specialized science at a level similar to those of crop science and forestry science.

To most land-use experts, however, agroforestry has a tropical connotation. They consider agroforestry as something that can and can only be identified with the tropics. That is a wrong perception. While it is true that the tropics, compared to the temperate regions, have a wider array of agroforestry systems and hold greater promise for potential agroforestry interventions, it is also true that agroforestry has several opportunities in the temperate regions too. Indeed, the role of agroforestry is now recognized in Europe as exemplified by this book, North America, and elsewhere in the temperate zone. Current interest in ecosystem management in industrialized countries strongly suggests that there is a need to embrace and apply agroforestry principles to help mitigate the environmental problems caused or exacerbated by commercial agricultural and forestry production enterprises. If we are to meet the society's needs and aspirations for forest-derived goods and services, we must find ways of augmenting traditional forestry by gleaning some portion of these benefits from agricultural lands where agroforestry can be practiced. In many places, the only opportunity to provide increased forest-based benefits, such as wildlife habitat or forested riparian systems, is through the increased use of agroforestry on agricultural lands. The publication of this book is very timely. As the editors say, the European Union has recognized the economic, ecological, and social advantages of agroforestry in its rural development policy; but the implementation of the policy is adversely affected by the lack of adequate information on the subject. The need for such a book is obvious.

I want to say how much I appreciate the enormous amount of work involved in bringing together such a volume. The state of agroforestry in Europe and literature on it being at early stages of development, it must have been a daunting task for the authors to piece together the information they have so painstakingly gathered for their chapters. I congratulate all the authors and the editors for such a

wonderful job. Undoubtedly, this is a significant contribution to agroforestry literature worldwide and a great service to the fledgling field of European agroforestry.

Distinguished Professor
University of Florida
Gainesville, Florida, USA
(Editor, *Advances in Agroforestry* Book-Series)

P. K. Ramachandran Nair
September 2008

Preface

While recent EU Rural Development policy clearly recognizes the economic, ecological, and social advantages of agroforestry systems, to date the implementation of such systems has been poor so far throughout most of Europe. In light of this, this collection of peer-reviewed papers brings together some of the most important current research in European agroforestry, and evaluates the current scope and future potential of agroforestry across the EU.

This volume contains a selection of papers covering the most recent research, embracing the wide range of geographical zones and crops and livestock systems found in Europe. While the majority of Europe's agroforestry practices are currently focused in the Mediterranean, this volume draws together examples from a wide range of countries – including France, Germany, Greece, Hungary, Ireland, Italy, Portugal, Slovenia, Spain, Switzerland, the Netherlands and the UK. The book also covers a range of agroforestry types, including silvopasture – Europe's predominant form of agroforestry – silvoarable, forest farming and multipurpose trees, but also explains some other practices like improved fallow and riparian buffer strips. Through these examples the book also discusses the potential roles for these traditional land management systems in addressing both environmental issues such as carbon sequestration, water quality, biodiversity conservation, desertification, soil preservation ecosystem services and socioeconomic issues such as rural population stabilization.

Augmented by detailed reviews of the main elements of European agroforestry and the issues that face it, this timely collection of research papers provides a valuable reference for advanced students and researchers, administrators and policy makers interested in a wide range of issues around land use, rural development, natural resource management, landscape ecology and conservation across Europe, and for those interested in agroforestry – including practitioners, researchers and extension organizations – worldwide.

This book is structured in four main parts: the Introduction, the European Mediterranean Agroforestry systems, the European Atlantic Agroforestry systems and the European Continental, Pannonian and Alpine Agroforestry systems. At the end of the book a chapter related to future directions is provided.

The **Introduction** part give the reader a general perspective on the development of agroforestry practices and systems in Europe in fourth chapters. It is important

to highlight that there has been no previous attempt in describing agroforestry in pan-European level although there are some books and other publications dealing with specific aspects of the main agroforestry practices implemented, e.g. silvopasture. The first chapter of the book introduces the reader to the description of the main agroforestry practices found in Europe: silvoarable, forest farming, riparian buffer strips, silvopasture, improved fallow and multipurpose trees. The current situation of the main components of agroforestry systems, i.e. tree and agricultural (including pasture and livestock), are briefly described to give the reader an initial balanced perspective on the status of European agroforestry systems and practices at a farm level. The second chapter reviews different types of classifications and functions of current agroforestry systems in Europe according to their components, spatial and temporal arrangements, functions, agroecological zone and socio-economic aspects, focusing on silvopastoral and silvoarable practices, the main types of agroforestry practiced in Europe. The third chapter of this part of the book is related to the future perspective for the use of these agroforestry systems at a farm level, based on their productive and ecological advantages. The fourth and final chapter of this part of the book deals with a social study conducted at 14 locations in seven countries within the European Union, to evaluate the degree of knowledge about agroforestry practices and the potential benefits and disadvantages that they can bring to farmers.

Part II dealing **European Mediterranean Agroforestry systems** has 10 chapters (Chapters 5 to 14). These chapters provide descriptions and development of agroforestry systems in the densely populated countries of the Mediterranean areas and examine how the economics of agroforestry systems in Europe has changed over time due to the different social conditions of the farmers. The countries/regions to which the chapters relate include Greece (Chapter 5), the transitional Atlantic-Mediterranean area of Western Europe (Chapter 6) and the four autonomous regions of the Mediterranean part of Spain: Cataluña, Murcia, Extremadura and Andalusia (Chapters 7 to 10). These have very different rural social structure, physical mountain geography and Mediterranean climate sub-classification types. While dehesa, the most widespread agroforestry system of southern Europe is the focus of Chapter 7. Chapter 8 deals with the forest grazing type of agroforestry practice in Cataluña. Chapter 9 presents studies on agroforestry practices in a river basin and along an altitudinal and precipitation gradient from 0 to 2,000 m asl and from 300 to 1,000 mm $year^{-1}$, respectively, in southern Spain. Various aspects of silvopasture are included in detail in the next two chapters (10 and 11). Chapter 12 deals with the main types of agroforestry practices in the Mediterranean and Alpine biogeographic regions of Italy. This chapter also evaluates the connection between them through traditional and current management. A socioeconomic study of cork oak agroforestry systems is the subject of Chapter 13. The part concludes with Chapter 14 that deals with forest farming, explaining the history of truffle production within the main European countries and presenting a synthesis of the best practices to reach high truffle productivity.

The next book part (Part III) deals with the **European Atlantic Agroforestry systems** in three chapters. This biogeographic region is characterized by having a

history of clear-cut separation between forest and agricultural land, at all levels including education, farming systems and policy. Allocation of the most productive areas to agricultural production, often at the expense of forest, has been an important feature of the land-use policy in the region. Thus, agroforestry systems are neither widespread nor properly implemented in this part of Europe. In the recent years, some important afforestation schemes have been carried out in this zone, even though some parts have the lowest proportion of forestland in Europe. The first paper of this part of the book (Chapter 15) describes a methodology used to locate the dominant trees distributed throughout Europe and demonstrates the advantages of applying stratification to estimate a complex land use resource, using the different ecological conditions found in the region. Chapter 16 deals with the development over time and description of current agroforestry practices in the Netherlands, while the opportunities for introducing silvopastoral and silvoarable systems in Ireland, one of the least forested areas of Europe, is the focus of Chapter 17. The chapters in this part clearly bring out the point that the main driving force behind the introduction of such systems in the region is the promotion of floral and faunal biodiversity and other aspects of environmental sustainability that are adversely impacted by agriculture.

The final part of the book deals with **European Continental, Pannonian and Alpine Agroforestry systems** in four chapters and explains that the main aims of implementing agroforestry systems in these areas are to exploit the environmental and crop protection functions offered by trees. The implementation of agroforestry practices in Germany is described in Chapter 18, whereas Chapter 19 describes the Alpine regions silvopastoral systems in Switzerland, where, unlike in the Mediterranean areas, supplementary food for livestock is obtained during summer time. Chapter 20 presents the Slovenian perspectives on agroforestry covering not only Alpine and Continental areas, but also Mediterranean areas and even some areas with Atlantic climatic characteristics. The final chapter of this part (Chapter 21) describes the specific characteristics of silvopastoral and silvoarable agroforestry practiced in the Pannonian region and explains how implementation practices such as hedgerows is very important in dealing with the special climatic characteristics of wind and snow in the region.

This book concludes with a synthesis (Chapter 22) of the information presented in the various chapters emphasizing the major challenges as well as opportunities of agroforestry in Europe.

We hope that this collection of research papers, augmented by detailed reviews of the main elements of European agroforestry and the issues facing it, will be a valuable reference source for advanced students and researchers, administrators and policy makers interested in a wide range of issues around land use, rural development, natural resource management, landscape ecology, and conservation across Europe, and for those interested in agroforestry – including practitioners, researchers and extension organizations – worldwide.

We thank all authors of individual chapters for their excellent contributions as well as splendid cooperation in dealing with repeated revisions of their manuscripts. Each chapter was peer-reviewed; the reviewers did a superb job in enhancing the

content and presentation quality of the respective chapters. Finally, a special word of appreciation to Professor P.K. Nair, the book-series editor, for suggesting the idea for such a book, and following it through its completion with consistent encouragement and valuable directives thought the process.

Rigueiro-Rodríguez A
McAdam A
Mosquera-Losada MR (Book Coordinator)

Contents

Contributors

T. Baiges
Centre de la Propietat Forestal (CPF), Departament de Medi Ambient i Habitatge, Generalitat de Catalunya, Torreferrussa, Spain

M. Bellido
Universidad de Extremadura, Plasencia, Spain

G. Bota
Centre Tecnològic Forestal de Catalunya (CTFC), Solsona, Spain

R.G.H. Bunce
Alterra Green World Research, P.O. Box 47, 6700 AA, Wageningen, The Netherlands

P.J. Burgess
Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK

A. Buttler
Swiss Federal Research Institute WSL Site Lausanne, Switzerland; Ecole Polytechnique Fédérale de Lausanne (EPFL), Laboratory of Ecological Systems, 1015 Lausanne, Switzerland; Laboratoire de Chrono-écologie, UMR 6565 CNRS, Université de Franche-Comté, Besançon, France

P. Campos
Institute of Economics and Geography of Spanish National Research Council (CSIC), Spain

P. Casals
Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM), Paterna, Valencia, Spain; Centre Tecnològic Forestal de Catalunya (CTFC), Solsona, Spain

M. Castro
Escola Superior Agrária de Bragança, Apartado 172, 5301-855 Bragança, Portugal

A. Chebil
Tunisian Research Institute of Rural Engineering, Water and Forest (INRGREF), B.P. 10, 2080 Ariana, Tunisia

C. Chocarro
Escola Tècnica i Superior d'Enginyeria Agrícola, University of Lleida, Lleida, Spain

E. Correal
IMIDA, Finca Sericícola 30150 La Alberca, Murcia, Spain

H. Daly-Hassen
Tunisian Research Institute of Rural Engineering, Water and Forest (INRGREF), B.P. 10, 2080 Ariana, Tunisia

F. de Bello
Centre Tecnològic Forestal de Catalunya (CTFC), Solsona, Spain

O. Dini-Papanastasi
National Agricultural Research Foundation, Forest Research Institute, GR-570 06 Vassilika, Thessaloniki, Greece

C. Dupraz
Institut National de la Recherche Agronomique, 2 Place Viala, 34060 Montpellier, France

M. Erena
IMIDA, Finca Sericícola 30150 La Alberca, Murcia, Spain

R. Fanlo
Escola Tècnica i Superior d'Enginyeria Agrícola, University of Lleida, Lleida, Spain

E. Fernández-Núñez
Crop Production Department, High Politechnic School, University of Santiago de Compostela, 27002 Lugo, Spain

N. Frank
Department of Silviculture, Faculty of Forestry, University of West Hungary, Bajcsy-Zs. u. 4. 9400, Sopron, Hungary

S. García-Barreda
Fundación Centro de Estudios Ambientales del Mediterráneo (Fundación CEAM), C/Charles R Darwin 14, Parque Tecnológico, 46980 Paterna, Valencia, Italy

F. Gillet
Swiss Federal Research Institute WSL Site Lausanne, Switzerland; Ecole Polytechnique Fédérale de Lausanne (EPFL), Laboratory of Ecological Systems, 1015 Lausanne, Switzerland

P. González-Hernández
Crop Production Department, High Politechnic School, University of Santiago de Compostela, 27002 Lugo, Spain

J.L. González-Rebollar
Estación Experimental del Zaidín – CSIC/IFAPA-CIFA, Granada, Spain

A.R. Graves
Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK

I. Ispikoudis
Faculty of Forestry and Natural Environment, Aristotle University of Thessaloniki, GR-541 24 Thessaloniki, Greece

F. Kohler
Swiss Federal Research Institute WSL Site Lausanne, Switzerland; Ecole Polytechnique Fédérale de Lausanne (EPFL), Laboratory of Ecological Systems, 1015 Lausanne, Switzerland

M. Kotar
Biotechnical Faculty, Department of Forestry and Renewable Forest Resources, University of Ljubljana, Chair for Forest Management planning and Biometrics, Vecna pot 83, SI-1111 Ljubljana, Slovenia

A.T. Kuiters
Alterra, Wageningen UR, P.O. Box 47, 6700 AA Wageningen, The Netherlands

F. Liagre
Assemblée Permanente des Chambres d'Agriculture, 9 Avenue Georges V, 75008 France, Paris

R. Luick
University of Rottenburg, Germany

K. Mantzanas
Faculty of Forestry and Natural Environment, Aristotle University of Thessaloniki, GR-541 24, Thessaloniki, Greece

T. Martínez
Instituto Madrileño de Investigación Agraria (IMIA), El Encín, Apdo 127, Alcalá de Henares, Madrid, Spain

M. Mayus
Wageningen University, Wageningen, The Netherlands

J. McAdam
Department of Applied Plant Science, Queens University, Belfast, Northern Ireland, UK; Applied Plant Science and Biometrics Division, Agri-Food and Biosciences Institute, Newforge Lane, Belfast, BT9 5PX, Northern Ireland, UK

P.M. McEvoy
Applied Plant Science and Biometrics Division, Agri-Food and Biosciences Institute, Newforge Lane, Belfast, BT9 5PX, Northern Ireland, UK

G. Moreno
Dpto de Biología Vegetal, Ecología y Ciencias de la Tierra, I.T. Forestal (Forestry School), Universidad de Extremadura, Plasencia, Spain

M.R. Mosquera-Losada
Crop Production Department, High Politechnic School, University of Santiago de Compostela, 27002 Lugo, Spain

A. Oosterbaan
Alterra, Wageningen UR, P.O. Box 47, 6700 AA Wageningen, The Netherland

P. Ovando
Institute of Economics and Geography of Spanish National Research Council (CSIC), Spain

J.L. Oviedo
Tunisian Research Institute of Rural Engineering, Water and Forest (INRGREF), B.P. 10, 2080 Ariana, Tunisia

V.P. Papanastasis
Faculty of Forestry and Natural Environment, Aristotle University of Thessaloniki, GR- 541 24, Thessaloniki, Greece

A. Pardini
Department of Agronomy and Land Management, University of Florence, Italy

P. Paris
Istituto di Biologia Agro-ambientale e Forestale, CNR, Porano, Italy

M. Pérez-Soba
Alterra Green World Research, P.O. Box 47, 6700 AA Wageningen, The Netherlands

A. Pisanelli
Istituto di Biologia Agro-ambientale e Forestale, CNR, Porano, Italy

M. Postma
Wageningen University, Wageningen, The Netherlands

F.J. Pulido
Ingeniería del Medio Agrícola y Forestal, I.T. Forestal (Forestry School), Universidad de Extremadura, Extremadura, Spain

M.E. Ramos
Estación Experimental del Zaidín – CSIC/IFAPA-CIFA, Granada, Spain

S. Reyna-Domenech
Fundación Centro de Estudios Ambientales del Mediterráneo (Fundación CEAM), C/Charles R Darwin 14, Parque Tecnológico, 46980 Paterna, Valencia, Italy

A. Rigueiro-Rodríguez
Crop Production Department, High Politechnic School, University of Santiago de Compostela, 27002 Lugo, Spain

S. Ríos
CIBIO, Universidad Alicante, Alicante, Spain

A. Robledo
Islaya, Consultoría Ambiental, Murcia, Spain

A.B. Robles
Estación Experimental del Zaidín – CSIC/IFAPA-CIFA, Granada, Spain

R. Romero-Franco
Crop Production Department, University of Santiago de Compostela, 27002 Lugo, Spain

J. Ruiz-Mirazo
Estación Experimental del Zaidín – CSIC/IFAPA-CIFA, Granada, Spain

J.J. Santiago-Freijanes
Crop Production Department, University of Santiago de Compostela, 27002, Lugo, Spain

B. Schindler
FINIS, Groß Zecher, Germany

M.T. Sebastià
Centre Tecnològic Forestal de Catalunya (CTFC), Solsona, Spain; Escola Tècnica i Superior d'Enginyeria Agrícola, University of Lleida, Lleida, Spain

M. Smith
23 Colinton Mains, The Green, Edinburgh EH13 9AC, Scotland

V. Takács
Department of Silviculture, Faculty of Forestry, University of West Hungary, Bajcsy-Zs. u. 4. 9400 Sopron, Hungary

M. Taull
Centre Tecnològic Forestal de Catalunya (CTFC), Solsona, Spain; Escola Tècnica i Superior d'Enginyeria Agrícola, University of Lleida, Lleida, Spain

M. Vicente
D. G. Medio Natural, Murcia, Spain

M. Vidrih
Biotechnical Faculty, Department of Agronomy, University of Ljubljana, Chair of Fodder Production and Pasture Management, Jamnikarjeva 101, SI-1111 Ljubljana, Slovenia

T. Vidrih
Biotechnical Faculty, Department of Agronomy, University of Ljubljana, Chair of Fodder Production and Pasture Management, Jamnikarjeva 101, SI-1111 Ljubljana, Slovenia

Reviewers

Aloui A
Silvopastoral Institute,Tunisie

Belesky D
AFSRC, USDA, USA

Boubaker A
Institut National Agronomique de Tunis, Tunisie

Cañellas I
CSIC, Spain

Casals P
CEAM, Spain

Castro M
Escola Superior Agrária de Bragança, Universidade de Braganza

Fanlo R
Escola Tècnica i Superior d'Enginyeria Agrícola. University of Lleida, Spain

Farrel T
School of Biology and Environmental Science, Dublin, Ireland

Fernández-Núñez E
Universidad de Santiago de Compostela, Spain

González-Hernández MP
Universidad de Santiago de Compostela, Spain

González-Rodríguez A
CIAM, Spain

Gonzalo Julián
Universidad de Valladolid, Spain

López ML
Universidad de Extremadura, Spain

McEvoy P
Universidad de Belfast, UK

Moreno G
Universidad de Extremadura, Spain

Mueller P
University Raleigh, USA

Najar T
Institut Nacional Agronomique de Tunis, Tunisie

Oliveira-Prendes A
Universidad de LLeida, Spain

Osoro K
SERIDA, Spain

Palai M
Forest Technology Centre of Catalonia, Spain

Paoli JC
INRA, France

Pantera A
Technological educacion institute of Lamia, Greece

Papanastasis VP
University of Thessaloniki, Greece

Pardini A
University of Firenze, Italy

Parlade J
Institute for Food and Agricultural Research and Technology, Spain

Piñeiro J
CIAM, Spain

Pinto M
NEIKER, Spain

Pulido F
University of Extremadura, Spain

Rebollar JL
CSIC, Spain

Robles A
CSIC, Spain

Rodríguez-Barreira S
Universidad de Santiago de Compostela, Spain

Rodríguez-Guitian MA
Universidad de Santiago de Compostela, Spain

Rodríguez-Soalleiro R
Universidad de Santiago de Compostela, Spain

Rois M
Forest Technology Centre of Catalonia, Spain

Romero-Franco R
Universidad de Santiago de Compostela, Spain

Rozados MJ
Centro de investigaciones forestales de Lourizán, Spain

Sainz MJ
Universidad de Santiago de Compostela, Spain

Santiago-Freijanes JJ
Universidad de Santiago de Compostela, Spain

Sibbald A
Farm Woodland Forum, UK

Silva-Pando FJ
Centro de investigaciones forestales de Lourizán, Spain

Snyder Unruh LJ
University of Florida, USA

Vidrih M
University of Ljubljana, Slovenia

Part I
Introduction

Chapter 1
Definitions and Components of Agroforestry Practices in Europe

M.R. Mosquera-Losada[1]*, J.H. McAdam[2], R. Romero-Franco[1], J.J. Santiago-Freijanes[1], and A. Rigueiro-Rodríguez[1]

Abstract Agroforestry systems are traditional land use systems that were and are used in Europe. They can be defined as those land use systems which involve two main components – trees/shrubs and an agricultural crop (which could also be pasture) and are artificially managed. Agroforestry systems can be implemented at a temporal and spatial scale for a land owner, who can use different agroforestry practices. Since human interaction with the environment in Europe is very important and has occurred for a long time there are different types of agroforestry practices in Europe that are described in this chapter and named, silvoarable, forest farming, riparian buffer strips, silvopasture, improved fallow and multipurpose trees. A brief description of the main agroforestry practice components, i.e. trees and agriculture (including pasture and livestock) in Europe will give an overview of the current and potential situation in Europe for the use of these systems.

Keywords Silvorable, forest farming, riparian buffer strips, silvopasture, improved fallow, multipurpose trees

Definitions of Agroforestry

Agroforestry can be defined as sustainable way of land management which integrates both agricultural and forestry practices on the same land management base. Agroforestry system practices have been defined by different authors (Nair 1993) as practices which involve "the deliberate integration of trees with agricultural crops and/or livestock either simultaneously or sequentially on the same unit of land". The International Centre for Research in Agroforestry (ICRAF) and the World agrofor-

[1] Crop Production Department, University of Santiago de Compostela, 27002 Lugo, Spain

[2] Applied Plant Science Division, Agri-Food and Biosciences Institute and Queen's University Belfast, Newforge Lane, Belfast BT9 5PX, Northern Ireland, UK

* Corresponding author: e-mail: mrosa.mosquera.losada@usc.es

A. Rigueiro-Rodríguez et al. (eds.), *Agroforestry in Europe: Current Status and Future Prospects*.

estry Centre (WAC) define the term agroforestry as "a dynamic, ecologically based natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels" and "A land-use system in which woody perennials (trees, shrubs, palms, bamboos) are deliberately used on the same land management unit as agricultural crops (woody or not), animals or both, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions between the different components", respectively. Finally the AFTA (Association for Temperate Agroforestry) (1997) in USA also defines Agroforestry systems as "an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock".

Hence agroforestry systems should involve two main components: trees/shrubs and an agricultural crop (which could also be pasture). All types of agroforestry systems integrate people as part of the system as they are artificial systems to a higher (i.e. domestic animals) or lower degree (i.e. wild animals in natural or national parks), where one component can be promoted over the other, or both at the same time trying to reach equilibrium between the different components. The promotion of one component over the other can be modified as the tree develops. Man, through traditional experience and practice or new knowledge, should promote the positive interactions between the two components, by an initial knowledge-based selection of the tree species and later by adequate management, mainly of the agricultural crop. Silvicultural practices applied during the main, stable years of the tree stand life could be implemented through the enhancement of the synergies of the tree and the crop (mainly related to thinning and pruning practices). However, the definitions are not clear if the shrubby or the tree component should be an indistinct component. For the purpose of this book agroforestry systems include shrubs as a main component of the woody vegetation.

Classification of Agroforestry Practices

Following the definitions given by AFTA (1997) and Alavalapati and Nair (2001) there are currently five basic types of agroforestry practices in temperate areas: windbreaks, alley cropping, silvopasture, riparian buffers and forest farming. This classification is mostly based on the main practices developed in America. Although the situation is different in Europe, this classification is still valid, but, it should be slightly changed and increased in scope (Table 1.1): silvoarable agroforestry, forest farming, riparian buffer strips, silvopasture, improved fallow and multipurpose trees. European farmers have had a longer history of interaction with forests than American farmers. This interaction, coupled with the significant range of climates and microclimates has led to the evolution of many combinations of agroforestry practices in Europe. Most of the types of agroforestry practices described around the world were present in different parts of Europe at different levels of intensity,

Table 1.1 Agroforestry practices in Europe (Modified from Association for Temperate Agroforestry (AFTA) 1997); Alavalapati and Nair 2001; Nair 1994; Alavalapati et al. 2004)

Agroforestry practice	Brief description
Silvoarable agroforestry	Widely spaced trees inter-cropped with annual or perennial crops. It comprises alley cropping, scattered trees and line belts
Forest farming	Forested areas used for production or harvest of natural standing specialty crops for medicinal, ornamental or culinary uses
Riparian buffer strips	Strips of perennial vegetation (tree/shrub/grass) natural or planted between croplands/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality
Improved fallow	Fast growing, preferably leguminous woody species planted during the fallow phase of shifting cultivation; the woody species improve soil fertility and may yield economic products
Multipurpose trees	Fruit and other trees randomly or systematically planted in cropland or pasture for the purpose of providing fruit, fuelwood, fodder and timber, among other services, on farms and rangelands
Silvopasture	Combining trees with forage and animal production. It comprises forest or woodland grazing and open forest trees

and overlapping both temporally and spatially depending of the livelihoods and needs of European citizens. There was an notable decline in the implementation of agroforestry practices in Europe in the 20th century, when agriculture was intensified, specialised and promoted. Most extended agroforestry practices nowadays in Europe are silvopasture and silvoarable practices (Agroforestry Forum 2007).

Silvoarable Practices

Silvoarable practices were defined by Eichhorn et al. (2006) as widely spaced trees inter-cropped with annual or perennial crops. The main characteristic of this kind of agroforestry practice is determined by the agricultural component, which is harvested every year or every few years in the case of energy crops. It is very important that trees are widely distributed across the land to facilitate the movement of machinery through the plots to reduce harvesting costs. This is also enhanced through the position of the trees in rows or surrounding the plots, when light interception is reduced and allows maximum light to the crop (Mosquera-Losada et al. 2005). The range and implementation of the most common silvoarable practices currently used in Europe are described in Chapter 2. They include (1) *alley cropping*, i.e. trees planted in single or grouped rows within agricultural or horticultural fields with crops growth in the wide alleys between the tree rows, (2) *scattered trees* at low density (not in rows) with an annual cropping pattern. Silvoarable systems can include annual crops like maize, wheat, oats, sunflower, vegetables or fodder production (to make silage or hay), but also perennial crops which are harvested every few years (e.g. energy crops) and (3) line belts such as

hedgerows, shelterbelts, windbreaks and forest belts. Belts are tree rows distributed around farms and, together with the riparian agroforestry systems are classified as "trees outside the forest" in European statistics (MCPE 2003). Nowadays, it can be included those tree formations planted at the sides of roadways or railways to separate them from agricultural land and which protect, at the same time, agricultural lands and artificial paths from strong wind and blown snow (Takács and Frank 2008). Hedgerows are usually made of trees or thorny shrubs which are cut and shaped in order to interweave the branches and create "walls" to separate agricultural crop areas from grasslands (Herzog 2000). The use of this kind of agroforestry practice reached its maximum around the 18th century and then started to decline. It is estimated that since 1969 between 40% to 80% of the European hedgerows have disappeared or degenerated due to the reallocation of agricultural holdings to create larger field plots (Herzog 2000). The main types of hedgerows are seen in Brittany (*bocages*), Normandy, Ireland, the Knicks and Walhecken in Germany, but they are not usually seen in the southern part of Europe. Shelterbelts, windbreaks and forest belts are usually aimed to protect crops growing in their lee (Takács and Frank 2008).

Forest Farming

Forest farming includes forested areas used for production or harvest of natural or cultivated speciality crops for medicinal, ornamental or culinary uses. There are many examples of this type of agroforestry practice in Europe like medicinal plants, mushrooms, truffles, berries, honey and decorative foliage as described by MCPFE (2003). This represents around 27% of the share of the total non-wood forest products from forest and other wooded land across 27 countries of Europe. The other non-wood forest products are game (30%) which is a kind of silvopasture, Christmas trees (24%), nuts (7%) and cork (11%). Mushrooms, including truffles, are the most important non-wood forest specialty crop in Europe. As a resource after game and Christmas trees, their use has been recorded in 15 out of 27 European countries (including Spain), followed by fruit and berries which were recorded in 17 countries. Medicinal plants are also important in 9 out of 27 European countries (including Spain). It is important to highlight that harvesting of these plants is usually uncontrolled, which makes it very difficult to manage sustainably the system and reduces its potential profitability. Mushrooms, medicinal plants and berries appear to be dominated by personal use, and their harvesting is not clearly regulated and can result in crop damage.

The main types of wild mushrooms harvested in European countries are ectomycorrhizal fungi developed in natural forests and plantations. Mushroom production can be associated with those broadleaved ecosystems (e.g. Atlantic and Mediterranean oaks, chestnuts) and also pine stands. Production is mostly in autumn, although, in some areas, spring production is important. Mushroom annual production is variable, and depending very much on intra-annual climate conditions, but there are

years in which the economic importance of this product is higher than other forest products in some areas. Mushroom production could be between 15 and 100 kg ha^{-1} $year^{-1}$. There are several dozen species of edible wild mushrooms that can be harvested in Europe and which have economic importance like *Amanita caesarea* (Scop.: Fr.) Grév., *Boletus edulis* Bull.: Fr. and other species of the same group like *Lactarius deliciousus* L.: Fr., *Cantharellus cibarius* Fr., *Hydnum repandum* L. ex Fr., *Tricholoma portentosuum* (Fr.) Quélet, *Morchella* spp., *Cantharellus tuberiformis* Fr. etc. Some crop and silvicultural techniques can enhance fungus production like clearance, pruning, thinning, fertilization or summer irrigation (Fernández and Rodríguez 2000). Truffle is an important crop and its history and recent advances in agroforestry are described in this book (Reyna-Domench and García-Barreda 2008).

Medicinal plants are an important economic resource for many countries (FAO 1995, 1997). The WHO estimates that around 80% of the world population use medicine plants for therapeutical uses. Around 25% of the commercial medicines used by the pharmaceutical industry are prepared with components which come directly from plant species, and the other 25% come from plants derived and modified in pharmaceutical laboratories (De Silva 1997). Europe is the main place in the world where medicinal and commercial transactions take place. This market is worth around 6.7 billions dollars annually (Laird and Pierce 2002). Germany is the main European medicinal plant market which is worth around 1.2 billion dollars and has commercialized between 500 and 600 plant species (Lewington 1992). The total European medicinal plant market involves around 2,000 species, between 1,200 and 1,300 of these are native species, the rest are imported. Most (80%) medicinal plant production has been commercialized in five European countries: Germany, France, Italy, Spain and United Kingdom. Annual European exports are around 70,000 t, approximately 20% going to the North American market (Lewington 1992).

Harvesting of wild medicinal plant populations is still very important world-wide, especially in countries like Albania, Bulgaria, Hungary and Spain. From all the autochthonous species commercialized in the European markets, around 90% come from wild populations, representing between 20,000 and 30,000 t per year. By country, it is estimated that between 30–50% of aromatic and medicinal plants commercialized in Hungary come from wild collection, 50–70% in Germany, 75–80% in Bulgaria and almost 100% in Albania (Lange and Schippmann 1997; Lange 1998). Particular species or groups of plant species collected are *Adonis vernalis* L., *Arctostaphyllos uva-ursi* (L.) Sprengel, *Arnica montana* L., *Cetraria islandica* (L.) Ach. Cast., *Drosera anglica* Hayne, *Drosera intermedia* Hudson, *Drosera rotundifolia* L., *Gentiana lutea* L., *Glycirrhiza glabra* L., *Menyanthes trifoliata* L., *Origanum* spp., *Paeonia* spp., *Primula* spp., *Ruscus aculeatus* L., *Sideritis*, spp. and *Thymus* spp. The intensive and unsustainable management of a lot of European populations of medicinal and aromatic plants has prompted the European Union to supervise commercial transactions with these types of products. An official list of plants to be regulated has been drawn up (Annex D of the EU Council Regulation No. 338/97 on “the protection of species of wild fauna and flora

by trade" regulation). Also the annexes of the Community Directive about the use of habitats, flora and fauna includes some of the medicinal plants under threat and therefore the member states should use policy measures to promote better management to avoid this scenario. Some of these plants are already included in the "Red lists" and in books of endangered flora of the different countries and 24 species are endangered at a European scale (Walter and Gillet 1998). For these reasons it is very important that the future market for aromatic and medicinal plants should be based on cultivation rather than wild collection. Around 130–140 species are already cultivated, but most are in an experimental phase or grown in small areas only. Only *Carum carvi* L., *Foeniculum vulgare* Mill., *Lavandula* spp. and *Papaver somniferum* L. are cultivated in extensive areas.

Riparian Buffer Strips

Riparian buffer strips of perennial vegetation (tree/shrub/grass) are planted between croplands/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality. In Europe they are usually located along streams or rivers and are often remnants of former river plains forest with willows (*Salix* spp.) alder (*Alnus glutinosa* (L.) Gaertn.) and a variety of hardwood trees (*Fraxinus excelsior* L., *Ulmus* spp. *Acer* spp., *Quercus robur* L.). They protect water bodies against sedimentation, soil erosion on adjacent agricultural lands, but of more current importance, against nitrate contamination. A Ministerial Conference on the Protection of Forests in Europe (MCPE 2003) considers tree forest riparian strips and line forests (hedgerows, shelterbelts, windbelts) as coming under the definition of trees outside forests. This kind of agroforestry (Long and Nair 1999) can be seen in different parts of the world. Most riparian forests (natural and plantations) are of high economic, ecological and landscape importance due to the modification and improvement of the landscape, the high wood quality of some of the component tree species attract a good price (*Populus* spp., *Alnus glutinosa*, *Alnus cordata* (Loisel.) Duby, *Fraxinus excelsior*, *Fraxinus angustifolia* Vahl, *Betula pubescens* Ehrh., *Betula alba* L., *Ulmus glabra* Huds, *Ulmus minor* Mill., *Celtis australis* L., *Acer pseudoplatanus* L., *Quercus robur*) and because they have been used as food for livestock. Mushrooms and medicinal plants are also produced in this kind of ecosystem. From an ecological point of view, they regulate light and temperature of the rivers, acting as green filters, which reduces the eutrophication processes, help stabilise river banks, act as food and cover for aquatic fauna and amphibian. They are communities of high biodiversity acting as corridors for flora and fauna.

Improved Fallow

Improved fallow is defined as fast growing, preferably leguminous woody species planted during the fallow phase of shifting cultivation; the woody species improve

soil fertility and may yield economic products. This kind of agroforestry system was used in the recent past in some parts of Europe. It can be said that until the use of fertilizers became widespread, there was a very close connection between forestry and agricultural land in Europe. The importance of agricultural land in a built-up area and the degree of fertility was linked to the area of forest it has (with a temporal and spatial perspective), with the exception of coastal areas, where the shells of molluscs and crustacean as well as algae were used to improve soil fertility. Until the end of the 1960s, *Ulex europaeus* L., *Cytisus striatus* (Hill) Rothm. and *Genista florida* L. (leguminous woody species) were sown to be harvested for compost in stables (they were used as a bed for animals, horse feed and wood production), and after 10–20 years rotation the same soil was used to grow wheat or rye. This was very labour demanding and, due to the high salary costs, is currently not profitable. If mechanised, this system could be used for organic farming. In the same way, in Galicia, long rotations of cereals and legume shrubs like *Cytisus striatus* were used for firewood and, when it was present on the land, a natural grass stratum was produced and used by livestock. This practice has been completely replaced in recent years by artificial fertilization and liming of those acid soils.

Multipurpose Trees

Multipurpose trees can be fruit and/or other trees randomly or systematically planted in cropland or pasture for the purpose of providing fruit (both for human and animal consumption), fuelwood, fodder and timber, among other services, on farms and rangelands. Leaves and fruits from some of the European species such as *Castanea sativa* Mill., *Fraxinus* spp., *Betula* spp. and *Quercus* spp. were used in the past to feed animals and help overcome feed shortage periods. The importance of fruit-trees distributed throughout agricultural land can be seen by the different names of this kind of practice has in Europe like "*Streuobst*" in Germany, "*près vergers*" in France, "fruit-tree meadows" and "orchards" in English. Despite the lack of information of this kind of system in most of European countries, there are around 1 million hectares of Streuobst in 11 European countries (Herzog 2000). In Spain and Portugal multipurpose trees are usually a practice linked to the most traditional agroforestry system in Europe called "*dehesa*", where acorn production of trees like *Quercus ilex* L. and *Quercus suber* L. was used in the past and still is, to feed animals like pigs. Acorn production from this agroforestry practice (multipurpose tree) is very important to sustain the system because it provides a cheap feed resource for animals when fodder such as grass is not available (Cañellas et al. 2007). In those years when summers are especially dry and pasture availability is reduced for a very long period of time, to overcome pasture shortage, trees are pruned to feed animals and enhance fructification, and thus are a sort of food "storage", as branches can be pruned when an especially dry summer appears. Multipurpose or fodder trees and shrubs are very important to feed animals during shortage periods

in most of the Mediterranean area (Dupraz 1999). This practice was also used in the past to feed humans in the humid part of Spain, where *Castanea sativa* Miller fruit was the basic human daily carbohydrate resource until a disease (ink illness – caused by the fungus *Phytophtora cambivora* (Petri) Buis, *Phytophtora cinnamomi* Rands)) destroyed most of the trees in the lowlands and in the areas prone to high humidity, which causes that this species was replaced by the potato as the main carbohydrate human resource. This practice has decreased since the mid 19th century. Chestnut woodlands are considered nowadays to have high economic importance due to their high quality wood and fruits. This explains the establishment of recent plantations over the past few decades with hybrids of *Castanea sativa* and *Castanea crenata* Sieb. & Zucc. (from Japan), which are interspersed with varieties of high quality fruit (big, easy peeling and with low number of partition walls). In some Atlantic areas (north-west Spain) some of the traditional agroforestry practices are recovering, like pigs grazing in these chestnut woodlands, and feeding on the fruits (*montanera*) during the fattening period, this is mainly done in this area with the autochthonous Galician pig breed (Celtic breed). A new disease (caused by *Chryphonectria parasitica* (Murril) Barr. & Anderson) is rapidly spreading through the European chestnut woodlands and is even affecting the ink-resistant hybrids. Some vaccines have recently developed for some of the types of the disease and currently research is been conducted to find some resistant ecotypes or breeds. Special cultural treatments like pruning and injections can reduce the spread of the disease because the common mode of entry of the pathogen is to infect the tree through an injury (Bounous et al. 2001).

Silvopasture

Silvopasture is the combination of trees with forage and livestock production. They can include (a) forest or woodland grazing when forestry production is promoted (high density stands, natural forests) mainly associated with wild or local or autochthonous rustic breeds of animals and (b) open forest trees (low density stand, recently afforested or reforested areas) which could have wild or domestic animals. Silvopasture is one of the main types of agroforestry practices used in the past and currently in Europe and can be found in all the biogeographic regions of Europe, such as Alpine (Mayer 2005), Atlantic (McAdam 2005; Rigueiro-Rodríguez et al. 2005), Boreal (Hytönen 1995), Continental (Boron 2005), Mediterranean (Eichhorn et al. 2006) and Pannonian (Takács and Frank 2008). This agroforestry practice is characterised by having an extra component, the grazing or browsing animal, in comparison with the other agroforestry practices, so it can include natural parks (mainly for preserving nature, and with an important social use, but managed by man) that can be found all over Europe, but also farms with domestic animals, i.e. the reindeer farms, *dehesas* or *montados*, associated with the Boreal and Mediterranean areas, respectively. Heterogeneity created by the presence of animals at an appropriate stocking rate has been recognised as an important tool in the