Chapter 1
Introduction: Challenges for Agroforestry in the New Millennium

Florencia Montagnini

1 Past and Current Emphasis in Agroforestry Research and Practice

Worldwide, terrestrial landscapes are being impacted by unsustainable management practices in agriculture, forestry and other human activities, as well as by climate change and subsequent chains of events. Sustainable techniques geared to harmonizing ecosystem productivity and conservation can contribute to mitigating or reversing detrimental effects on landscapes. However, degraded landscapes usually exist in a complex mosaic that is constantly changing, therefore dynamic land use designs and management strategies are needed to overturn these trends. Among these strategies, agroforestry systems (AFS) are becoming increasingly relevant worldwide as society has come to recognize their multiple roles and services: biodiversity conservation, carbon sequestration, adaptation and mitigation of climate change, restoration of degraded ecosystems, and tools for rural development.

Many publications have dealt with different scientific, technical, and educational aspects of AFS. Although AFS have been traditionally practiced in many forms by humans, they only called the attention of the academic world in the 1970s–1980s, when the need to find alternatives to increase agricultural productivity, improve degraded soils and favor small landholders, especially in the more impoverished rural regions of the tropics worldwide, became more pressing.

The initial emphasis of the research in AFS was on showing how AFS could be a viable productive alternative. Most of the books published in this period dealt with different aspects of AFS design, and spatial and temporal arrangement of their components, focusing on multipurpose tree species and their functions and products

F. Montagnini (✉)
School of Forestry and Environmental Studies, Yale University, New Haven, CT, USA
e-mail: florencia.montagnini@yale.edu

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(Steppler and Nair 1987; Nair 1989; Reifsnyder and Darnhofer 1989; MacDicken and Vergara 1990; Jordan et al. 1992; Montagnini et al. 1992; Ong and Huxley 1996; Buck et al. 1999; Huxley 1999; Ashton and Montagnini 2000, among others). Also, numerous "Working Papers" and other documents were published by ICRAF (International Center for Research in Agroforestry, currently World Agroforestry Center), and CATIE (Tropical Agriculture Research and Higher Education Center) (OTS/CATIE 1986; CATIE 1999, 2001), each with their own regional emphasis (Africa, Latin America).

In the same period, nitrogen fixing trees and shrubs received special attention focusing on species of *Acacia*, *Alnus*, *Albizia*, *Erythrina*, *Gliricidia*, *Leucaena* and *Prosopis* (NAS 1979; MacDicken 1994; CATIE 1999; Gómez et al. 1995; Escobar et al. 1996; Shelton 1996; Giller 2001; Cordero and Dossier 2004; Evans and Turnbull 2004). In addition, models were developed for economic and financial evaluations of AFS, as well as for estimations of impacts on soils and for designs directed to specific situations (for example, Ramakrishnan 1992; Sullivan et al. 1992; Young 1997).

Later, responding to increasing environmental and rural development issues worldwide, research subjects on agroforestry turned into aspects related to the challenges to contribute to alleviate poverty and improve food security (Garrity 2004; Nair et al. 2004; CGIAR 2012; Nair and Garrity 2012; Montagnini et al. 2015a). Likewise, in the last decade emphasis has been placed on the role that AFS can play to contribute to the adaptation to climate change, and mitigation of greenhouse gas emissions through fixation of atmospheric carbon (Montagnini and Nair 2004; Montagnini 2005; Palm et al. 2005; Nair et al. 2010; FAO 2012; Nair and Garrity 2012; Montagnini 2015; Montagnini et al. 2015a, among many others).

2 Agroforestry Systems: Compromise Among Productive and Environmental Functions?

It has been estimated that AFS cover about 1000 million hectares worldwide (Zomer et al. 2009, 2014; Nair et al. 2010; Somarriba et al. 2012). This is a very rough estimate based on percent tree cover in agricultural land; AFS are assumed to comprise agricultural land which contains 10–30% tree cover (See chapter 2). The most frequent AFS are shaded annual and perennial crops, silvopastoral systems, live fences, and windbreaks. Traditional as well as more modern multistrata AFS such as homegardens and successional agroforestry designs provide households with food sources and fuelwood, as well as high value products to generate cash (Lok 1998; Kumar and Nair 2006; Montagnini 2006; Toensmeier 2007, 2013; Montagnini et al. 2015a, b; Montagnini and Metzel 2015). Perennial crops such as cacao, coffee, and yerba mate gain considerable advantage in terms of quality of products and system

sustainability when grown in AFS. In addition, when designed and managed as organic, AFS yield products which can obtain more favorable market prices (Eibl et al. 2015; Rapidel et al. 2015; Virginio Filho et al. 2015). More than 80% of rural people in the developing world still depend on fuelwood for cooking as well as warmth (Angelsen et al. 2014; FAO 2015). AFS can play a role in supplying fuelwood energy and facilitating the provision of other sources of energy, thus avoiding forest cutting for fuelwood (Marlay 2015).

Silvopastoral systems, when properly designed and managed, can provide short term income from cattle products as well as long term returns from the trees helping diversify investments, while providing a full set of environmental benefits and services at the same time (Murgueitio et al. 2009, 2011; Chará et al. 2015; Colcombet et al. 2015; Murgueitio et al. 2015). Live fences, windbreaks and riparian buffer strips are complementary AFS which apart from their uses as such they contribute to connectivity in fragmented agricultural landscapes (Gordon and Newman 1997; Schroth et al. 2004; Batish et al. 2007; Francesconi and Montagnini 2015, among others).

Currently AFS are considered to be a land use that can achieve a compromise among productive and environmental functions. Among the latter, the potential AFS contributions to the recovery of ecosystem and landscape attributes, such as the restoration and conservation of biodiversity, watershed hydrological services, and connectivity of fragmented landscapes have recently received special attention (Mc Neely and Scherr 2003; Schroth et al. 2004; Chará and Murgueitio 2005; Jose and Gordon 2008; Redondo Brenes and Montagnini 2010; Nair and Garrity 2012; Montagnini et al. 2011; Calle et al. 2013; Montagnini et al. 2015a, b, among others). AFS are also playing an important role as part of the so called "climate-smart" landscape approaches that simultaneously embrace mitigation and adaptation policies and programs. Such landscape approaches are proposed as strong alternatives to REDD+ (Reducing Emissions from Deforestation and Degradation) programs (Van Noordwijk et al. 2015).

Several indigenous communities manage AFS using techniques that include residue management and ash deposition, enhancing nutrient recycling and conservation, and maintaining high species diversity which all promote agroecosystem sustainability (Montagnini and Jordan 2005; Montagnini 2006; Montagnini and Metzel 2015). However, several of these communities remain marginalized, and poverty and resource degradation prevail. Likewise, other types of AFS have been shown to effectively increase productivity and maintain sustainability under a varied set of site conditions. Apparently, AFS can play a significant role in rural development even in the most challenging socioeconomic and ecological conditions, but still there is a lot of work to do to reach these goals. AFS can help smallholder farmers attain higher productivity and sustainability, however these achievements do not always translate into significantly larger financial returns to farmers due to difficulties in the value chain of the AFS products and access to the right markets.

3 Agroforestry Research for Development: Challenges

Many international institutions and programs, government agencies, foundations, Non-Government Organizations (NGOs) and others are conducting research for development geared to decreasing rural poverty and hunger while maintaining landscape integrity and ecosystem services (CGIAR 2012). Considerable funding is spent in projects directed to enhancing productivity and sustainability of smallholder forestry and agroforestry practices, including food security and nutritional benefits, through better management of production systems.

These projects and programs face many questions and challenges, for example: How can they integrate the traditional knowledge of smallholders with scientific knowledge on environmental and agricultural strategies to promote the most suitable systems for each situation? How can barriers be removed to smallholders to access markets for tree and other AFS products, allowing them to capture more of their value, especially for people who are socially or economically marginalized (including women)? What types of products and markets are most suitable, and what interventions are most cost effective to realize these outcomes? Can successful cases of AFS be scaled-up and scaled-out to reach the target population outside the areas or regions affected by individual projects and programs?

These complex questions need innovative approaches from varying perspectives and knowledge bases. This book gathers fresh and novel contributions from a set of Yale University researchers and associates who intend to provide alternative and sometimes departing insights into these pressing questions. The book focuses on the functions that AFS can provide when well designed and implemented: their role in rural development as they can improve food security and sovereignty and contribute to provision of energy needs to the smallholders; and their environmental functions: contribution to biodiversity conservation, to increased connectivity of fragmented landscapes, and to adaptation and mitigation of climate change.

The chapters present conceptual aspects and case studies ranging from traditional to more modern approaches, from tropical as well as from temperate regions of the world, with examples of the AFS functions mentioned above. The first section is dedicated to describing the main agroforestry challenges and alternatives with case studies from tropical dry, humid and temperate ecosystems worldwide. The second section is dedicated to explaining how agroforestry systems were practiced by indigenous communities in a variety of settings and how they can transition from subsistence to market oriented systems. This transition, to be successful requires an integration of ecological, indigenous and scientific knowledge as tools for sustainable development, as well as adapting indigenous agroforestry systems for integrative landscape management and sustainable value chain development. Section 3 is dedicated to the multiple environmental services that agroforestry can provide in multifunctional landscapes. From the lessons learned, in the Conclusions chapter pending questions and challenges are summarized with suggestions for alternative approaches to fulfill the expectations on the roles that agroforestry can play to satisfy

the increasing rural development and landscape conservation needs faced in the current millennium. The Conclusions chapter also deals with larger scale economic problems and barriers that limit the large scale adoption of agroforestry systems and gives suggestions to overcome these barriers.

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