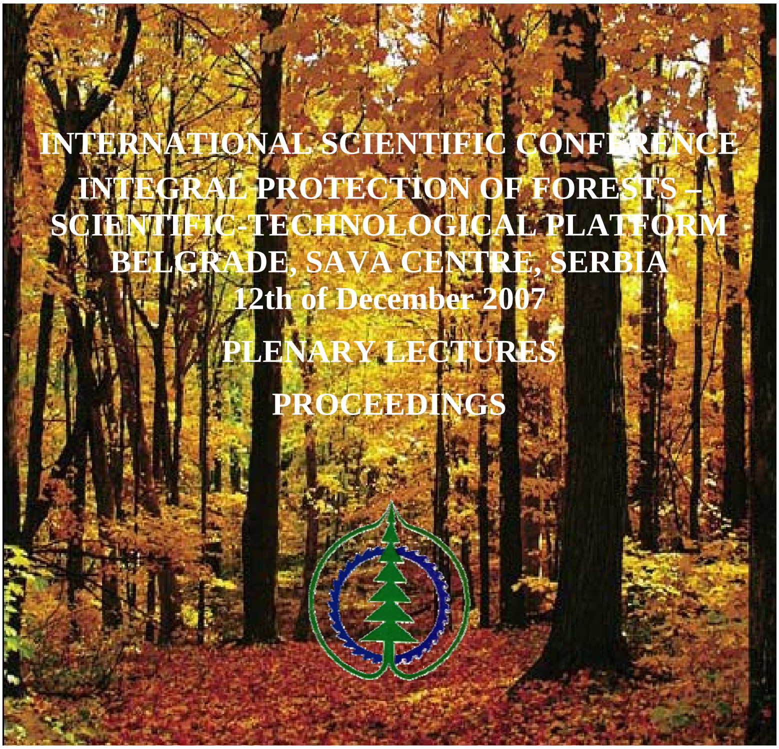
INSTITUT ZA ŠUMARSTVO INSTITUTE OF FORESTRY
BEOGRAD BELGRADE

# ZBORNIK RADOVA

COLLECTION
TOM 56

Yu ISSN 0354-1894



INTERNATIONAL SCIENTIFIC CONFERENCE
INTEGRAL PROTECTION OF FORESTS –
SCIENTIFIC-TECHNOLOGICAL PLATFORM
BELGRADE, SAVA CENTRE, SERBIA
12th of December 2007
PLENARY LECTURES
PROCEEDINGS

BEOGRAD BELGRADE
2007

# INSTITUT ZA ŠUMARSTVO BEOGRAD

# INSTITUTE OF FORESTRY BELGRADE

## ZBORNIK RADOVA

## PROCEEDINGS

| | |
|---|---|
| **Izdavač** | **Publisher** |
| Institut za šumarstvo | Institute of Forestry |
| Beograd, Srbija | Belgrade, Serbia |

•

| | |
|---|---|
| **Za izdavača** | **For Publisher** |
| Dr Ljubinko Rakonjac | Ph.D. Ljubinko Rakonjac |

•

| | |
|---|---|
| **Redakcioni odbor** | **Editorial Board** |
| Dr Mara Tabaković-Tošić | Ph.D. Mara Tabaković-Tošić |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Miloš Koprivica | Ph.D. Miloš Koprivica |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Radovan Nevenić | Ph.D. Radovan Nevenić |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Pero Radonja | Ph.D. Pero Radonja |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Dragana Dražić | Ph.D. Ph.D.agana Ph.D.ažić |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Ljubinko Rakonjac | Ph.D. Ljubinko Rakonjac |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Mihailo Ratknić | Ph.D. Mihailo Ratknić |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Zoran Miletić | Ph.D. Zoran Miletić |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Milorad Veselinović | Ph.D. Milorad Veselinović |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Dr Dragana Stojičić | Ph.D. Dragana Stojičić |
| Institut za šumarstvo, Beograd | Institute of Forestry, Belgrade |
| Assoc. Prof. Dr Iantcho Naidenov | Assoc. Prof. Dr Iantcho Naidenov |
| Bugarska | Bulgaria |
| Prof. Dr Nikola Hristovski | Prof. Dr Nikola Hristovski |
| Makedonija | Macedonia |
| Dr Kalliopi Radoglou | Dr Kalliopi Radoglou |
| Grčka | Greece |

•

| | |
|---|---|
| **Glavni i odgovorni urednik** | **Editor in Chief** |
| Dr Mara Tabaković-Tošić | Ph.D. Mara Tabaković-Tošić |

•

| | |
|---|---|
| **Tehnički urednik** | **Technical Editor** |
| Mr Tatjana Ćirković | M.Sc. Tatjana Ćirković |

•

| | |
|---|---|
| **Sekretar Zbornika** | **Secretary** |
| Mr Tatjana Ćirković | M.Sc. Tatjana Ćirković |

•

| | |
|---|---|
| **Tiraž** | **Printed in** |
| 150 primeraka | 150 copies |

•

| | |
|---|---|
| **Štampa** | **Printed by** |
| Standard 2 | Standard 2 |

International Scientific Conference

# INTEGRAL PROTECTION OF FORESTS – SCIENTIFIC-TECHNOLOGICAL PLATFORM

## PLENARY LECTURES

### *PROCEEDINGS*

| Citiranje | Citation |
|---|---|
| Međunarodna naučna konferencija | International Scientific Conference |
| Integralna zaštita šuma – | Integral Protection of Forests – |
| Naučno-tehnološka platforma | Scientific-Technological Platform |

All rights reserved. No part of this publication might be reproduced by any means: electronic, mechanical, copying or otherwise, without prior written permission of the publisher.

Belgrade, December 2007.

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

630

**Zbornik radova** / Institut za šumarstvo
= Collection/Institute of Forestry;
glavni i odgovorni urednik Mara
Tabaković-Tošić. – 1991, t. 34/35-
Beograd (Kneza Višeslava 3): Institut za
šumarstvo , 1991- (Beograd: Standard 2).
- 24 cm

. – Je nastavak: Зборник радова – Институт
за шумарство и дрвну индустрију = ISSN
0351-9147
ISSN 0354-1894 = Zbornik radova – Institut
za šumarstvo
COBISS.SR-ID 27739138

International Scientific Conference

# INTEGRAL PROTECTION OF FORESTS – SCIENTIFIC-TECHNOLOGICAL PLATFORM

## PLENARY LECTURES

***PROCEEDINGS***

### HONOURED COMMITTEE:

Ph.D. Ana Pešikan, Ministry of Science – minister
Ph.D. Saša Dragin, Ministry of Environmental Protection – minister
Aleksandar Vasiljević, dipl. ing., Directorate of Forestry – director
Ministry of Agriculture, Forestry and Water Management Republic of Serbia
Vladan Živadinović, dipl. ing., PE „Srbijašume“ – general manager
Prof. Lidija Amiđžić, Ph.D., Nature Protection Agency – director
Ph.D. Ljubinko Rakonjac, Institute of Forestry Belgrade – director

### SCIENTIFIC COMMITTEE:

Ph.D. Radovan Nevenić, Institute of Forestry, Belgrade
Ph.D. Ljubinko Rakonjac, Institute of Forestry, Belgrade
Ph.D. Dragana Dražić, Institute of Forestry, Belgrade
Ph.D. Mara Tabaković-Tošić, Institute of Forestry, Belgrade
Ph.D. Snežana Rajković, Institute of Forestry, Belgrade
Ph.D. Dragana Stojičić, Institute of Forestry, Belgrade
Ph.D. Mihailo Ratknić, Institute of Forestry, Belgrade
Ph.D. Miloš Koprivica, Institute of Forestry, Belgrade
Ph.D. Pero Radonja, Institute of Forestry, Belgrade
Ph.D. Zoran Miletić, Institute of Forestry, Belgrade
Ph.D. Milorad Veselinović, Institute of Forestry, Belgrade
Prof. Stanimir Kostadinov, Ph.D., Faculty of Forestry, Belgrade
Prof. Dragan Karadžić, Ph.D., Faculty of Forestry, Belgrade
Ph. D. Saša Orlović, Institute of Lowland Forestry and Environment, University of Novi Sad
Ph.D. Martin Lorenz, BFH, Federal Research Centre for Forestry and Forest Products, Hamburg, Germany
M.Sc. Richard Fischer, BFH, Federal Research Centre for Forestry and Forest Products, Hamburg, Germany
Prof. Srđan Bojović, Ph.D., IBISS BU, Belgrade
Ph.D. Ilpo Tikkanen, Europen Forest Institute, Finland
Ph.D. Malgorzata Gajos, University Silesia, Poland
Ph.D. Miroslav Benko, Institute of Forestry, Jastrebarsko, Croatia
Ph.D. Leonidha Peri, Faculty of Forestry Tirana
Ph.D. Makedonka Stojanovska, Faculty of Forestry, Skoplje, Makedonija
Ph.D. Dijana Vuletic, Institute of Forestry, Jastrebarsko, Croatia
Ph.D. Hajri Haska, Institute of Forestry, Tirana
Ph.D. Mersudin Avdibegović, Faculty of Forestry, Sarajevo, BIH
Ph.D. Milan Mataruga, Faculty of Forestry, Banja Luka, BIH
M.Sc. Slobodan Bajagić, Croatia

### ORGANIZATION COMMITTEE:

M.Sc. Ljiljana Brašanac, Institute of Forestry, Belgrade
M.Sc. Svetlana Bilibajkić, Institute of Forestry, Belgrade
M.Sc. Tomislav Stefanović, Institute of Forestry, Belgrade
M.Sc. Đorđe Jović, Institute of Forestry, Belgrade
M.Sc. Tatjana Ćirković, Institute of Forestry, Belgrade
Zoran Poduška, dipl. ing., Institute of Forestry, Belgrade
Aleksandar Lučić, dipl. ing., Institute of Forestry, Belgrade

**Address of the Organizing Committee**
INSTITUTE OF FORESTRY
Kneza Viseslava 3
11030 Belgrade
Serbia
www.inforserb.org, www.izas.org.yu

# SADRŽAJ CONTENTS

## SCIENTIFIC SESSION I:
## THE ROLE OF FORESTRY SECTOR IN PRESERVATION AND DEVELOPMENT OF NATURAL RECOURSES – LOCAL AND INTERNATIONAL SCALE

## SCIENTIFIC SESSION II:
## PROTECTION AND DEVELOPMENT STATE OF FORESTS AND ENVIRONMENT – EDUCATION, RESEARCHING, TRAINING, NEEDS

## SCIENTIFIC SESSION III:
## MULTIFUNCTIONAL USE AND SUSTAINABLE MANAGEMENT OF FOREST RECOURSES

INSTITUT ZA ŠUMARSTVO • BEOGRAD
INSTITUTE OF FORESTRY • BELGRADE

International Scientific Conference
INTEGRAL PROTECTION OF FORESTS – SCIENTIFIC-TECHNOLOGICAL PLATFORM
December 12th, 2007., Belgrade

## *SCIENTIFIC SESSION II*

## PROTECTION AND DEVELOPMENT STATE OF FORESTS AND ENVIRONMENT – EDUCATION, RESEARCHING, TRAINING, NEEDS

## *PLENARY LECTURE*

# THE INTEGRATED PROTECTION AND SUSTAINABLE FOREST ROLE

*Snežana RAJKOVIĆ, Mara TABAKOVIĆ-TOŠIĆ*[1]

**Abstract:** *In such a quickly changing world, can anything be sustainable? What do we want to sustain? How can we implement such a nebulous goal? Is it too late? With the contradictions and questions have come a hard look at our present forest production system and thoughtful evaluations of its future. If nothing else, the term "sustainable forest" has provided "talking points," a sense of direction, and an urgency, that has sparked much excitement and innovative thinking in the world. Keep the following in mind: a) interactions between farming systems and soil, water, biota, and atmosphere are complex--we have much to learn about their dynamics and long term impacts; b) most environmental problems are intertwined with economic, social, and political forces external to forestry; c) some problems are global in scope while others are experienced only locally; d) many of these problems are being addressed through conventional, as well as alternative, agricultural channels; e) the list is not complete; and f) no order of importance is intended.*

*Role of forestry in producing sustainable raw material - timber - clear.Wide range of additional benefits: local employment and rural development; habitat creation and biodiversity; environmental protection, e.g. riparian woodland; recreation and amenity; landscape enhancement; carbon sequestration; environmental education, culture, folklore, heritage. Forestry is a multi-benefit landuse - environmental, social and economic benefits.*

*So, how best do we manage our forests to maximise all of these benefits without reducing their capacity to provide them to future generations?*

---

[1] Snežana Rajković, Ph.D., Mara Tabaković-Tošić, Ph.D, Institute of forestry, Belgrade
*Translation: Marija Stojanović*

*Solution in* ***Sustainable Forest Management*** *(SFM)*

**Key word**: integrated protection, sustainable, forest, management

## INTRODUCTION

During the past 50 years, the earth's population doubled to reach its current level of 6 billion. Today world population is increasing by 80 million annually, with the total projected to reach 10 billion within 40 more years. Humanity must learn to live within the constraints imposed by the physical environment as both a provider of inputs and a sink for wastes. The fact that today more than 1 billion people do not have access to clean water and 1.7 billion people lack basic sanitation illustrates that the demands of a growing human population and an expanding global economy are already placing considerable stress on natural systems. This raises huge challenges for policy-makers as they seek to reconcile the needs and aspirations of a growing population with resource limitations.

Forestry is faced with the challenge of meeting an increasing demand for wood products, as well as for an expanding array of services, such as clean water, recreation, and wildlife habitat. In most regions, these needs will have to be met from a fixed or shrinking land base. Forests may be able to produce sufficient wood but production costs will rise and so too will the cost of wood products. Forest management must consider the potential for negative impacts to the environment, as well as how to cope with the uncertainties of weather and climate change.

Ultimately the challenge is to find ways to sustain the provision of goods and services that society derives from forests in ways that…" meet the needs of the present without compromising the ability of future generations to meet their own needs." Bruntland (1987).

Following the 1992 Earth Summit, there have been numerous efforts throughout the world to define sustainable forest management (SFM). Foremost amongst these have been the efforts to establish Criteria and Indicators (C&I) that provide a common framework for describing, monitoring, and evaluating SFM. Although, the various C&I efforts originated from country-led efforts, there is a surprising similarity in the criteria that evolved. All C&I approaches seek to characterize SFM on the basis of a range of benefits derived from forests and they all incorporate elements of the following criteria (Wijewardana 1998): Extent of Forest Resources, Healthy Forest Ecosystems, Productive Functions, Biological Diversity, Protective Functions, Socioeconomic Benefits, Legal, Policy, and Institutional Framework.

The first six of the seven criteria can be viewed as a statement of the goods and services that society derives from its forests.

From this perspective, there are places in the world that are already experiencing difficulty with some of these criteria. Operationally, it seems less likely that a country will conclude that it is failing at SFM, but rather that in some locations, for some specific goods and services, society's expectations are not being met. For example, in some places the fragmentation of forests across the landscape has resulted in the reduction of many plant and animal species that rely on forest habitat. In other regions there are projections of inadequate wood supply. Insufficient water quality and aquatic habitat are issues that now affect most regions.

Agriculture and forestry account for much of the world's land use. Too often we treat agriculture and forestry separately, yet these two sectors are often interwoven on the landscape and share many of the same goals. If we are to truly meet 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 (Ruark 1999).

Agroforestry practices are an important category of planted forests or "trees outside forests" (Long and Nair 1999) that have the potential to provide a wide array of forest-related benefits to society (See Box 1). Indeed, in many places the only opportunity to provide increased forest-based benefits, like wildlife habitat or forested riparian systems, is through the increased use of agroforestry on agricultural lands. Also, in many forest-based ecosystems, agroforestry principles are being employed to derive benefits, such as non-timber forest products (Nair 2001).

## Definition of Agroforestry

Agroforestry is the combination of agricultural and forestry technologies to create integrated, diverse and productive land use systems (Garrett et al. 2000). Agroforestry has the ability to provide short-term economic benefits while the farmer waits for traditional longer-term forestry products. An example of an agroforestry system is a riparian buffer planting that can attenuate flooding effects and protect water quality, while providing wildlife habitat, recreational opportunities and harvestable products, like edible berries and medicinal herbs.

Agroforestry encompasses a very large and diverse set of practices ranging from croplands in which a minimal tree component has been added to complex forest production that has been integrated into an existing forest structure. Differences exist in how agroforestry is defined and perceived between tropical and temperate zones and reflect the wide variation in the climate, soils, pressures on the land and socioeconomic values where agroforestry can be applied. After examining many definitions and examples of agroforestry used globally, Nair (1985) concluded that the "strict scientific definition should stress two characteristics common to all forms of agroforestry:

- The deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals, either in some form of spatial mixture or in sequence.
- There must be a significant interaction (positive and/or negative) between the woody and non-woody components of the system, either ecologically and/or economically."
- Scientific evidence is now available to show that the spatial and temporal heterogeneity created by the agroforestry plantings can help enhance resource, increase production, reduce risk of monocultural agricultural and forestry practices, and achieve system stability and sustainability (Sanchez 1995; Ong and Huxley 1996; Lefroy et al. 1999; Nair and Latt 1998; Nair 2001). The biological advantages of agroforestry are 1) increased site utilization, 2) improved soil characteristics, 3) increased productivity, 4) reduced soil erosion, 5) reduced microclimate extremes, 6) positive use of microclimate changes (i.e. shade), 7) enhanced above- and below-ground biodiversity (i.e. natural enemy populations). These advantages in turn provide the economic and/or social values being sought from these systems.

A general classification developed by Nair (1985) puts the many agroforestry practices existing world wide into three major types based on the combination of the components:

- Agrisilvicultural: crops and woody plants
- Silvopastoral: pasture and/or animals and woody plants
- Agrosilvopastoral: crops, pasture and/or animals and woody plants
- A fourth category, Other Systems, is also included to catch those practices that don't quite meet any of the prior three types, such as apiculture with trees.

A full discussion of the many forms and practices of agroforestry practiced world wide is beyond the scope of this paper, but readers are referred to Nair (1989), Nair et al. (1995), and Garrett et al. (2000).

The Code lists the objectives of each forest operation, e.g. the production of suitable planting stock, improving tree quality; efficient and environmentally-friendly harvesting. Key factors identify those elements of the operation likely to impact on the three values of SFM. Operational descriptions outline the components of each operation and the best practice methods to ensure compliance with SFM. Potential adverse impacts are listed in order to emphasise the need for best management practice. The most likely adverse impacts arising from careless or incorrect operations are highlighted. Also listed are best practices. These are measures needed to avoid potential adverse impacts, and include care for the physical environment, safety, efficiency and proper planning and consultation with local interests. Each section is accompanied with a list of suitable references included to provide greater technical detail and background material for each operation.

FORESTRY AND WATER QUALITY GUIDELINES have been revised, widened and updated. Sensitive water catchment areas are defined and their management prescribed. Guidelines are given relating to the best forest management practices to ensure the maintenance of high water quality. Recommendations are also made in relation to cultivation, drainage, fertilising and storage, the use of chemicals, herbicides and fuels, road-making, bridges and culverts, and harvesting.

Revised FORESTRY AND THE LANDSCAPE GUIDELINES are presented to ensure that all new plantations complement, rather than detract from, the landscape. The objectives of landscape design are introduced, together with a landscape character type approach. The forest cycle is outlined in terms of operations and their impact on the landscape. Also outlined are measures to mitigate adverse impacts and to enhance the overall landscape, involving shape, scale, diversity, visual force and unity.

Revised FORESTRY AND ARCHAEOLOGY GUIDELINES are designed to ensure that Ireland's rich heritage of archaeological sites and artefacts is not damaged by forest operations. They deal specifically with relevant legislation, sources of records of known archaeological sites, types of sites, protective measures to be employed, and contact details.

These new FOREST BIODIVERSITY GUIDELINES recognise the importance of the maintenance and enhancement of forest biodiversity, and implement the objectives in a forestry context of the National Biodiversity Plan. They describe a range of measures to conserve and enhance biodiversity in forests, such as species and structural diversity, retained habitats and open spaces, the retention of deadwood, the control of troublesome species such as rhododendron, and the use and conservation of native provenances.

The new FOREST HARVESTING AND THE ENVIRONMENT GUIDELINES have been produced to ensure that all forest harvesting operations, including felling, extraction, roading and site restoration, are environmentally sustainable. They describe the impact of harvesting on water, forest soils, landscape, archaeological sites, forest health and vitality, and biodiversity, and lay down clear instructions to ensure best practice.

## SFM Criteria That Agroforestry Can Help Address

While there are certainly differences between tropical and temperate agroforestry, or for that matter between how agroforestry is perceived and practiced in developing and industrialized countries, this paper focuses on the principles and benefits they have in common for addressing SFM. Agroforestry responds to economic, environmental, and social issues common to most regions of the earth. The roles which agroforestry can play in helping the forestry sector achieve SFM can be gauged by the extent to which agroforestry is relevant to the internationally agreed upon criteria of SFM. This paper examines agroforestry's relationship to the first six criteria:

## Extent of Forest Resources (inter alia, carbon)

Agroforestry systems are most extensive in developing countries where approximately 1.2 billion people depend directly on a variety of agroforestry products and services (IPCC 2002). When land conversion was examined, Watson et al. (2000) documented that the greatest potential for carbon uptake is through the conversion of previously degraded lands into well-managed agroforestry systems. Schroth et al (2002) studied the reforestation of primary forest lands in Amazonia that had been previously cleared for crops or pasture. Reforestation with multi-strata agroforestry systems allowed for high rates of biomass accumulation, with the additional benefit of the early generation of income from annual and semi-perennial intercrops. According to IPCC (2000), the potential land area suitable for agroforestry in Africa, Asia, and the Americas may be as high as $1{,}215\text{x}10^6$ ha. The current area under agroforestry is estimated at $400\text{x}10^6$ha; of this $300\text{x}10^6$ ha are classified as arable and $100\text{x}10^6$ha as forest lands.

**Carbon Storage** – Agroforestry plantings can sequester substantial carbon (Watson 2000), but it is important to understand the opportunities of climate change mitigation activities in the context of multiple spatial scales. Agroforestry can be used to link forest fragments and other critical habitat as part of a broad landscape management strategy that enables species to migrate for population genetics reasons and in response to climate change. Trees and shrubs planted in shelterbelts can store carbon in their shoots and roots, while protecting soils and crops and providing biodiversity and habitat for wildlife (Pandey 2002). Through either deposition of wind-blown soils or interception of surface runoff sediments, many of the linear-based agroforestry practices, such as shelterbelts and riparian buffers, can trap significant amounts of carbon-rich topsoil that would otherwise be lost from these systems (Lal et al. 1999; Kimble et al. 2003). Riparian forest buffers are natural carbon sinks and when suitable trees and shrubs are grown in these moist environments they also filter out contaminants from adjacent agricultural or community activities.

In temperate systems agroforestry practices have been shown to store large amount of carbon (Kort and Turlock 1999; Schroeder 1994). Potential C storage from agroforestry systems in temperate regions has been estimated to range from 15-198 t C $\text{ha}^{-1}$ with a modal value of 34 t C $\text{ha}^{-1}$ (Dixon 1995). Nair and Nair (2003) estimated C sequestration potential through agroforestry practices in the United States by 2025 as 90.3 Mt C $\text{y}^{-1}$. In the tropics, Palm et al. (1999) report that agroforestry systems helped to regain 35 percent of the original C stock of the cleared forest, compared to only 12 percent by croplands and pastures. Fay et al. (1998) estimated the area for potential conversion to these agroforestry systems at $10.5\text{x}10^6$ ha $\text{y}^{-1}$. Based on a preliminary assessment of national and global terrestrial C sinks, two primary beneficial attributes of agroforestry systems have been identified: (1) direct near-term C storage (decades to centuries) in trees and soils and (2) potential to offset immediate greenhouse gas emissions associated with deforestation and subsequent shifting cultivation. A projection of carbon stocks for smallholder agroforestry systems indicated C sequestration rates ranging from 1.5 to 3.5 Mg C $ha^{-1}$ $y^{-1}$ and a tripling of C stocks in a 20-year period, to 70 Mg C $ha^{-1}$. According to one estimate, median carbon storage by tropical agroforestry practices is around 9, 21, and 50 Mg C $ha^{-1}$ in semiarid, subhumid, and humid ecozones, respectively. The total carbon emission from global deforestation at the currently estimated rate of 17 million ha $y^{-1}$ is 1.6 Pg. Assuming that one hectare of agroforestry could save 5 hectares from deforestation and that agroforestry systems could be established in up to 2 million hectares in the low latitude (tropical) regions annually, a significant portion of carbon emission caused by deforestation could be reduced by establishing agroforestry systems (Palm et al. 1999).

## Healthy Forest Ecosystems

Forest activity at a specific site needs to be integrated into a broader land-use context that considers the management of land and water resources as regional units (Miller 1996). Agroforestry plantings can help add structural and functional diversity to landscapes and, if strategically located, they can help restore many ecological functions (Olson et al. 2000). While agroforests are typically less diverse than native forest, they do contain a significant number of plant and animal species. This diversity can, in time, provide ecological resilience and contribute to the maintenance of beneficial ecological functions (Lefroy et al. 1999, Vandermeer 2002). Similar to plantation forests, agroforests can help relieve some of the pressure to harvest native forests (although their presence as such is not a sufficient condition for protection of old growth forests).

## Productive Functions: (inter alia, wood / non-timber products)

Agroforestry practices and agroforests can be used to produce harvestable wood for fuelwood, pulp, saw timber, and veneer products. The potential for agricultural lands to augment the world wood supply is substantial (Watson et al., 2000), and has the added benefit of bolstering on-farm income. Many agroforestry designs can also be used to produce non-timber commercial products. Agroforestry plantings mixed into and at the edges of forest plantations can be used to produce a wide array of products, like medicinals, ornamentals, and food products, which are compatible with wood production. This will also allow for greater structural diversity and the development of more diverse plant communities.

## Biological Diversity

There is not enough forested habitat remaining in some landscapes to support some species of plants and animals. Even when there are forest reserves in an area, they may be too small to contain the habitat requirements of all species. In addition, most species have populations that extend beyond reserve boundaries (Kramer et al. 1997). Agroforestry provides ways of augmenting the supply of forest habitat and providing greater landscape connectivity. Where croplands occupy most of the landscape, linear riparian forest buffers and field shelterbelts can be essential for maintaining plant and animal biodiversity, especially under a changing climate scenario. Agroforestry adds plant and animal biodiversity to landscapes that might otherwise contain only monocultures of agricultural crops (Noble and Dirzo 1997, Guo 2000).

The use of corridors to connect fragmented habitats has long been proposed as a mechanism to enhance population processes (Wilson and Willis 1975). There are arguments for and against the use of distinct corridors (Simberloff et al. 1992, Perault and Lomolino 2000), but it is important to recognize that corridors are not necessarily distinct and linear. Often a ‘corridor’ may simply mean habitat areas that are sufficiently close to each other (i.e., functionally linked) to enable dispersal. If spatial arrangement is considered agroforestry plantings can be used to connect forest fragments and other critical habitats in the landscape Freemark (2002). Modest considerations, like mixing tree species, allowing for small clearings and water catchments in planting, and incorporating understory vegetation can greatly improve habitat for many animals and create micro-site conditions for plant species (Spies and Franklin 1996).

Freemark (2002) demonstrated the important role of farmland habitat for the conservation of plant species in Eastern Canada. In the Great Plains region of the United States, where cropland occupies most of the landscape, linear riparian zones and field shelterbelts were argued to play essential roles in maintaining biodiversity (Guo 2000, Brandle et al. 1992). In Central and South America, shaded coffee plantations integrate leguminous, fruit, fuelwood, and fodder trees (Beer 2001). These systems have been documented to contain over 100 plant species per field and support up to 180 bird species (Michon and de Foresta 1990, Altieri 1991, Thrupp 1997). In mature complex multi-strata agroforestry systems of Indonesia, plant diversity was in the order of 300 species ha-1, while bird diversity was found to be 50 percent that in the original rainforest. In addition, almost all mammal species were still present at some level in these agroforestry systems (Thrupp 1997).

## Protective Functions: (inter alia, soil / water)

Agroforestry plantings have the potential to contribute significantly to maintaining or improving soil and water quality in a region, while helping to maintain the carbon cycle by sequestering large amounts of carbon in their biomass. The degree to which these and other ecological functions can be provided will depend on plant species composition and their physical structure both above- and below-ground.

**Soil Quality** – One of the main conceptual foundations of tropical agroforestry is that trees and other vegetation improve the soil beneath them. Observations of interactions in natural ecosystems and subsequent scientific studies have identified a number of facts that support this concept. Research results during the past two decades show that three main tree-mediated processes determine the extent and rate of soil improvement in agroforestry systems. These are: 1) increased N input through biological nitrogen fixation by nitrogen-fixing trees, 2) enhanced availability of nutrients resulting from production and decomposition of substantial quantities of tree biomass, and 3) greater uptake and utilization of nutrients from deeper layers of soils by deep-rooted trees (Nair et al. 1999). The other major avenue of soil improvement through agroforestry is through soil conservation. When properly designed and managed, agroforestry techniques can contribute to ecosystem protection and restoration functions by reducing water- and wind erosion and enhancing soil productivity.

**Water Quality** – Most watersheds contain a mixture of land uses, including forestry and agriculture. Protecting water quality requires an integrated multi-sectoral approach to watershed management. Streams that course through agricultural lands are often devoid of vegetation in their riparian zones and runoff containing excess fertilizers, pesticides, animal wastes, and soil sediments enters surface waters unabated. Agroforestry technologies, like riparian forest buffers, have been shown to be effective in reducing water pollution from agricultural activities when they are well designed and properly located in a watershed (Dosskey 2002). These buffers can stabilize stream channels and slow and reduce the transport of runoff to streams. This allows more time for infiltration of water and contaminants into the soil and increases the ability of the environment to degrade pesticides and animal waste products. Linked systems of upland and riparian tree-based buffer systems, designed in regards to other landscape practices and features, can optimize soil and water conservation in the watershed, along with other economic and social services. Agroforestry practices are also being adapted to design best management practices to detain and treat stormwater runoff from communities and restore ecological functions to watersheds.

## Socioeconomic Benefits: (inter alia, silvopastoral / green infrastructure)

In societies where a major part of the population still makes their living off the land, the first concern may be annual income and it is here that agroforestry efforts differ most from conventional ‘tree plantation’ efforts (Dixon 1995, Leakey and Sanchez 1997). In addition, communities are increasingly looking for ways to address social and environmental issues with "green" solutions. Two examples are provided:

**Silvopastoral** - Research has demonstrated that many forage plants will yield high levels of quality biomass when grown under up to 50 percent shade. This knowledge is being used to design agroforestry timber/grazing systems in conifer stands. These silvopastoral systems allow trees to be grown as a long-term product, while on the same piece of ground an annual income can be generated from grazing livestock (Clason and Sharrow 2000). In a silvopasture system trees are grown at a low stocking density to allow about half the sunlight to reach the ground to grow forage. Forest management is encouraged as trees are thinned and pruned periodically to maintain proper light levels. As a result, most of the wood produced is high-value saw timber or veneer quality. While farmers often see economic diversification as the main motivation for establishing silvopasture, other benefits include erosion control, improved wildlife habitat, and carbon sequestering. In addition, the low tree stocking and managed understory makes them inherently low risks for damage by wildfires.

**Green Infrastructure in Communities** - In societies where many live in urban/suburban environments, concerns over the accelerating loss of open and green space tend to become prominent. This is a quality-of-life issue to many and raises the potential for agroforestry applications at the agricultural/community interface to restore ecological functions that provide for stormwater management, wildlife habitat, recreational opportunities, and aesthetic enhancements, as well as a wide array of non-timber products (Box 2) (Thaman 1993). Communities have long understood the need for "gray infrastructure" like water and sewer lines, power lines, and roadways. More recently, the importance of "green infrastructure" that consists of a planned and managed, interconnected network of natural areas (waterways, wetlands, forests and conservation lands like greenways and parks) and adjacent working lands (farms, ranches, and corporate lands) has gained recognition in many communities (The Conservation Fund 2002). Agroforestry approaches that utilize trees, shrubs, and grasses to manage stormwater runoff are also being adapted to meet community needs to detain and treat stormwater. The vegetation can also act as a living filter to improve water quality downstream and protect stream channels.

## Community Resources' Urban Non-timber Product Project

The "hidden bounty" of agroforestry technologies in communities goes far beyond aesthetics and scenic bike and walking trails. They can provide a myriad of environmental services, from air and water quality, to soil stabilization, climate modification, and wildlife habitat, and, as documented by Community Resources, simultaneously provide economic returns in the forms of non-timber forest products. From a 2-year study in the Baltimore urban forests, the following was found. Individuals and organizations collected over 100 products from 78 species. Alternative products collected ranged from edible products to medicinal, horticultural and craft materials. Collections were by a wide diversity of ethnic and socio-economic groups. The potential value of these products was on par with the per acre values suggested for the environmental services such as energy savings and pollution prevention.

## The Ecological Foundation for Agroforestry

Agroforestry plantings provide us with an excellent tool to meet farmer needs while restoring ecological functions to the landscape. By adding structural and functional diversity to the landscape, these tree-based plantings can perform ecological functions that can have significance far greater than the relatively small amount of land that they occupy (Guo 2000). (Box 3)

## Ecological Functions Created by Agroforestry Plantings

- HABITAT: provides resources (inter alia, food, shelter and reproductive cover) to support an organism's needs.
- CONDUIT: conveys energy, water, nutrients, genes, seeds, organisms, and other elements.
- FILTER/BARRIER: intercepts wind, wind-blown particles, surface/subsurface water, nutrients, genes and animals
- SINK: receives and retains objects and substances that originate in the adjacent matrix of land.
- SOURCE: releases objects and substances into the adjacent matrix of land.

These five functions are described in more detail elsewhere (Forman and Gordon 1986).

**Site-Level Diversity** - Agroforestry, as implied by its name, combines components from both agriculture and forestry through spatial and temporal manipulation of the crop and animal components. It is structurally and functionally more complex than either crop or tree monocultures alone. Greater stratification of resource utilization (nutrients, light, and water) and greater structural diversity lends itself to increased capture of sunlight and a tighter coupling of nutrient cycles. Above- and belowground diversity provides more system stability and resilience. Enhanced site-level diversity typically results in higher levels of belowground microbial diversity and production (Olson et al. 2000).

**Landscape Diversity -** Many ecological functions that contribute to the sustainability of the landscape, such as water and soil quality and wildlife habitat, become fully expressed only at the landscape and watershed levels. For instance, water quality is the end result of a myriad of ecological processes that occur and aggregate up through the watershed. It is influenced by the natural features of the landscape and by the cumulative activities of all the "neighbors" living in the watershed. Without some type of watershed-level coordination, the benefits ascribed to agroforestry and to the many other conservation practices for managed lands may never be fully realized. While isolated agroforestry plantings may provide the desired services at the site level, such as enhanced food or fiber production, agroforestry systems that connect with forests other landscape features are needed to get the desired services at the landscape and watershed levels. Environmental services, such as wildlife corridors, reduced flooding, and improved water and soil quality, all benefit from connectivity (Forman 1995). Agroforestry can provide more protective functions to the landscape when plantings are designed that coordinate with other landscape features throughout the working landscape.

## A Planning Framework to Optimize Agroforestry’s Capability for Multiple Benefits

Agricultural and urban landscapes are assemblages of interactive components that are continually being modified by humans to produce goods and services. Sustainability of forestry, agriculture, and community sectors ultimately rest on how well we can achieve any kind of coordinated land management strategy in a landscape full of mixed ownerships, management areas, and political boundaries (Sampson 1998). This is very complicated social challenge but can be approached with a planning process that is (The Conservation Fund 2002):

- Proactive ….not reactive
- Systematic ….not haphazard
- Holistic ….not piecemeal
- Multi-jurisdictional ….not single jurisdiction
- Multifunctional ….not single purpose
- Multiple Scales ….not single scale

Agroforestry designs may be typically based on site-focused assessments at the farmer level. However, many of the conservation problems that agroforestry can address are unrecognizable, or are otherwise inadequately accounted for at this scale. How agroforestry plantings are arranged and connected within the larger landscape will determine the quantity and quality of benefits attained. To realize agroforestry's capability to provide multiple services to farmers and society, agroforestry must be planned and designed using information gathered from a variety of spatial and temporal scales. Thaman and Clark (1993) pointed out that "to maintain the landscape in good health, it is not necessary that every landholding, every stretch of land, contain trees, just as every farmer need not be an agroforester – but it is necessary that there be sufficient trees in the right places". How strategically these systems are interspersed throughout the landscape and how strategically designed in terms of species composition at the site level, will ultimately determine the types and levels of forest-related goods and services agroforestry will be able to deliver. Multiple-objective planning is based on the principle that optimal benefits are achieved by strategic placement of land uses and conservation practices. Due to landscape heterogeneity, a strategic land-use planning approach is necessary for agroforestry systems (Sanchez 1995). Designing agroforestry systems that restore or enhance targeted ecological functions will therefore be a task of creating strategic configurations across ownerships and land uses.

## Melding Regional-, Landscape- and Site-Level Concerns

A planning framework that integrates regional, landscape, and site scale planning approaches, serves the primary purpose of aiding agroforestry design at the site level with the additional landscape perspective for developing landscape scale plans to guide strategies for agroforestry adoption, for creating agroforestry programs and for targeting resources to meet landscape level objectives and educating local stakeholders on the value of agroforestry (Bentrup et al. 2000, Franco et al. 2003). To realize agroforestry's capability to provide multiple services to farmers and society, tools that meld regional-, landscape- and site scale concerns can be used to deploy a variety of agroforestry practices across the landscape in strategic spatial arrangements.

Each scale in the process provides different kinds of information critical to meeting landowner and community objectives. At the regional scale, a reconnaissance of existing information provides a general assessment of environmental conditions and resource issues. At the landscape scale, more detailed information is collected and analyzed with geographical information systems (GIS) technologies to identify critical problem areas and desired future conditions. Landscape assessments are made to determine if and what agroforestry practices are appropriate for solving problem area issues and for achieving desired future conditions. The site scale component of the framework incorporates the regional reconnaissance and landscape assessments with site-specific information.

Design alternatives that integrate community-desired future conditions and landowner objectives are generated for the site. Design alternatives include buffer size, composition, and management recommendations.

## Fostering Use of Agroforestry in Sustainable Land Use Strategies

Much of the current endeavors in agroforestry worldwide are focused on meeting the needs for human subsistence. This pressing objective tends to create management aimed at maximizing that primary concern. To create system sustainability, however, requires that multiple concerns are addressed, at least to varying degrees. Agroforestry has tremendous potential to help farmers balance the sometimes conflicting goals of production with stewardship by providing tree-based goods and services while keeping the land in agricultural production. Through these services and goods, agroforestry technologies can be used to create environmental and economic linkages across the agricultural, urban and forested continuum. Agroforestry is not a panacea but should be included in the set of options when tackling issues of population growth, urban sprawl, landscape fragmentation, and the increasing need to produce forest and agricultural goods and services on a decreasing land base.

Although there are some notable exceptions, the general lack of economic rewards to farmers for the environmental services provided to society by agroforestry practices has limited its promotion and adoption (Thaman and Clark 1993). An operational shift in thinking that recognizes the broader working nature of our managed landscapes, along with new ways of valuing the productive and protective functions agroforestry provides in these systems, is needed to encourage the greater adoption of agroforestry in both temperate and tropical systems.

## REFERENCES

1. Altieri, M.A. 1995. Agroecology – The Science of Sustainable Agriculture. Westview Press, London.
2. Beer, J. (ed) 2001. Highlights of CATIE's research in agroforestry during the 1990s. Agroforestry Systems, Special Issue, 51: 75-176.
3. Bentrup, G., M. Dosskey, M. Schoeneberger, G. Wells, T. Leininger, and K. Klenke. 2000. Planning for multipurpose riparian management. p. 423-426. In: P.J. Wigington and R.L. Beschta (eds), Riparian Ecoogy and Management in Multi-Land Use Watersheds. American Resources Association, Middleburg, VA.
4. Brandle, J.R., T.D. Wardle, and G.F. Bratton. 1992. Opportunities to increase tree planting in shelterbelts and the potential impacts on carbon storage and conservation. p. 157-175. In: R.N. Sampson and D. Hair (eds) Forests and Global Change, Vol. 1: Ch. 9. American Forests, Washington D.C.

5. Bruntland Commission. 1987. Our Common Future. The World Commission on Environment and Development. Oxford University Press. Oxford, United Kingdom. p.43.
6. Clason, T.R. and S. H. Sharrow. 2000. Silvopasture practices. p. 119-147. In: H.E. Garrett, W.J. Rietveld, and R.F. Fisher. (eds) North American Agroforestry: An Integrated Science and Practice. American Society of Agronomy. Madison, Wisconsin, USA.
7. Dixon, R.K. 1995. Agroforestry systems: sources or sinks of greenhouse gases? Agroforestry Systems 31: 99-116.
8. Dosskey, M.G. 2002. Setting priorities for research on pollution reduction functions of agricultural buffers. Environmental Management 30:641-650.
9. Fay, C., H. DeForeta, M. Sarait, and T.P. Tomich. 1998. A policy breakthrough for Indonesian farmers in the Krui dammar agroforesters. Agroforestry Today 10(2): 25-26.
10. Forman, R.T. 1995. Landscape Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, MD USA.
11. Freemark, K.E., C. Boutin, and C.J.Reddy. 2002. Importance of farmland habitat for conservation of plant species. Conservation Biology 16:399-412.
12. Garrett, H.E., W. J. Rietveld, and R.F. Fisher. (eds). 2000. North American Agroforestry: An Integrated Science and Practice. American Society of Agronomy, Inc. Madison, WI.
13. Guo, Q. 2000. Climate change and biodiversity conservation in Great Plains agroecosystems. Global Environmental Change 10:289-298.
14. IPCC (Intergovernmental Panel on Climate Change): 2000, 'Land-use, Land-use Change and Forestry, Special report. Cambridge University Press, Cambridge.
15. Kort, J. and R.Turlock. 1999. Carbon reservoir and biomass in Canadian prairie shelterbelts. Agroforestry Systems 44:175-189.
16. Kramer P., C.P. van Shaik, and J. Johnson. 1997. Lost stand – protected areas and the defense of tropical biodiversity. Oxford Univ. Press, Oxford, UK.
17. Lal, R., Kimble, J. M., Follett, R. F., and C. V. Cole (eds). 1999. The Potential of U. S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect. CRC Press, Boca Raton, FL. 128 p.
18. Lefroy, E. C., Hobbs, R. J., O'Connor, M. H., and J. S. Pate (eds). 1999. Agriculture as a Mimic of Natural Ecosystems. Kluwer Academic Publishers, Dordrecht, The Netherlands. 438pp.
19. Long, A. J., and Nair, P. K. R. 1999. Trees outside forests: Agro-, community, and urban forestry. New Forests. 17: 145-174.
20. Michon, G., and H. DeForesta. 1990. Complex agroforestry systems and the conservation of biological diversity in harmony with nature. Proceedings of International Conference on Tropical Biodiversity. Kuala Lumpur (SEA MEO-BIOTROP).
21. Nair, P.K.R. 1985. Classification of agroforestry systems. Agroforestry Systems 3:97-128.
22. Nair, P.K.R. (ed) 1989. Agroforestry Systems in the Tropics. Kluwer Academic Publishers, Dordrecht, The Netherlands, 245 p.
23. Nair, P. K. R. 2001. Agroforestry. pp. 375-393. In: Our Fragile World: Challenges and Opportunities for Sustainable Development, Forerunner to The

Encyclopedia of Life Support Systems, Chapter 1.25, Vol. I. UNESCO, Paris, France, & EOLSS, UK.

24. Noble, I.R. and R. Dirzo. 1997. Forests as human-dominated ecosystems. Science 277:522-525.
25. Olson, R.K., M.M. Schoeneberger, and S.G. Aschmann. 2000. An Ecological Foundation for Temperate Agroforestry. p. 31-61.In: H.E.,Garrett, W.J. Rietveld, and R.F. Fisher. (eds). North American Agroforestry: An Integrated Science and Practice. American Society of Agronomy. Madison, Wisconsin, USA.
26. Ong, C. K. and Huxley, P. A. (eds.) Tree-Crop Interactions. CABI, Oxon, UK., 385 p.
27. Palm, C.A., P.L. Woomes, J. Alegre, L. Arevaldo, C. Castilla, D.G. Cordeiro, B. Feigl, K. Hariah, J. Kotto-Same, A. Mendes, A. Moukam, D. Murdiyarso, R.
28. Pandey, D.N. 2002. Carbon sequestration in agroforestry systems. Climate Policy 2:367-377.
29. Perault, D.R., and M.V. Lomolino. 2000. Corridors and mammal community structure across a fragmented old growth forest landscape. Ecological Monographs 70:401-422.
30. Ruark, G.A. 1999. Agroforestry and sustainability: making a patchwork quilt. J. of Forestry 97:56.
31. Sanchez, P.A. 1995. Science in agroforestry. Agroforestry Systems 30:5-55.
32. Sampson, N. 1998. Farm and Forest: Which Way to Sustainability. IN: Agriculture and Conservation Policies: 2002 and Beyond. Center for Agriculture in the Environment. http://www.aftresearch.org/researchresource/wp/wp98-7.html(verified March 5, 2003)
33. Schroeder, P. 1994. Carbon storage benefits of agroforestry systems. Agroforestry Systems 27: 89-97.
34. Schroth, G. S.A. D'Angelo, W.G. Teixeira, D. Haag, and R. Lieberei. 2002. Conversion of secondary forest into agroforestry and monoculture plantations in Amazonia: consequences for biomass, litter, and soil carbon stocks after seven years. Forest Ecology and Management 163:131-150.
35. Spies, T.A. and J.F. Franklin 1996. The diversity and maintenance of old-growth forests. In: Biodiversity in Managed Landscapes. R.C. Szaro and D.W. Johnston (eds) Oxford University Press, New York.
36. Simberloff, D., J.A. Farr, J. Cox, and D.W. Mehlman. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology 6:493-504.
37. Thaman, R.R. (1993). Pacific Island urban agroforestry. p. 145-156. In: W.C. Clark and R.R. Thaman (eds) Agroforestry in the Pacific Islands: Systems for Sustainability. United Nations Press, NY.
38. Thaman, R.R. and W.C. Clark. 1993. Agroforestry in the Pacific Islands: systems for sustainability. p. 191-215. In: W.C. Clark and R.R. Thaman (eds) Agroforestry in the Pacific Islands: Systems for Sustainability. United Nations Press, NY.
39. The Conservation Fund. 2002. Green Infrastructure: A Strategic Approach to Green Space Planning and Conservation. The Conservation Fund. Washington DC. USA.

40. Thrupp, L.A. 1997. Linking biodiversity and agriculture: challenges and opportunities for sustainable food security. World Resources Institute, Washington D.C.
41. Vandermeer, J. H. (ed.) 2002. Tropical Agroecosystems. CRC Press, Boca Raton, FL. 268 p.
42. Watson, R.T. I.R. Noble, B. Bolin, N.H. Ravindranath, J.D. Verarda, and D.J.
43. Dokken. 2000. Land-use, Land-use Change and Forestry, IPCC Special Report. Cambridge University Press, Cambridge, 388pp.
44. Wijewardana, D. 1998. Criteria and indicators for sustainable forest management. ITTO Newsletter. Vol. 8, No. 3.
45. Wilson, E.O., and E.O. Willis. 1975. Applied biogeography. p. 522-534. In: M.L. Coady and J.M. Diamond (eds). Ecology and Evolution of Communities. Harvard University Press, Harvard, Mass., USA