World Agroforestry into the Future

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Preface

Standing where we are today, it is increasingly hard to believe that not so long ago agroforestry was not a familiar word, let alone a recognized concept. It is a tribute to the vision of many thousands of professionals during the past quarter century that agroforestry has now achieved such wide recognition as an integrative science and practice with enormous potential to transform lives and landscapes in today's and tomorrow's world. Their hard work and dedication has meant that millions of people around the world now not only know about agroforestry but are also directly benefiting from it.

Before the World Agroforestry Centre (ICRAF) was launched in 1978, agriculture and forestry were commonly treated as mutually exclusive endeavours in research and in practice. But tropical small-scale farmers eventually taught us that the integration of trees in agricultural landscapes has enormous untapped potential to benefit people and the environment. What remained was to deploy the power of science to accelerate the knowledge generation and productivity increases that would effectively exploit this potential.

From the outset, ICRAF scientists collaborated with rural people to learn how agroforestry systems are evolved, and to find ways to better adapt and scale up the most successful science-based agroforestry innovations. They were pioneers of an integrated research model that works to blend different disciplines in order to tackle complex land management challenges and opportunities.

Upon reaching the Silver Anniversary mark, The World Agroforestry Centre convened an international conference to reflect on the accomplishments of agroforestry research, and to conduct a forward-looking assessment of the role of agroforestry science in addressing the key global and regional challenges in the future. Distinguished speakers were invited to share their analysis and views on a wide range of topical issues. These were presented in sessions that were organized around the four global themes of the Centre's work: Trees and Markets, Land and People, Environmental Services, and Strengthening Institutions.

This volume contains a selection of those presentations that were subsequently written up and peer-reviewed. It represents a snapshot of current thinking on the science of agroforestry and exciting future opportunities for its application. We want to thank all those that participated in and contributed to the conference and to this volume. And I want to offer particular thanks to the Canadian International Development Research Centre for their financial contribution to the completion of this publication, and to all of the donor institutions that have invested in the Centre over the years.

This 25th Anniversary Conference was a chance to mark the occasion of our birthday by examining the impact that ICRAF and agroforestry have made and can make. While our quarter-century may seem to be a watershed year, when we can look back on our achievements and forward to our future, in fact we are doing this all the time. We have created a culture of science within the Centre and do not like to stand still or rest on our laurels. Most recently we restructured our focus so that we concentrate on the four global themes mentioned above. This allows us to better appreciate the interconnectedness of the environment and try to retain – or recapture – the natural balance. We recognize that, far from being destructive, change is important. If I can predict anything, it is that as different as the needs of 2003 were from 1978, those of 2028 will be different again.

Dennis Garrity
Director General
World Agroforestry Centre
May 2006

Opening

Opening the conference on a personal note, the Honourable Kipruto arap Kirwa, Kenya's Minister for Agriculture gave Kenya's perspective on agroforestry. He noted that schools and young people should be more involved in tending to trees. This would nurture a responsibility for the global environment, land care and sustainable development in the next generation. "We look at forests and agroforestry as lessening the pressure on land and providing a source of cash… The more we invest in agroforestry, the better our future," he observed. "So the challenge is how to inculcate our people so they understand that the more you invest in agroforestry, the better and brighter your life and that of your children."

In his welcoming remarks, Dr Eugene Terry, Chair of the Centre's Board of Trustees, noted that the Centre's accomplishments have transformed lives and landscapes; not to mention the Centre itself. He added that the development of the Centre started from the inside out, as it transformed itself into a truly global enterprise tackling global issues. That change continues today with the Centre's recently launched theme-based structure that supersedes its previous focus on individual programmes. "This conference will help us get valuable feedback on these new ideas from our partners and stakeholders," he added.

Thanking all investors, particularly Kenya, which hosts the World Agroforestry Centre's global headquarters, Dr Terry stated, "Only by working together in the future, as we have in the past, can we realize the potential of agroforestry and sustainable development. Each one of us should rededicate our effort as we move into the next phase of this institution's existence."

Managing the landscape

Observing that about a quarter of the world's poor depend to some degree on forests, Mr Ian Johnson, Chair of the Consultative Group on International Agricultural Research (CGIAR) and Vice-President of the World Bank, noted, "ICRAF has shown us that forests are more than trees, and that farming is closely connected to landscape management. The Centre has understood both the local and the global dimensions of this connection. The World Bank will increase its commitment to forests, which are a survival base for the poor."

According to Mr Syaka Sadio of the Food and Agriculture Organization of the United Nations (FAO), land degradation is the most serious environmental issue in Africa. He added that the world food situation has never been so worrying, especially in the face of rising populations, declining yields and the decreasing quality of land resources. "At the current rate, we will achieve our Millennium Development Goals 140 years later than planned," he lamented. But there is a glimmer of hope in this bleak picture: "Agroforestry seems to have promising potential to reduce the decline in soil fertility and to increase income. Agroforestry should be respected as a tool for integrating many different sciences. Trees outside of forests, including all forms of forestry in urban areas and rural gardens, are a practical approach to increasing incomes and enhancing soil fertility. Over the last 25 years, ICRAF has accumulated a major knowledge base that is essential to the advancement of these efforts."

Mr Bakary Kante, Director of the Division of Policy Development and Law at the United Nations Environment Programme (UNEP), reaffirmed the Centre's important accomplishments: "Twenty-five years of passionate research in agroforestry is a major achievement, not just for the World Agroforestry Centre, but also for the millions of farmers who benefit from the work of the Centre… Because of the wonderful work that is undertaken here, we are successfully integrating agroforestry into the Clean Development Mechanism (CDM). Agroforestry integrates environmental concerns and poverty eradication. In arid lands, trees like shea and baobab are helping the poor to survive, and guaranteeing children three meals a day."

Towards the future

"Today's needs are very different from those of 25 years ago. I am convinced that the Centre's current staff, Board and management will carry the Centre confidently into the next 25 years," predicted Ms Eva Ohlsson of the Swedish Agency for International Development Cooperation (Sida), who spent six years conducting research with ICRAF in Western Kenya in the 1990s. Sida is a leading donor and supporter of the Centre's early work on sesbania fallows in Zambia. These tree fallows and other fertilizer tree systems are now widely practised across southern Africa.

Other prestigious partners added their voice. "We continue to derive encouragement from our affiliation with the World Agroforestry Centre," affirmed Ms Maureen O'Neil, President of the International Development Research Centre (IDRC). She explained that "the Centre that IDRC helped establish is a continuing source of pride for us. Integrated interdisciplinary participatory research is one of the founding principles of both IDRC and the Centre. Only through partnerships can all the resources needed to solve a problem be harnessed."

Dr Bjorn Lundgren, the Centre's Director General through the 1980s, remarked that networking and partnership were the Centre's way of doing business long before they became popular elsewhere. "We were one of the first interdisciplinary institutions. It was also in the 1980s that we laid the foundation of agroforestry as a science," he recalled.

Lundgern's observations were echoed by Dr Pedro Sanchez, the Centre's Director General during the 1990s and winner of the World Food Prize in 2002. He commented that the Centre's impact at its foundation extended further than networking, "We began to talk science and not just hope." He then took a look into the future, and declared that. "ICRAF is at the forefront in the global science of watersheds, and in using light to predict soil properties. Using technologies such as these, we can simultaneously address the needs of the poor and conduct cutting-edge research."

Further reflections on the Centre's past came from Dr M.S. Swaminathan, who also articulated a vision for the Centre's future. As the first Vice-Chair of ICRAF's Board of Trustees, Dr Swaminathan has been intimately connected with the World Agroforestry Centre from its very earliest moments, having been part of a small group of 10-or-so visionary minds that met at IDRC's headquarters in Canada in late 1977. This group helped to develop agroforestry as a concept, and successfully played 'midwife' to the birth of the Centre. That meeting was convened by David Hopper, the first President of IDRC. Inspiration was provided by the late John Bene's well-known paper that first proposed the imperative of an international centre dedicated to championing the science and practice of agroforestry[1]. Bene (1910–1986) served as ICRAF's first Board Chair (1977–1979), and was succeeded by Swaminathan.[2]

In a video-taped speech, Dr Swaminathan urged agroforesters to broaden their reach and pay greater attention to the vast coastal ecosystems. Agroforestry can open new pathways to utilizing coastal areas at a time when freshwater supplies are dwindling worldwide. He declared that the gender dimension of agroforestry and its impact on women is crucial and must not be overlooked. He noted that agroforestry systems should be designed to ensure that they really meet the needs and problems of the people, while also seeking to understand the rationale behind local land management practices.

Charting a course for the future, Swaminathan encouraged the Centre to pursue a new paradigm of partnerships that emphasize public goods over patents, especially public goods that benefit resource-poor farmers and farm families throughout the tropical world. In conclusion, he recounted, "Agroforestry has always inspired me. I am glad that ICRAF has grown into its present stature and taken an appropriate name – the World Agroforestry Centre. Livelihood security and ecological security are two sides of the same coin. By choosing an agroforestry specialist for the World Food Prize for the first time, the connection between food, forestry and agroforestry has been clearly recognized."

The 25th Anniversary Conference of the World Agroforestry Centre (ICRAF) was officially opened by the Honourable Kipruto arap Kirwa, Kenya's Minister for Agriculture. Notable delegates, most of whom have played an important part in the history of the centre, spoke at the opening session. Also in attendance were distinguished guests, including: the Ugandan High Commissioner to Kenya, His Excellency Matayo Kyaligonza; the Permanent Secretary in Kenya's Ministry of Agriculture, Joseph Kinyua; David Kaimowitz, Director General of the Center for International Forestry Research (CIFOR); Carlos Sere Director General of the International Livestock Research Institute (ILRI); Roger Leakey, a former Director of Research at the Centre; and directors and scientists from many national research institutions in Africa, Asia and Latin America.

[1] Bene, J.G., H.W. Beall and A. Côté 1977. Trees, food and people: land management in the tropics. International Development Research Centre (IDRC), Ottawa, Canada.

[2] For a fuller version of ICRAF's early history, refer to the companion booklet for this volume: ICRAF 2003. The World Agroforestry Centre: Looking back at the first quarter century and ahead to the next. ICRAF, Nairobi, Kenya.

Agroforestry and the Future

"Beyond question, agroforestry can greatly improve life for people in the developing world, and do so within a reasonably short time."

Bene et al. 1977

Keywords:
Millennium Development Goals, fertilizer tree systems, expanded tree cropping, improved tree product processing and marketing, agroforestry transformation

Chapter 1

Science-based agroforestry and the achievement of the Millennium Development Goals

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Abstract

The Millennium Development Goals (MDGs) of the United Nations (UN) are at the heart of the global development agenda. This chapter examines the role of agroforestry research for development in light of the MDGs. It reviews how agroforestry is materially assisting to achieve the goals. And it discusses how the agroforestry science agenda can be realigned to further increase its effectiveness in helping developing countries to meet their MDG targets. Promising agroforestry pathways to increase on-farm food production and income contribute to the first MDG, which aims to cut the number of hungry and desperately poor by at least half by 2015. Such pathways include fertilizer tree systems for smallholders, and expanded tree cropping and improved tree product processing and marketing. These advances can also help address lack of enterprise opportunities on small-scale farms and child malnutrition. The rate of return to investment in research on tree crops has been shown to be quite high (88%). But enterprise development and enhancement of tree product marketing have been badly neglected. Tree domestication, and the commercial processing and marketing of tree products and services is a new frontier for agroforestry research for development. A major role is also emerging in the domain of environmental services, particularly the development of mechanisms to reward the rural poor for the watershed protection, biodiversity conservation, and carbon sequestration that they provide to society. Agroforestry research for development is contributing to virtually all of the MDGs. But recognition for that role must be won by ensuring that more developing countries have national agroforestry strategies, and that agroforestry is a recognized part of their development agenda.

Introduction

Achieving the Millennium Development Goals (MDGs) is at the heart of the global agenda. The goals embody the world's aspirations to eliminate desperate hunger and poverty, ensure decent health, enable universal education and elevate the status of women, while conserving and regenerating the global environment. Attaining these goals is the greatest challenge of our generation. Their accomplishment will bring benefits to everyone, including greater economic abundance, peace, and security to all people on the globe. Success in achieving the MDGs requires overcoming hunger and poverty in ways that are more thorough, comprehensive and holistic than ever before. We must attack these problems at their roots, through development that permeates the heart of rural poverty in the developing world.

A clear vision is evolving that articulates how agroforestry research and development can contribute materially to achieving these goals and aspirations. The vision drives a strategy that harnesses the best of global science. This chapter lays out that vision and strategy, providing a framework for the sections and chapters that make up the remainder of this volume.

Where agroforestry fits in

Trees play a crucial role in almost all terrestrial ecosystems. They provide a wide range of products and services to rural and urban people. As natural vegetation is cleared for agriculture, trees are integrated into productive landscapes – the practice known as agroforestry.

Agroforestry is practised by millions of farmers, and has been a feature of agriculture for millennia. It encompasses a wide range of working trees that are grown on farms and in rural landscapes, and includes the generation of science-based tree enterprise opportunities that can be important in the future. Among these are: fertilizer trees for land regeneration, soil health and food security; fruit trees for nutrition and income; fodder trees that improve smallholder livestock production; timber and fuelwood trees for shelter and energy; medicinal trees to combat disease, particularly where there is no pharmacy; and trees that produce gums, resins or latex products (Garrity 2004). Many of these trees have multiple uses, each providing a range of benefits.

An estimated 1.2 billion rural people currently practise agroforestry on their farms and in their communities, and depend upon its products (World Bank 2004). Their tree-based enterprises help ensure food and nutritional security, increase their income and assets, and help solve their land management problems. Trees play a particularly pivotal role wherever people depend on fragile ecosystems for survival and sustenance.

During the past 30 years, agroforestry has progressed from being a traditional practice with great potential to the point where development experts agree that it provides an important science-based pathway for achieving important objectives in natural resource management and poverty alleviation. Despite its ubiquitous use by smallholder farm families, there is inadequate awareness about the potential of agroforestry to benefit millions of households trapped in poverty. We need a global 'agroforestry transformation' to mobilize science and resources to remove the socio-economic, ecological and political constraints to widespread application of agroforestry innovations, and thereby help attain the MDGs.

Building on three decades of work with smallholder farmers in Africa, Asia and Latin America, coupled with strategic alliances with advanced laboratories, national research institutions, universities and non-governmental organizations (NGOs) across the globe, the World Agroforestry Centre and its partners are poised to foster such an agroforestry transformation.

Aiming for an 'agroforestry transformation'

The World Agroforestry Centre's mission is to advance both the science and practice of agroforestry to help realize this transformation. The target is a future in which millions of poor farming households have access to a wide variety of adapted and productive tree enterprises that improve livelihoods in a holistic way (World Agroforestry Centre 2005). Underpinning this is crucial scientific research that will ensure a stream of necessary technical, policy and institutional innovations. The Centre has identified seven major global challenges related to the MDGs to which we aim to contribute. These challenges are:

1. To help eradicate **hunger** through pro-poor food production systems in disadvantaged areas based on agroforestry methods of soil fertility replenishment and land regeneration.
2. Reduce rural **poverty** through market-driven, locally led tree cultivation systems that generate income and build assets.
3. Advance the **health and nutrition** of the rural poor through agroforestry systems.
4. Conserve **biodiversity** through integrated conservation-development solutions based on agroforestry technologies, innovative institutions, and better policies.
5. Protect **watershed services** through agroforestry-based solutions that enable the poor to be rewarded for their provision of these services.
6. Enable the rural poor to adapt to **climate change**, and to benefit from emerging carbon markets, through tree cultivation.
7. Build **human and institutional capacity** in agroforestry research and development.

Mission goals

To address these seven global challenges, the Centre is pursuing four mission goals:

Goal 1

Enhance access by smallholders to high-quality tree germplasm and expanded market opportunities for smallholder tree products.

Goal 2

Advance understanding of the role of trees in practical and productive land and farm management and to foster integrated farming systems based on appropriate agroforestry systems for key agroecological domains.

Goal 3
Increase recognition and deployment of pro-poor agroforestry strategies that generate local benefits while providing global environmental services.

Goal 4
Greatly improve the capacity for effective research, development and education in agroforestry by a wide range of individuals and institutions in the developing world.

The Centre's collaborative advantage in addressing these challenges lies in its role in being able to synthesize and integrate the science and practice of agroforestry at multiple levels. Scientific teams deploy the necessary experience in research, development and education to produce agroforestry innovations in accordance with local needs and priorities. Collaboration with local development partners helps integrate these innovations into their work with the rural poor. Our research in more than 30 developing countries allows for learning and synthesis across a wide range of social, economic, ecological and institutional contexts.

Four integrated research and development-support themes

The mission goals are addressed through four global themes, each related to a corresponding goal.

Theme 1 – Trees and Markets
This theme focuses on the key smallholder tree commodities, their cultivation, value-added processing and the market environment for tree-based products. Poor farmers in less-favoured environments often cannot compete advantageously in the production of basic food commodities. They need to meet their basic needs while diversifying towards higher-value products. This requires a new approach. New tree species need to be domesticated. New strategies and methods for tree product development and the diversification of cultivation systems need to be pursued to better meet the needs of farmers and markets. The theme focuses on four aspects of this: tree domestication with intensification of tree cultivation systems; sustainable seed systems and management of genetic resources of agroforestry trees; enterprise development and enhancement of tree product marketing; and farmer-led development, testing and expansion of tree-based options.

Theme 2 – Land and People
This theme focuses on the household farm system and the integration of trees into productive enterprise portfolios that meet family needs. It seeks to understand the basis for the role of trees in sound land management and quantifies the long-term consequences of agroforestry practices on small-scale agriculture in order to derive locally relevant land management options. Smallholders need integrated portfolios of tree enterprises that address their basic needs and provide cash income. These are being assembled and disseminated in a range of agroecological domains, along with the best-bet agroforestry management options. The components of these systems include trees for improving soil fertility, fruits and vegetable trees for nutrition, fodder for livestock, live fencing, timber, fuelwood, and services such as microclimate regulation. Smallholder tree cash crops (coffee, cocoa, rubber) are a major contributor to rural incomes in many tropical countries. Work on diversifying these systems through integrating other valuable agroforestry trees into them enables smallholders to buffer their incomes in the face of volatile and declining cash crop prices. The poor are often enmeshed in highly complex poverty traps. Thus, we are developing and fostering pro-poor participatory technology development approaches and the enabling policies to address these complex constraints.

Theme 3 – Environmental Services
This theme aims to develop pro-poor agroforestry strategies for both local benefits and global conservation. The work focuses on watershed protection, biodiversity conservation and climate change mitigation and adaptation. The goal is to identify agroforestry systems and landscape mosaics that meet farmer needs for food and income while enhancing these services. Centre scientists are refining the principles and practices to enable communities to farm sustainably while protecting watershed services. Our recent breakthroughs in cost-effective methods for rapidly assessing land quality have greatly enhanced this work. These are combined with the methods of integrated natural resource management (INRM) that the Centre has helped pioneer in its research around the world.

The work in this theme is also advancing the understanding of, and capacity to manage biodiversity in human-dominated landscape mosaics in the tropics. This work is helping to develop the scientific basis for 'ecoagriculture' – an approach to increasing agricultural productivity while protecting natural biodiversity. Agroforestry is also playing a critical role in developing integrated biodiversity conservation approaches for the most critical global hotspots while enhancing the livelihoods of the rural poor in adjoining areas. Centre teams are on the ground in many of these areas, working to develop a global network of successful cases, in collaboration with the Center for International Forestry Research (CIFOR) and other partners.

We are also clarifying the processes for smallholder adaptation to climate change by developing more resilient tree-based farming systems. ICRAF is also working to successfully demonstrate how smallholder farmers can benefit by adopting agroforestry systems that sequester carbon and contribute to climate change mitigation. And we are providing science-based evidence on the tradeoffs and complementarities between land use for environmental services and for livelihoods of smallholder farmers.

Theme 4 – Strengthening Institutions
Agroforestry is a relatively new field of science and development. The Centre recognized early on that there is a major need to build the capacity of regional, national and local institutions to effectively participate in generating and applying innovations in agroforestry and INRM. The work in this theme thus supports the development of high-quality and relevant education programmes, knowledge sharing networks, and mechanisms to link with farmers for effective sharing and management of knowledge for development. It adds value to the efforts of national agricultural, forestry and natural resource institutions by enhancing their ability to develop vibrant agroforestry research programmes and link that research to human development.

The Centre has fostered the development of two major networks that support educational institutions throughout Africa and Asia. They incorporate multidisciplinary approaches to land management into curricula, and develop and improve teaching and learning resources and techniques in INRM. Recognizing that agroforestry is an excellent means through which to convey environmental concepts in elementary schools, the Centre and the Food and Agriculture Organization of the United Nations (FAO) have launched a global programme called Farmers of the Future to foster this approach in the primary and secondary school systems of developing countries.

Strategic links have also been established with farmers' groups and development-oriented organizations to bolster awareness among policy makers and development institutions and improve access to knowledge products on agroforestry and INRM. This work is fostering innovative community-based approaches to sustainable land management. These include Landcare, a farmers' movement that exhibits great promise in Asia and Africa.

Cross-thematic issues

Agroforestry and the advancement of women
In the developing world 60–80 percent of farmers are women. Rural women in developing countries grow and harvest most of the staple crops that feed their families. This is especially true in Africa, where women account for 75 percent of household food production (UNDP 1999, as cited in Bread for the World Institute 2003). Food security throughout the developing world depends primarily on women. Yet they own only a small fraction of the world's farmland and receive only a fraction (less than 10 percent) of agricultural extension services.

Agroforestry offers many entry points to improve the status, income and health of women and children. Rainwater harvesting and tree-growing on farms reduces the drudgery of fetching water and fuel from distant areas. Research on gender and agroforestry is examining these issues, and exploiting important entry points through which women's property rights can be enhanced, and how household agroforestry systems can specifically address their nutritional, health and economic needs.

Agroforestry linkages with better health and nutrition
Advances in agroforestry can improve the health and nutrition of the rural poor. The expansion of fruit tree cultivation on farms can greatly increase the quality of children's nutrition. This is particularly important because indigenous fruit tree resources in local forests are often overexploited. Work with national partners to domesticate a range of nutritious wild indigenous fruits seeks to save these species from overexploitation and develop them for local and regional markets. These efforts will contribute to MDG 4 on reducing child mortality.

There are many complex linkages between agroforestry and the fight against HIV/AIDS. Forty million people currently live with HIV. There is potential for agroforestry to generate much-needed income, improve nutrition, reduce labour demands and stabilize the environment in AIDS-affected communities. The range of threats and the various opportunities have yet to be thoroughly explored, and incorporated into the research and development agenda.

Regional programmes

The Centre focuses primarily on seven regions where the problems of poverty, food insecurity and environmental degradation are most acute. High population density, extreme poverty and land degradation overlap to create strategic entry points for the establishment of an agroforestry transformation.

At the regional level, we concentrate on research, education and development priorities for different agro-ecological zones including dryland areas, humid forest zones, and tropical highlands. The Centre also assists its partners in developing national agroforestry plans and incorporating agroforestry into poverty reduction strategies, and food security and environmental policies. Research networks and policy initiatives provide leverage to promote agroforestry and increased impact.

Africa

Forty-eight percent of the African population is desperately poor – the highest proportion in any region of the world. Per capita food production is declining, and malnourishment and poverty continue to increase. But the global community is mobilizing its resources to address this intolerable situation. An analysis of the farming systems in Africa by FAO (Dixon et al. 2001), and recent comprehensive studies by the InterAcademy Council of Scientific Societies (2004) and the UN Millennium Project (2005) have provided a thorough picture of the constraints and possibilities in attempting to alleviate hunger and rural poverty in Africa. These studies identify hotspots where focused efforts can enhance farm productivity, increase rural incomes and transform agriculture to become a more dynamic driver of economic growth. In their recommendations on how to address the constraints, these studies highlight agroforestry as a crucial pathway toward greater prosperity.

The World Agroforestry Centre currently invests three-quarters of its income in its four African regional programmes. We foresee a series of 'evergreen revolutions' in Africa based on the intensification and diversification of farming systems that have demonstrated potential for major productivity increases. The Centre has teams on the ground investigating key opportunities for science-based agroforestry to help overcome poverty in nearly all of the key hunger spots. This will involve bringing together the best technology for trees, crops, and livestock into integrated farming systems suited to the diverse ecologies, backed by better markets, more vibrant rural institutions, and a more conducive policy framework for development.

Asia

On this vast continent the Centre has two regional programmes: Southeast Asia and South Asia. In Southeast Asia we focus on improved land-use practices that integrate productive trees into agroforest landscapes that provide important environmental services. The incidence of desperate poverty is decreasing in this region, but poverty remains concentrated in the less-favoured upland environments. These areas are particularly well suited to agroforestry. A unique network; Rewarding the Upland Poor for Environmental Services (RUPES) is investigating the nature of these services and developing the basis to recognize property rights and transfer benefits. These advances are based on the deployment of negotiation support systems, a methodology that provides a science-based approach to managing the trade-offs among competing interests in managing critical environments. In South Asia we focus on four main ecosystems with large populations of rural poor. We work in collaboration with a strong, well-established research, development and education system, and are linking South Asian agroforestry science with African regions that have similar ecologies.

Latin America

Here we participate with the Amazon Initiative. This is a consortium that brings together a number of international and national research institutions to focus on reversing natural resource degradation, while improving the livelihoods of the rural poor. In Latin America, Southeast Asia, and the African Humid Tropics regions, we are building on our long-term involvement with the system-wide programme of the Consultative Group on International Agricultural Research (CGIAR) known as Alternatives to Slash-and-Burn (ASB). ASB focuses on the landscape mosaics (comprising both forests and agriculture) where global environmental problems and poverty coincide at the margins of the remaining tropical forests.

Connecting to the global policy environment

Agroforestry is one of the few productive land uses that contribute directly and synergistically to the objectives of all the key international environmental and sustainable development conventions. In particular, it contributes to the goals of the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC) and its Clean Development Mechanism (CDM), the United Nations Convention to Combat Desertification (UNCCD), and the United Nations Forum on Forests (UNFF). The Centre also strives to ensure that the science and practice of agroforestry reaches the mainstream within such international policy fora and initiatives as the New Partnership for Africa's Development (NEPAD). Similarly, the MDGs provide important milestones that have helped to mobilize and channel the interests of developing country governments, development banks and donor agencies.

Forging strategic partnerships and alliances

The science and practice of agroforestry are inherently complex, integrating a range of disciplines, communities and institutions. Thus, partnerships and alliances are crucial to fostering an agroforestry transformation.

Our partners include farmers and farming communities, national and international research organizations, government agencies, development organizations, NGOs, advanced research laboratories and other CGIAR centres. Successful management of agroforestry research, development and educational programmes hinges on the balance and coordination of available expertise to achieve synergy.

In forging partnerships with such institutions, we are able to bring together and focus a critical mass of relevant disciplines and resources to design effective agroforestry strategies, programmes and activities. We need to span the continuum from analysis of research needs through technology development, testing, adoption and implementation of agroforestry innovations. And, in doing so, tap into opportunities provided by institutions and organizations that have knowledge, experience, mandates and resources that complement those of the Centre. We must continue to promote local participation in advancing agroforestry science and practice, thereby incorporating indigenous knowledge and expertise into our work, and vigorously ensure the scaling up and long-term sustainability of agroforestry as a science and a practice.

In conclusion

In the study by John Bene and his colleagues (1977) – upon which the creation of a global centre dedicated to agroforestry was based – it is written:

> "A new front should be opened on the war against hunger, inadequate shelter and environmental degradation. This war can be fought with weapons that have been in the arsenal of rural people since time immemorial, and no radical change in their lifestyle will be required… Beyond question, agroforestry can greatly improve life for people in the developing world, and do so within a reasonably short time."

A quarter-century ago, when this Centre was created, the world was a very different place in many respects. Then, as now, about a billion people lived in desperate poverty and there was food insecurity for hundreds of millions in the developing world. But one thing that has changed since then is that the global community is many times wealthier than it was, and has the benefit of the intervening decades of development experience. Perhaps most important of all it has united behind a set of definitive goals, with explicit measurable targets to hold us accountable for solving each problem. They enable us to focus together on what is really important in our world today: to eliminate hunger and desperate poverty, the most complex, demanding problems that the human community faces. Clearly, there is a tremendous responsibility that scientists and development professionals must bear. We have considerable freedom in choosing the problems on which we work, including the very complex intellectual challenges that tax our intelligence and creativity. This is a special privilege. The issue is what we do with that privilege, with that special opportunity to make a difference. I only hope that in another 25 years our efforts will be judged to have been adequate to that task.

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Trees and Markets

"The scaling up of participatory domestication to tens of millions of new households across the developing world is probably the biggest challenge for agroforestry, both in terms of the logistics of training and supervision, and in the adaptation to new species, environments and markets."

Leakey et al.

Keywords:
Dacryodes edulis, Irvingia gabonensis, Sclerocarya birrea, eco-agriculture, Green Revolution, domestication, agroforestry tree products (AFTPs)

Chapter 2

Trees and markets for agroforestry tree products: Targeting poverty reduction and enhanced livelihoods

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Abstract

Agroforestry tree domestication as a farmer-driven, market-led process emerged as an international initiative in the early 1990s, although a few studies pre-date this. A participatory approach now supplements the more traditional aspects of tree improvement, and is seen as an important strategy for meeting the Millennium Development Goals of eradicating poverty and hunger and promoting social equity. Considerable progress towards the domestication of indigenous fruits and nuts has been achieved in many villages in Cameroon and Nigeria that focuses on 'ideotypes', based on an understanding of the tree-to-tree variation in many commercially important traits. Vegetatively propagated cultivars are being developed by farmers for integration into their polycultural farming systems, especially cocoa agroforests. However, if agroforestry is to be adopted on a scale that has meaningful economic, social and environmental impacts, it is crucial that markets for agroforestry tree products (AFTPs) are expanded. Detailed studies of the commercialization of AFTPs, especially in southern Africa, provide support for the wider acceptance of the role of indigenous tree domestication in the enhancement of livelihoods for poor farmers in the tropics. Consequently, policy guidelines are presented in support of this new approach to sustainable rural development – an alternative to the biotechnology approaches being promoted by some development agencies.

Introduction

In the context of reducing poverty and enhancing the livelihoods of poor smallholder farmers, this chapter presents the evolution over the last 10–15 years of tree domestication strategies, approaches and techniques aimed at promoting the cultivation of trees and the development of markets for agroforestry tree products (AFTPs). It relates the domestication of agroforestry trees to the commercialization of their products and examines the important role that markets play in the adoption of agroforestry and in the achievement of some of the Millennium Development Goals (MDGs). Finally, it suggests that the domestication and commercialization of AFTPs represents a rural development paradigm that is appropriate for wider implementation in developing countries.

Trees

The origins of tropical tree domestication

The domestication of many species for food and other products has been carried out for thousands of years in almost every part of the world, often arising from extractive uses by indigenous people (Homma 1994). The concept of domesticating trees was first presented by Libby (1973), but at this time it was focused on timber trees and was virtually synonymous with tree improvement, including the emerging clonal approaches. In 1992, a conference was held in Edinburgh, entitled 'Domestication of Tropical Trees: The Rebuilding of Forest Resources' (Leakey and Newton 1994a; 1994b), which embraced tree cultivation within the concept of domestication. The recent interest in domestication is not restricted to tree species; a range of new herbaceous crops are also being studied (Smartt and Haq 1997). Many indigenous vegetables are candidates for domestication (Schippers 2000) and can be components of multistrata systems, where there is a need for new shade-tolerant crops.

These days, the World Agroforestry Centre's tree domestication activities fall within a Trees and Markets research theme that stresses the commercialization of AFTPs in the overall poverty alleviation strategy of the Centre. While the focus of this chapter is on the development of marketable products from agroforestry trees, interest in tree domestication encompasses trees for other purposes such as soil amelioration, fodder, fuelwood, timber, boundary demarcation, and so on.

The aim of tree domestication

The definition of tree domestication, established at the 1992 Edinburgh conference, encompasses the socioeconomic and biophysical processes involved in the identification and characterization of germplasm resources; the capture, selection and management of genetic resources; and the regeneration and sustainable cultivation of the species in managed ecosystems (Leakey and Newton 1994a; 1994b). This concept has subsequently been refined and expanded with emphasis on it being a *farmer-driven* and *market-led* process (Leakey and Simons 1998; Simons 1996; Simons and Leakey 2004) that takes a participatory approach to involve local communities (Leakey et al. 2003; Tchoundjeu et al. 1998). Furthermore, not just species but also whole landscapes can be domesticated as a result of changing plant exploitation practices (Wiersum 1996).

Since the mid-1990s, a growing number of donors have recognized the potential of tree domestication to achieving ICRAF's vision and mandate for agroforestry to contribute to both poverty alleviation and the provision of environmental services (see Figure 1). The rationale is that domestication and commercialization of indigenous trees through agroforestry will provide an incentive for subsistence farmers to plant trees in ways that will reduce poverty and enhance food and nutritional security, human health and environmental sustainability. In this way, agroforestry tree domestication is seen as an important component of strategies to achieve the Millennium Development Goals (Garrity 2004; also see Chapter 1 this volume, especially goals relating to environmental sustainability and food security (Goals 1 and 3–8: www.un.org/millenniumgoals). It is important to note, however, that to bring about effective outcomes from this research the messages have to be clearly and widely disseminated to farmers, foresters and many relevant institutions.

The genetic improvement of trees has usually been the prerogative of national and international research institutes, but since the start of the Centre's Tree Domestication Programme (a forerunner to its Trees and Markets theme), the approach pursued has been a participatory one.

The Humid Lowlands of West and Central Africa (HULWA) was the first of the Centre's regions to develop participatory approaches that went beyond simply collecting germplasm. This started with the development of guidelines for species priority setting, derived by a partnership of international and national scientists with farmers and both non-governmental and community-based organizations (Franzel et al. 1996). This project has since evolved in several ways:

1. It now includes a range of different species.
2. It has used, disseminated and refined a simple low-technology system for the vegetative propagation of tropical trees, appropriate for use in small, low-cost village nurseries (Leakey et al. 1990; Mbile et al. 2004; Shiembo et al. 1997).
3. It has been quantitatively examining the tree-to-tree variation in a range of fruit and nut traits to determine the potential for highly productive and qualitatively superior cultivars (e.g. Anegbeh et al. 2005; Atangana et al. 2002; Leakey et al. 2005c; Ngo Mpeck et al. 2003; Waruhiu et al. 2004).
4. Perhaps most importantly, it has been successfully scaled-up to regional level (Tchoundjeu et al. 1998) and now encompasses 40 villages in southern Cameroon (about 2500 farmers) 11 villages in Nigeria (2000 farmers), 3 villages in Gabon (800 farmers) and 2 villages in Equatorial Guinea (500 farmers).

Together these developments result in a model participatory domestication strategy. This strategy is aligned with the United

Nations Environment Programme's Convention on Biological Diversity (Leakey et al. 2003; Simons and Leakey 2004; Tchoundjeu et al. 1998), by recognizing the rights of local people to their indigenous knowledge and traditional use of native plant species, and to benefit from commercial development of this knowledge.

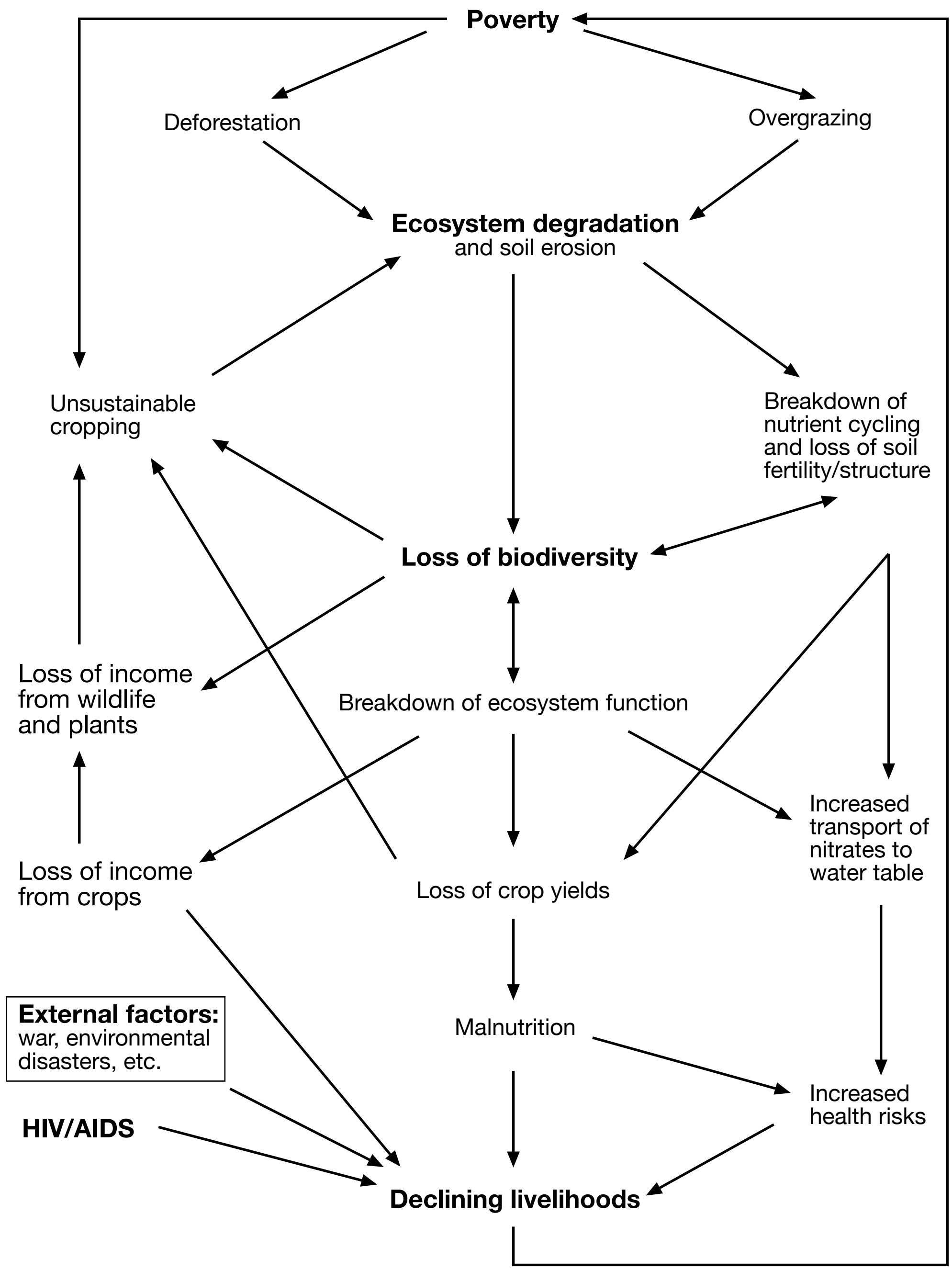

Figure 1. *The cycle of biophysical and socioeconomic processes causing ecosystem degradation, biodiversity loss, and the breakdown of ecosystem function, in agricultural land in many tropical countries.*

The extraction of fruits and medicinal products from indigenous trees by hunter-gatherers is a traditional practice in most tropical regions (Sullivan 1999). It has also been noted that farmers frequently maintain indigenous fruit and nut trees within their farming systems and sell the products locally. Yet despite these observations, and the findings of the species prioritization process, international donors were initially sceptical about investing in new crop species. This scepticism perhaps stemmed from a deep commitment to the Green Revolution, coupled with a top-down approach to rural development in the tropics – still evident in the on-going pursuit of new biotechnological solutions (Lipton 1999; McCalla and Brown 1999).

As proof, a study of the frequency distribution patterns of traditional species found that subsistence households are indeed committed to their traditional food species (Leakey et al. 2004). This conclusion has been corroborated by the quantification of the numbers of indigenous fruit trees in farmers' fields in Cameroon, especially on small farms (Degrande et al. in press; Schreckenberg et al. 2002). In Benin, relative densities of widely used species are typically higher in farmers' fields than in the natural savanna vegetation because of preferential retention by farmers (Schreckenberg 1999). Interestingly, evidence from South Africa indicates that the yield of marula (*Sclerocarya birrea*), a traditionally important indigenous fruit tree, is increased by 5- to 15-fold through cultivation in homestead plots and fields (Shackleton et al. 2003a). Mean fruit size is also greater from trees in these plots, again with some evidence for domestication by farmers (Leakey 2005; Leakey et al 2005a; 2005b).

Identification, capture, retention and protection of genetic diversity

Domestication has been defined as human-induced change in the genetics of a species to conform to human desires and agroecosystems (Harlan 1975). It is not surprising therefore, that much of the work to domesticate agroforestry trees has focused on both the identification of intraspecific genetic variability of the priority species and the vegetative propagation techniques to capture these superior combinations. However, one desirable trait is not necessarily correlated with another: thus large fruits are not necessarily sweet fruits, and do not necessarily contain large nuts or kernels. This multitrait variation, coupled with the variability of each individual trait, results in a considerable opportunity for selection of trees with good combinations of traits, but also makes it more unlikely that an ideal tree will be found. Thus, large numbers of trees have to be screened to find the rare combinations of traits. This rapidly becomes impractical and very expensive. Consequently, the practical approach is to search for trees that have particular market-oriented trait combinations (or ideotypes) – such as big, sweet fruits for the fresh fruit market (a fruit ideotype) or big, easily extracted kernels for the kernel market (kernel ideotype), etc.

Trees can also be selected for production traits such as yield, seasonality and regularity of production, reproductive biology, and reduction of susceptibility to pests and diseases (Kengue et al. 2002). High yield is obviously a desirable trait in any cultivar, but, within reason, may not be as important in the early stages of domestication as the quality attributes. Fruiting season time/length, ripening period and seedlessness are other important variables that could be selected for (Anegbeh et al. 2005).

Such great intraspecific genetic diversity needs to be preserved. Domestication is generally considered to reduce genetic diversity, a situation that may occur where the domesticated plant replaces or dominates the wild origin, but is probably not the case at the current level of domestication of agroforestry trees. For example, the range of fruit sizes in on-farm populations of *Dacryodes edulis* and *Irvingia gabonensis* has been increased by the early stages of domestication (Leakey et al. 2004). Nevertheless, the maintenance of genetic diversity is essential. Modern molecular techniques can identify the 'hot-spots' of intraspecific diversity (Lowe et al. 2000), which should, if possible, be protected for in situ genetic conservation, or be the source of germplasm collections if ex situ conservation is required. In addition, when developing cultivars, they should originate from unrelated populations with very different genetic structures.

Having identified the superior trees with the desired traits, the capture of tree-to-tree variation using techniques of vegetative propagation is relatively simple and well understood (Leakey 2004b; Leakey et al. 1996; Mudge and Brennan 1999). Cuttings from mature trees have a low rate of propagative success, and the number of people with the appropriate skills to carry it out may be a constraint to its widespread application in the future (Simons and Leakey 2004). However, propagation by juvenile leafy cuttings is very easy for almost all tree species and is currently the preferred option for participatory domestication in village nurseries (Mbile et al. 2004; Mialoundama et al. 2002; Shiembo et al. 1996; Tchoundjeu et al. 2002b).

Cultivation and the growth of cultivars

The final stage of the domestication process is the optimal integration of selected plants into the farming system (Leakey and Newton 1994a; 1994b). In African farmland, a wide range of densities and configurations are grown (Kindt 2002). In Cameroon, for example, cocoa agroforests have been reported to contain around 500 cocoa bushes growing with 15 other types of trees and shrubs (Gockowski and Dury 1999). Agroforestry is expected to provide positive environmental benefits on climate change and biodiversity (Millennium Development Goal 7). However, research is needed to determine the impacts of such diversity on agroecosystem function (Gliessman 1998; Leakey 1999b; Mbile et al. 2003); carbon sequestration (Gockowski et al. 2001) and trace gas fluxes; and on the sustainability of production and household livelihoods.

Markets

The term agroforestry tree products (AFTPs) is of very recent origin (Simons and Leakey 2004) and refers to timber and non-timber forest products (NTFPs) that are sourced from trees cultivated outside of forests, to distinguish them from NTFPs extracted from natural systems. However, some products will be marketed as both NTFPs and AFTPs during the period of transition from wild resources to newly domesticated crops. Consequently, both terms are used in the following sections.

Economic and social benefits from trading AFTPs

To be effective, there must be a link between tree domestication and product commercialization, which requires the involvement of food, pharmaceutical and other industries in the identification of the characteristics that will determine market acceptability (Leakey 1999a). In West and Central Africa, a number of indigenous fruits and nuts, mostly gathered from farm trees, contribute to regional trade (Ndoye et al. 1997). In Cameroon, the annual trade in products from five key species has been valued at US$7.5 million, including exports worth US$2.5 million (Awono et al. 2002). Women are often the beneficiaries of this trade; they have especially indicated their interest in marketing *D. edulis* fruits because the fruiting season coincides with the time to pay school fees and to buy school uniforms (Schreckenberg et al. 2002). It is also the women who are the main retailers of NTFPs (Awono et al. 2002). Marula (*Scleocarya birrea*) is another fruit with a harvesting season that coincides with the start of the school year, and therefore the greater involvement of women.

These tangible market benefits are supplemented by additional benefits such as the availability of products for domestic consumption, the use of household labour for harvesting/processing free of charge, and ease of access to informal markets, etc. Because the production and trading of AFTPs are based on traditional lifestyles, it is relatively easy for new producers to enter with minimal skills, little capital and with few needs for external inputs. Together these make this approach to intensifying production and enhancing household livelihoods very easy, and adoptable by poor people.

The linkages between domestication and commercialization of AFTPs

As already indicated, domestication that is market-orientated has the greatest likelihood of being adopted on a scale that has impact on the economic, social and environmental problems afflicting many tropical countries. This requires that agroforesters work closely with the companies processing and marketing the products (Leakey 1999a). However, in doing this it is important to remember that smallholder farmers are the clients of the research and development (R&D) work and that there needs to be a functional production–to–consumption chain; principles that were apparently forgotten during recent domestication of peach palm (*Bactris gasipaes*) in Amazonia, resulting in the underperformance of the market (Clement et al. 2004).

In many cases, the successful commercialization of AFTPs relies on domestication to ensure that supply can keep up with the growing demand of a developing market. Through cultivar development, domestication can also help to overcome another constraint to commercialization: variability of quality (taste, size and purity). Domestication can also lead to an extended season of production, as is being done in West Africa with *D. edulis*, making it easier to supply industries throughout the year. Kiwi fruit (*Actinidia chinensis*) and macadamia nuts (*Macadamia integrifolia*) are good examples of co-ordinated domestication and commercialization.

The important question here is whether agroforestry can prevent the negative impacts that result from domesticating crops in a monoculture system, which can cause environmental degradation through deforestation, soil erosion, nutrient mining and loss of biodiversity. These systems can also result in social inequity and the 'poverty trap' for small-scale producers who are unable to compete in international trade with large or multinational companies. In theory, agroforestry is beneficial to the environment and beneficial to the poor farmer.

However, if the domestication of AFTPs is so successful that the market demand for one of them reaches the point where monoculture plantations, either in the country of origin or in some overseas location, are viable, this could undermine the whole purpose of developing new crops. Without markets there will not be the opportunity for subsistence households to increase their standard of living, while expanded market opportunities could lead to their exploitation by unscrupulous entrepreneurs. Having said that, recognizing the traditional role of NTFPs/AFTPs in food security, health and income generation, it is clear that the potential benefits from domestication outweigh the risks, and that commercialization is both necessary and potentially harmful to small-scale farmers practising agroforestry (Leakey and Izac 1996). Important areas for further study include the complex issues surrounding commercialization of genetic resources and benefit sharing (ten Kate and Laird 1999) and traditional knowledge (Laird 2002) and ways in which smallholder farmers can secure their intellectual property rights on farmer-derived innovations.

One strategy that reduces risk is to domesticate a wide range of AFTP tree species, especially those with local and regional market potential. In this way, coupled with strong indigenous rights, it is very unlikely that the market demand will attract major companies and, even if products of a few species do become international commodities, there will be others that remain.

Not all interest from international companies in agroforestry is unwelcome. For example, Daimler-Benz has taken a smallholder, multistrata agroforestry approach to producing raw materials for its C-class Mercedes-Benz cars in Brazil, and in partnership with the International Finance Corporation has been developing this as a new paradigm for public–private sector partnerships (Mitschein and Miranda 1998; Panik 1998). Smallholder cocoa farmers in Africa and Asia are supported by chocolatier Masterfoods (formerly M&M Mars) as they diversify their cocoa farms into cocoa agroforests, integrating fruit trees (often indigenous species) into the cocoa farm so that the shade trees are also companion crops (Leakey and Tchoundjeu 2001). This has been done as a risk-aversion strategy to provide new sources of income, in response to fluctuating market prices. Interestingly, cocoa is not the only former plantation cash crop to now be an important agroforestry species. Rubber is perhaps the best example, especially in Southeast Asia (Tomich et al. 2001), while tea and coffee are moving in the same direction.

A somewhat different but interesting example of AFTP commercialization is the case of marula, a tree of dry Africa, which is starting to be marketed by subsistence farmers for traditional beer and for industrial processing as an internationally marketed liqueur, 'Amarula', by Distell Corporation. Marula kernel oil ('Maruline') is also breaking into international cosmetics markets. This species thus provides an opportunity to examine the impact of different commercialization strategies on the livelihoods of the producers, the sustainability of the resource and the economic and social institutions. In other words, who or what are the winners and losers arising from the commercialization of indigenous fruits and nuts?

Winners and losers: impacts on livelihoods

The Centre for Ecology and Hydrology,UK, in collaboration with a wide range of institutions, conducted a large, multidisciplinary, multi-institutional study to determine the 'winners and losers' of the various commercialization strategies for a number of different NTFP products from two tree species (*S. birrea* and *Carapa guianensis*) in different environments and in structurally and ethnically different communities (Shackleton et al. 2003a; Sullivan and O'Regan 2003). The study specifically examined the effects of commercialization on the five forms of livelihood capital (human, social, financial, natural and physical). In brief, the authors concluded that to improve the livelihood benefits from commercializing NTFPs it is important to improve:

- The quality and yield of the products through: domestication and the dissemination of germplasm; and enhancing the efficiency of post-harvest technology (extraction, processing, storage, and so on).
- The marketing and commercialization processes by: diversifying markets for existing and new products; investing in marketing initiatives and campaigns; and promoting the equitable distribution of benefits.

The following lessons were learnt for NTFP commercialization from the study of *S. birrea* (abridged from Shackleton et al. 2003b), that apply equally to AFTPs:

- NTFPs are most important for poor and marginalized people.
- NTFPs make up income shortfalls but do not significantly alleviate poverty. How domestication may change this still needs to be determined.
- Engagement in NTFP commercialization and the extent of benefits is variable even among the poorest households.
- Benefits of NTFP commercialization must be weighed against the negative social and cultural costs of commercialization.
- Land and usufruct rights must be clear, government intervention must be pitched at the appropriate level, and political support for the NTFP industry must be secured.
- NTFP commercialization can lead to improved management and conservation of the resource in certain circumstances.
- NTFP cultivation needs to be community-owned and driven.
- Benefits can be accrued at the local level.
- Intellectual property right (IPR) systems that promote poverty alleviation, food security and sustainable agriculture are urgently needed.
- Models of commercialization based on partnerships between producer communities, non-governmental organizations (NGOs) and the private sector are most likely to succeed.
- The diversification of species used, products produced, markets traded, and players involved, is an extremely important strategy to minimize the risks of NTFP commercialization for rural communities.
- Scaling up and introducing new technologies can shift benefits away from women and the most marginalized producers.
- NTFPs form only part of a far broader ecological, economic, social and political landscape. For example, continued land clearance, the need for biomass energy, and wood for woodcarvings can be a greater threat than the commercialization of a fruit product.
- NTFP trade and industries are dynamic in space and time. There are seldom permanent winners and losers.

The conclusion from this study was that NTFP commercialization can create both winners and losers, but positive outcomes can be maximized if external players promote community involvement, and if the communities themselves work together and use their own strengths to manage and use their resources effectively. This is supported by the findings of a study investigating the role of tree domestication in poverty alleviation (Poulton and Poole 2001). Nevertheless, to ensure that those engaged in participatory domestication are winners, the current difficulties facing farmers wishing to protect their rights to their cultivars need to be resolved.

Policy guidelines

Inevitably, in a new research area such as this, many questions remain unanswered; indeed they cannot be answered until the techniques and strategies outlined above have been in use for longer periods and on larger scales. Nevertheless, there seems to be growing confidence on the part of institutions like ICRAF, and their donors, that this approach to agroforestry and the alleviation of poverty has merit. This is emphasized by suggestions that these concepts have a role to play in the achievement of several of the Millennium Development Goals (Garrity 2004).

One clear policy message is that it is important to recognize the 'chicken and egg' relationship between domestication and commercialization (Leakey and Izac 1996) – and the folly of doing one without the other. However, it is clear that the relationship between domestication and commercialization is delicately balanced. Both the lack of a market and the excessive growth of a market pose a threat. Sound policy interventions will probably be needed to ensure that smallholder subsistence farmers are the beneficiaries of the domestication of AFTPs. Policy makers tend not to think much about the differences between a monocultural approach to growing a new crop versus an agroforestry approach. However, in the extreme 20 million trees can either be grown by four farmers planting 5 million apiece, or by 1 million farmers each growing only 20 trees. Each scenario will likely have very different social and economic outcomes.

Desirable policy interventions (from Tchoundjeu et al. 2004; Ndoye et al. 2004; Wynberg et al. 2003) may be to:

- Promote the participatory domestication of tree species fitting a variety of on-farm niches.
- Focus domestication activities on the capture and use of intraspecific variation existing in wild/semi-domesticated populations and utilize the relatively quick economic and social returns from participatory domestication.
- Promote local-level processing and marketing of indigenous fruits, nuts and other tree products in parallel with domestication .
- Recognize the considerable training and extension needs of rural communities that are required to achieve the scaling up necessary to meet the Millennium Development Goals.
- Clarify land and usufruct rights to facilitate the successful and effective commercial development of AFTPs, recognizing that Western approaches may not be appropriate for indigenous resource tenure systems.
- Develop and implement systems to protect community-based cultivars (through participatory domestication) as part of legislative reforms for biodiversity management, indigenous knowledge protection, and plant genetic resource conservation and use.
- Ensure the continued use of a wide range of NTFPs to support rural livelihoods.
- Establish basic management, financial and institutional capacities to ensure that local people capture a greater share of the benefits from commercialisation.

Features of this approach to rural development

Although this chapter has focused on the reduction of poverty and the enhancement of smallholder livelihoods, the problems of poverty, land degradation, loss of biodiversity, social deprivation, malnutrition, hunger, poor health and declining livelihoods are all inextricably linked and cyclical (Figure 1). Consequently any attempts to alleviate the problems have to target a number of different points within the cycle. Agroforestry is advocated as one of many

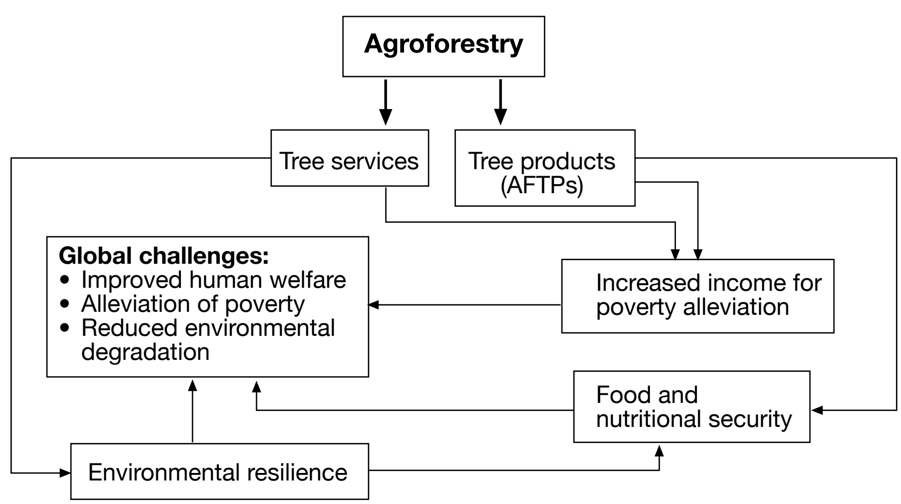

Figure 2. *The relationship between the two functions of agroforestry trees and their potential to mitigate global problems arising from unsustainable land use.*
Source: Leakey and Tomich (1999).

means of meeting these global challenges (Figure 2).

The potential of this approach of course comes with some risks (Figure 3). Furthermore, the domestication of AFTPs may reduce the market-share of wild-collected NTFPs, thereby disadvantaging landless rural people. However, the number of people benefiting from this domestication probably greatly outweighs those who are disadvantaged.

A number of studies imply that the income from AFTPs can contribute to meeting the Millennium Development Goal of halving the number of people living on less than US$1 per day. For example, in Cameroon, studies of farmers growing indigenous fruits have found that the net present value per hectare of cocoa is about US$500 greater when grown with indigenous fruits than when grown without (Gockowski and Dury 1999). To these benefits can also be added the AFTP products used in domestic consumption, which represent a saving on expenditure, and the cash earned from selling AFTPs that may be reinvested in the farms in the form of new and better inputs. It is clear therefore, that it is difficult to evaluate the total benefits obtained from marketable AFTPs.

Thus the challenge posed by the Millennium Development

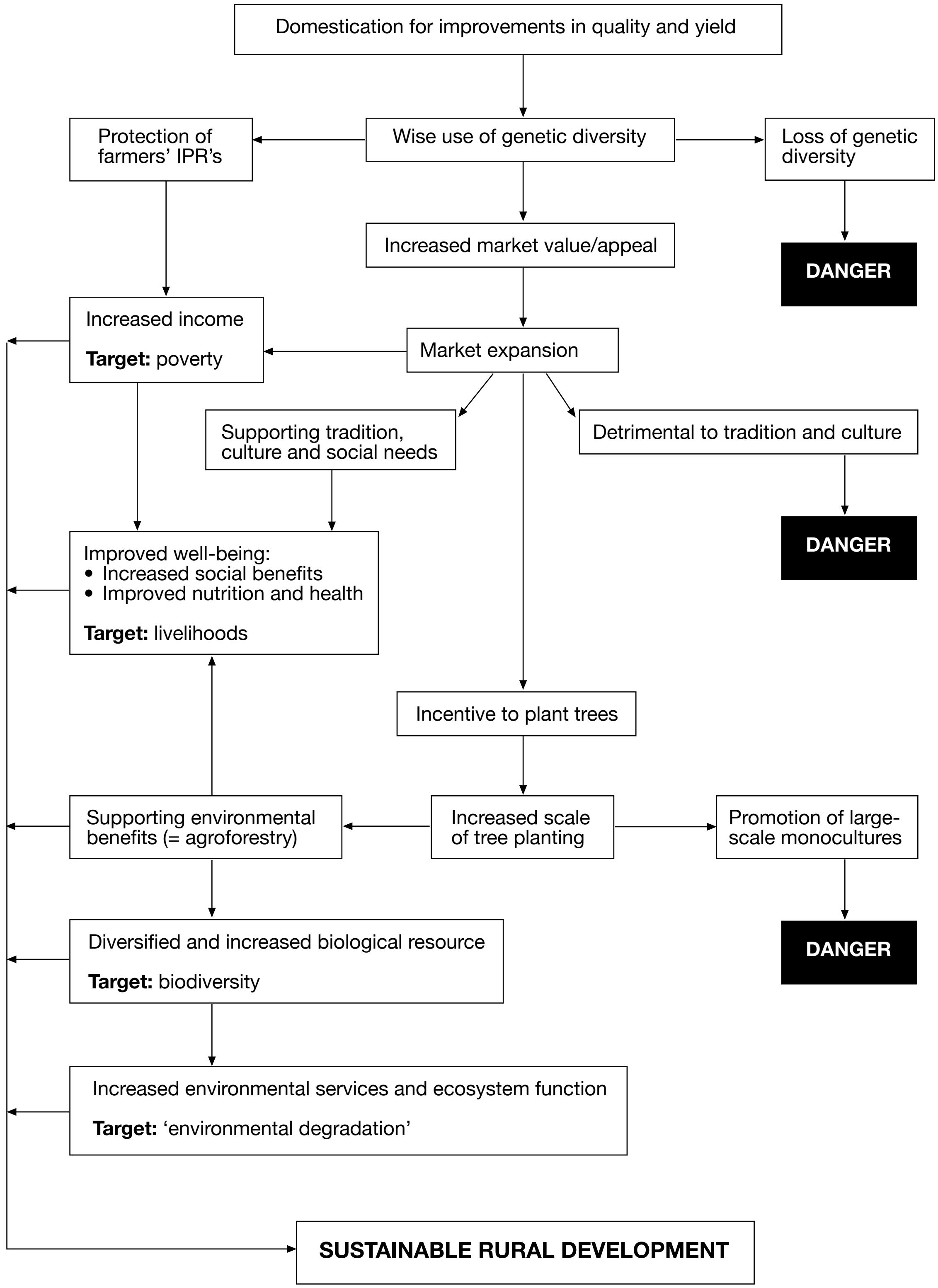

Figure 3. *Potential impacts on sustainability of domesticating agroforestry trees.*

Goals is not so much how to find a way to achieve them at the household level, but much more how to scale up AFTP production between now and 2015 to reach the millions of poor rural families (60 million in HULWA alone) for whom AFTPs might provide a step out of poverty. The AFTP approach could be thought of as a 'really green revolution' (Leakey 2001).

Development issues for the future

The scaling up of participatory domestication to tens of millions of new households across the developing world is probably the biggest challenge for agroforestry, both in terms of the logistics of training and supervision, and in the adaptation to new species, environments and markets. Techniques including vegetative propagation, and the acquisition and protection of 'community plant breeders rights' on the cultivars created by communities, are also areas where urgent action is needed. Failing to achieve this will discourage villagers from investing their time, effort and limited resources in a venture that could be taken away from them. Policy makers should realize that participatory domestication that enables community rights to be protected and realized represents a new and acceptable approach to biodiscovery – the antithesis of biopiracy.

As demand grows, markets will start to be more interested in quality rather than quantity. This will require refinements in the ideotypes for each particular market; necessitating, in turn, better market information than is currently available. Therefore, to avoid the potential pitfalls of domestication (Figure 3), strategies such as deliberate retention of intraspecific variation for pest and disease resistance, etc. will be important (Leakey 1991). In addition, as commercial interests increase, it will be important to maintain a focus on diversified agroforestry production that should promote integrated pest management (Leakey 1999b).

Around the world, agricultural R&D institutions must be helped to develop new skills in the domestication of indigenous species, the processing/storage of their products, market analysis and in developing market linkages (Garrity 2004). This level of expansion will also require high-level policy support to ensure a coordinated and coherent approach to the domestication and commercialization of AFTPs.

Conclusions

In the 9 years since agroforestry tree domestication was institutionalized at the Centre, great progress has been made. This review has focused on progress in the humid zone of West and Central Africa and in Southern Africa, but similar programmes are in progress in the Sahel, East Africa, Amazonia and Southeast Asia, as well as outside the Centre. Hopefully, the experiences reported here for agroforestry based on locally relevant tree species and markets will be of great benefit to other areas of the world embarking on similar people-centred concepts for rural development. We suggest that this approach offers a viable alternative to biotechnology-based advances in agricultural science for developing countries.

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Perennial tree crops, plantations, exports, price variability, smallholders, farmer organizations, diversification, certification, sustainable development, quality control

Chapter 3

The future of perennial tree crops: What role for agroforestry?

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Abstract

Perennial tree crops play a fundamental role in the economies of many of the least developed countries in the tropics where they occupy millions of hectares and few alternative agricultural enterprises exist. They can be a major factor in local poverty alleviation, and global demand for such tree products as chocolate, coffee and rubber continues to grow. Today smallholders produce 80–95% of tree products. As perennial landscape features tree crops can impact land tenure and provide many of the biodiversity and soil protection functions of natural forests. They rarely compete with food crops and by incorporating valuable intercropped annual or perennial species they can provide the basis for productive agroforestry systems.Perennial tree crops currently face many problems, including product price instability, increased industrial concentration within certain commodity chains, withdrawal of state support and weak research efforts. Neither past attempts to regulate trade nor more recent market liberalization has stabilized prices for their products. Producers now need to focus more on diversifying and increasing product quality to ensure more stable incomes. Few poor countries currently have the resources to help producers diversify, and increasingly it will be up to farmer organizations to attract investments from the private sector by improving their product quality. Even the most complex and diverse tree crop/agroforestry systems are generally not very intensive and are often low-yielding. There is potential to increase the range and quality of their products and services. Since most perennial tree crops are produced on smallholdings, social concerns must be taken as seriously as economic and technical aspects. Research is needed on diversifying plantations and the agronomic effects of tree shading, as well as on building the capacity of farmer groups and focusing on commodity quality, certification and value addition. Land tenure regulations, taxes and funding must be addressed. It is also important to promote examples of existing industries that have successfully diversified their outputs while maintaining the quality and supply of the main commodity.

Introduction

Over recent decades, there has been an explosion in the number and variety of perennial tree crops planted in the humid tropics. We define these crops as plant species with a woody support system that periodically produce a valuable crop (for food, income or environmental benefit) other than, or in addition to, timber.

A sustained, worldwide rise in the demand for goods such as chocolate, coffee and natural rubber has led to plantations being established in every continent in the region so that they now occupy tens of millions of hectares. For instance, world cocoa consumption has risen from barely 100,000 tonnes at the beginning of the 20th century to 3.2 million tonnes in 2003–2004

(ICCO 2005). There is a similar trend for oil crops such as coconut (oil is extracted from the dried kernel – the copra) and, more recently, oil palm. Natural rubber, which was a gathered crop in Amazonia at the end of the 19th century, is now harvested from plantations covering more than 10 million hectares worldwide (International Rubber Study Group 2004).

These crops play a fundamental role in the economy of many developing countries, particularly in those that are the least developed and most heavily indebted. Most of the crops are bound for the export market and are an important pillar of overall growth and rural development. "More than 50 developing countries depend on three or fewer commodities for more than half of their export earnings. All heavily indebted poor countries (HIPCs) depended on primary commodities for more than half of their merchandise export earnings in 1997," (World Bank 1999). Except for palm oil, where estates still represent a significant amount of the planted area, most of these perennial crops (80–95%) are grown on small to very small farms (Gilbert and Ter Wengel 2000; World Bank 2002; International Rubber Study Group 2004).

Some of these crops (e.g. oil palm and coconut) contribute to food security at both local and regional levels, while most of them generate income at the household level. They also play a major role in generating foreign exchange at the national level. In addition, such crops can contribute to the sustainability of agricultural systems and, in some cases, play an important role in the preservation of species and ecosystem diversity (Ruf and Zadi 1998; Gockowski 2001; Schroth et al. 2004)

With market liberalization and globalization raising concerns about the sustainable management of land and other natural resources, many stakeholders in tree crop commodity chains are concerned about the future of their crops. In order to address these issues there have been a number of major conferences on the future of tree crops, some of which looked at a range of products (e.g. the perennial crops conference in Yamoussoukro, Côte d'Ivoire in 2001), while others concentrated on one commodity (e.g. the United Nations Conference on Trade and Development (UNCTAD) cocoa conference in 2001, the International Coffee Organization conference in Bangalore in 2004, and the Roundtable for Sustainable Palm Oil that hosted its third roundtable in November 2005 [www.sustainable-palmoil.org]). Other meetings have focused on possible solutions to land management, which include agroforestry and forms of certification and quality zoning approaches (e.g. presentations at the World Agroforestry Congress in Orlando, Florida and the World's Wildest Coffee event in Nairobi, Kenya, both in 2004).

This chapter provides a brief overview of the significance of tree crops to sustainable development and the relationship between tree crops and agroforestry systems. It then reviews the major problems – in some cases crises – in the main tree crop sectors. Finally it suggests ways to create more sustainable tree crop systems, focusing on how these solutions tie into an agroforestry research and development (R&D) agenda. It shows how agroforestry R&D may play a role either directly (e.g. in improving the productivity of farming systems) or indirectly (e.g. through capacity building of farmer organizations) in tree crop systems.

Tree crops and sustainable development

Economic importance

Perennial tree crops have become critical components of many of the national economies in the humid tropics. Millions of hectares are planted to cocoa, coffee, coconut, rubber and oil palm plantations, mostly in developing countries (Table 1). Production is calculated in millions of tonnes; markets are growing and generally absorb any surges in supply, albeit with 'booms and busts' that can and have destabilised local economies. Geographical distribution varies depending on the crop: almost 70% of cocoa is produced in sub-Saharan Africa; more than half of all coffee comes from Latin America; and more than 90% of natural rubber, palm oil and coconut oil is produced in Asia (Table 2).

Tree crops account for a significant percentage of total agricultural exports in many countries: in Côte d'Ivoire they comprise 35%; in Ethiopia 26%; in Ghana 25%; and in Kenya 23%, while in Uganda they account for a massive 53% of all agricultural exports. In Uganda, increased earnings from coffee exports were responsible for half of the drop in the percentage of people living under the poverty threshold, which fell from 54% in 1992 to 35% in 2000 (World Bank 2002).

The total value of tree crop exports for Africa amounted to almost US$5 billion in 2000 (World Bank 2002), including around US$1.5 billion for Côte d'Ivoire and US$640 million each for Ghana and Kenya. The value of global trade in products such as coffee is considerable. For instance, the United States imported US$1.7 billion worth of green coffee in

Table 1. *Areas planted with perennial tree crops in the humid tropics, 2003.*

Cocoa 62 countries 6 980 000 ha		**Coconut** 88 countries 10 707 000 ha		**Coffee** 82 countries 10 025 000 ha		**Oil Palm** 42 countries 11 678 000 ha		**Rubber** 28 countries 8 250 000 ha	
Countries	%	Countries	%	Countries	%	Countries	%	Countries	%
Côte d'Ivoire	24	the Philippines	29	Brazil	24	Malaysia	30	Indonesia	32
Ghana	21	Indonesia	25	Indonesia	11	Nigeria	28	Thailand	23
Nigeria	16	India	18	Mexico	7	Indonesia	26	Malaysia	15
Brazil	8	Sri Lanka	4	Colombia	6	Guinea	3	Vietnam	5
Indonesia	7	Thailand	3	Vietnam	5	Thailand	2	India	5

Source: FAOSTAT 2005.

Table 2. *Production of major perennial tree crops, 2003.*

Cocoa [1] 3 102 000 t		**Coconut (copra)** [2] 5 281 000 t		**Coffee** [3] 6 204 000 t		**Oil Palm** [2] 27 920 000 t		**Rubber** [4] 7 980 000 t	
Countries	%	Countries	%	Countries	%	Countries	%	Countries	%
Côte d'Ivoire	43	the Philippines	45	Brazil	28	Malaysia	48	Thailand	36
Ghana	16	Indonesia	24	Vietnam	14	Indonesia	37	Indonesia	22
Indonesia	14	India	13	Colombia	11	Nigeria	3	Malaysia	12
Nigeria	5	Papua New Guinea	3	Indonesia	6	Thailand	2	India	9
Brazil	5	Mexico	2	Mexico	4	Colombia	2	China	6

Sources: 1. ICCO 2005; 2. Oil World 2005; 3. ICO 2005; 4. International Rubber Study Group 2004.

2003 alone (FAOSTAT 2005). However, some products such as palm oil are used almost entirely by the domestic market. The majority of tree crop products are exported in a raw, unprocessed state. In order to reduce their dependence on international markets, many producing countries are now attempting to carry out more processing locally to add value to their products.

Social importance

Historically, growing tree crops was the preserve of large private or public investors. Nowadays, tens of millions of smallholders participate and tree crops provide employment and income for hundreds of millions of people in the rural zones of countries in the humid tropics. This shift has taken place partly because of the high cost of maintaining large plantations – particularly given the significant market fluctuations – and partly because the end of colonialism has led to a loss of plantation rights. However, large-scale plantations still exist, for example sun-grown coffee is produced over wide tracts of Brazil, large-scale oil palm plantations are found in Malaysia and Indonesia, and tea plantations are common in south Asia and eastern Africa.

Smallholdings, which usually employ family labour, have more flexibility in the face of social and economic factors. Consequently, smallholder farming systems now largely dominate copra, cocoa and natural rubber production: there are 700,000 cocoa producers in Côte d'Ivoire and 1.6 million in Ghana. The same is also true for other commodities: Vietnam's remarkable surge in coffee production, making it the world's second largest producer (it went from an annual average of 100,000 tonnes in the 1980s to more than 800,000 tonnes in 2001–2002), comes from small production units.

Tree crops bring in cash for agricultural environments that often have few alternatives. They also help to integrate local economies with regional and international markets. Wealth created in this way generally has a multiplier effect that improves the entire local economy and can also benefit the national community.

Moreover, several studies have shown that there is rarely any real competition between food crops and perennial tree crops. Food security is generally better in perennial tree crop zones than elsewhere (Krueger and Berg 2002). However, there are still risks in farming tree crops for a livelihood, particularly when there is centralized control of tree crop markets that also extends to market and extension systems for food crops grown by the same farmers. If the market for tree products declines then the whole rural infrastructure may decline, as was the case during the cocoa crisis in Cameroon in the early 1990s and the more recent coffee crisis in Kenya (Rice 2003; Ruf 1995) Tree crops have a considerable impact on land tenure. In societies where land ownership is communal or customary, the perennial nature of the crops introduces profound changes in land distribution, hence in social relations because plantations tend to be owned by individuals or families rather than collectively. Clearing land for plantations is an important avenue for securing tenure in areas with little formal land registration.

The fact that tree crops are at the heart of changes in social and territorial structures is only just beginning to be realized in some countries. "Tree crops have gone hand-in-hand with a territorialization process," commented Charlery de la Masselière at Yamoussoukro (Charlery de la Masselière 2001).

Many different kinds of social or trading networks may be established or transformed because of tree crops. The quality and nature of such networks is a decisive element in how well tree crops can contribute to sustainable community development. In many countries in the past, farmers could not realize the benefits of their work owing to state and parastatal control of market chains. Policies such as those controlling taxation, extension, 'forced cooperation' and farmers' organizations weakened the ability of farmers to improve their market position and hence alleviate poverty. Those who benefited the most were the early adopters and landowners, including those who rented out land to others and made a living from the profits (Berry 1975). Owing to this history, deregulation has not helped because farmers are not well organized to deal with large-scale, private-sector actors.

Environmental importance

For a long time, tree crop plantations were extended by clearing forest on pioneer fronts, i.e. areas with low land occupation pressure that are therefore cheaper. This contributed to deforestation, but at a time when environmental concerns were not a priority.

Since the Rio Summit in 1992, environmental concerns have been acknowledged as integral components of sustainable development. Faced with the threat of depletion of primary forests, land that has already been cultivated needs to be replanted. Perennial tree crops are forest-type cultivated ecosystems that can constitute sustainable systems:

- They help to protect existing forests by supplying wood for industry and energy. For example, in Sri Lanka "perennial crop-based farming systems supply over 50% of national timber and 80% of the fuelwood needs", (Pushpakumara 2001).
- They make a substantial contribution towards carbon sequestration. For example, rubber trees can sequester more than 100 tonnes of carbon per hectare over 33 years (Hamel and Eschbach 2001).
- The permanent cover and fairly systematic use of cover crops effectively protects soil from erosion. "A well-managed tea plantation results in an annual [soil] loss of only 0.24 t ha^{-1}, compared with 25–100 t ha^{-1} for vegetables, potatoes and tobacco, and 0.3 t ha^{-1} for dense forest," (Kaosa-ard and Rerkasem 1999).
- Soil cover also reduces the risk of leaching, and legumes – often associated with tree crops – help to improve the nitrogen balance.
- Use of pesticides is limited: either they are not necessary or farmers cannot afford them.
- It is possible to maintain a degree of diversity in multi-storey plots such as those for 'jungle rubber' in Indonesia, cocoa agroforests in Cameroon and intercropped coffee in Ethiopia, India and Indonesia
- Most perennial crops are less sensitive to fertility levels than food crops, and some of them can help to stabilize the agroecology of marginal or degraded lands. In Central America, *Arabica* coffee trees help to fix many fragile mountain soils.

While these are positive aspects of tree crop systems, conservation biologists warn that even complex tree crop/agroforestry systems are not equivalent to natural forests. Furthermore, farm inputs such as pesticides, particularly the copper-based fungicides used on cocoa, can harm other species. Tree crop plantations can encroach significantly on protected areas (e.g. the cocoa being planted within Lore Lindu Park in Sulawesi, Indonesia; Schroth et al. 2004).

When managed in smallholder plantations, individual agroforestry patches often become fragmented making it harder to retain a working ecosystem. Recent thinking in conservation science calls for ways to connect forest patches and smallholder tree crop/agroforestry systems with larger protected forests to boost the conservation benefits to the landscape scale. There are numerous challenges to these proposals including the spread of diseases, pesticide use and the effects of animals on crops (see case studies in Schroth et al. 2004).

Tree crops within agroforestry systems

According to ICRAF, "Our vision is an agroforestry transformation in the developing world, resulting in a massive increase in the use of working trees on working landscapes by smallholder rural households that helps ensure security of food, nutrition, income, health, shelter and energy and a regenerated environment" (World Agroforestry Centre 2005). This all-embracing definition means that, in many cases, perennial tree crops can be considered to be agroforestry systems; they provide many of the services identified by ICRAF as being relevant, including: income generation, soil fertility enhancement, carbon sequestration, weed control, microclimate improvement and reclamation of degraded lands. Even the most complex and diverse tree crop/agroforestry systems, including the jungle rubber systems in Indonesia, are generally not very intensive and are often low-yielding, usually because of a lack of high-yielding varieties or appropriate cultural techniques. While some agroforestry systems, such as shade coffee, can be extremely efficient, knowledge of the mechanisms that govern these systems and the ideal crop combinations remain highly specific to each region, limiting the possibilities of sharing results between regions.

If these systems are to be improved sustainably, their assets – such as the environmental and biodiversity benefits, risk-sharing and labour use – need to be promoted and improved. Similarly, their weaknesses, which are primarily of a technical or economic nature relating to low productivity and quality of the products, need to be addressed.

Challenges to tree crop systems

Despite the undeniable advantages offered by perennial tree crops, there are concerns about the role they should play in sustainable development. Price instability, market inefficiencies, difficulties in diversifying, gaps in commodity chain organization, problems in renewing the means of production, and quality demands are a few of the problems that need to be dealt with when considering their future.

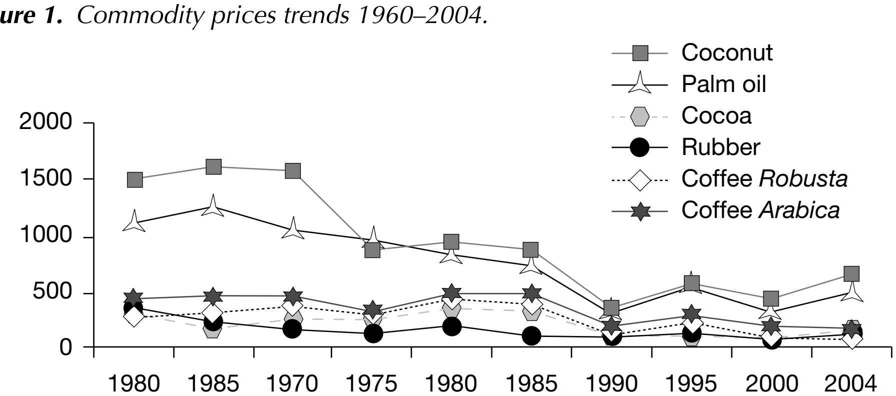
Variability in prices and market inefficiencies

Variability in commodity prices is one of the most serious risk factors for the future of certain commodity chains (Ruf 1995). Perennial tree crops underwent their greatest crisis in the 1990s when tropical agricultural prices declined (Figure 1). Over the present decade, countries also shifted emphasis between the crops they were growing (Table 3). At the end of this period, copra was trading at around US$200 per tonne and palm oil was between US$250 and US$300 per tonne, i.e. around the same level as in the 1960s. Given that the American price index had risen five-fold in that time, in real terms copra and palm oil prices were a fifth of their 1960s value (World Bank 2005)

While market prices have improved for products such as cocoa, rubber and oil, the gap between prices paid by end users and those paid to producers is widening (Oxfam 2002). In the case of coffee, for which prices have remained dramatically low, price weakness is combined with an extremely volatile market, with fluctuations depending on numerous uncontrollable factors. The mere hint of a frost forecast in Brazil – the world's leading producer – can send coffee prices soaring; a denial a few weeks later can cause a slump. Similarly, political uncertainties in Côte d'Ivoire are having a visible impact on cocoa prices.

In order to cope with such variability, stakeholders have attempted to establish

Figure 1. *Commodity prices trends 1960–2004.*



Source: World Bank 2005.

Table 3. *Area planted with each of five main tree crops ('000 000 ha).*

	Cashew		Cocoa		Coffee		Oil Palm		Rubber	
	1995	2003	1995	2003	1995	2003	1995	2003	1995	2003
Brazil	700	673	739	589	1870	2396	33	52	50	103
Côte d'Ivoire	70	125	1900	1700	920	400	134	141	46	70
Ghana	2	13	1000	1500	10	8	100	115	15	18
Kenya	0.85	2	–	–	160	170	–	–	–	–
Vietnam	189	258	–	–	155	500	–	–	278	437

Source: FAOSTAT 2005.

trade regulation mechanisms: international agreements with or without buffer stocks, stabilization funds or cartels of producing countries. None of these arrangements have so far withstood the test of time and they do not harmonize with the current moves towards liberalization and globalization. International funding organizations such as the International Monetary Fund (IMF) and the World Bank have in fact pushed for the dismantling of such state control and regulatory mechanisms through structural adjustment programmes (SAPs).

As well as affecting international trade, price declines and fluctuations increase the risk to producers, who no longer have any guarantee of remuneration and may end up with debts that require them to sell or mortgage their land. These situations are exacerbated for perennial tree crops, which, by definition, are a long-term investment. Farmers who obtain a poor price for their groundnuts can change their crop and production method for the next cycle; changing a coconut-based farming system is an entirely different matter. The upside to agroforestry systems is, however, that farmers can be more flexible about whether they choose to harvest a tree crop or not, although in many cases this is scarcely enough to compensate.

So far, market liberalization has not produced mechanisms or institutions that can adjust supply to a somewhat inflexible demand and therefore play a regulatory role to satisfy all concerned. In part this can be attributed to the weakness of farmer organizations, particularly those in Africa, which is the result of having previously had State-run enterprises and cooperatives. In some countries, farmer organizations are highly politicized, leading to in-fighting and rigid organizational hierarchies. The private sector is unlikely to create appropriate regulatory institutions by itself because firms compete with each other and the dominant firms prefer private market arrangements. The weakening of the State by liberalization and the SAPs was justified on the grounds of State mismanagement, but the vacuum it has left has not been filled. Disinvestment has in fact considerably weakened national research and extension capabilities that at least used to provide some support to farmers.

One must also question whether liberalization is actually being implemented. Controls on trade still exist in many countries, particularly in Africa. For example, prices for food crops may be kept low by controls at the national level, or there may be caps on the price of tree crops (timber and non-timber forest products) that make them unprofitable.

Difficulties in diversifying

Many tree crop experts consider diversification to be vital to protect product prices again entering a heavy downward trend. But such diversification, which needs to take place on both farm and producing country scales, comes up against numerous obstacles.

In many countries, impoverished farmers lack both the information or training on plantation diversification and the technical or financial resources required to diversify. This is all the more true for farmers of perennial tree crops, which experience long immature periods and wide price variations. They are also more likely to face uncertainties surrounding land tenure and tree use regulations, particularly around protected and indigenous species, which can seriously curb diversification efforts.

On a national level, few poor countries currently have the human, technical and financial resources needed to help producers diversify and increase local processing. For example, in most countries in Africa it is difficult for smallholders to obtain quality tree germplasm that might make such processing feasible (Ræbild et al. 2005).

Perhaps the most serious problem is the weak internal markets and market chains in many countries. For tree products in high demand such as charcoal, there are numerous regulations that inhibit markets (Russell and Franzel 2004). While smallholder systems of timber intercropped with coffee or another tree crop are being developed in Central America, southern Asia and South Africa, they are still in their infancy in most of sub-Saharan Africa. There are great differences in the markets for fruit and fruit products throughout Africa: they are weak in eastern and southern Africa but strong in West Africa. Furthermore, export has not taken off to any great extent and there is little value addition; countries in eastern and southern Africa find it hard to compete for export markets with the horticultural expertise of South Africa (Petit and Barghouti 1992; Maizels 1999).

Not enough made of technical innovations?

The development of most perennial tree crops has taken place outside the natural range of the plants, and has been based on pioneer-type models exploiting existing, untouched forest resources and using cheap labour. First cropping cycles therefore benefit from soils that are fertile from their forest past and where specific parasites are absent.

Major research efforts have led to significant progress in improving plantation yield and productivity by improving varieties, cultural practices and parasite control. Such efforts have increased yields of some crops five-fold over the last 50 years; harvests of natural rubber, for example, have gone from 500 kg ha^{-1} to 2,500 kg ha^{-1}. In general, their pioneering mindset leads farmers to increase their yields by expanding area cultivated rather than by increasing productivity per unit area. Cocoa is a clear example: Spanish reports of Central American native plantations dating from the colonial period indicate annual yields to be around 700 kg ha^{-1} which is higher than current average world production of less than 500 kg ha^{-1} per annum.

Today, some crops have aged, as have the people who planted them and the soils that bear them; this type of extensive farming is reaching its territorial limits and nearing its end. Although high-yielding varieties may exist locally, they are rarely easily accessible and affordable for smallholders. New systems and technical innovations are needed to permit replanting and intensification (Ruf and Konan 2001; Ruf and Schroth 2004) The integrated pest management approach is in its infancy in most areas and few producers can afford to buy the recommended phytosanitary products. And while multiple species cropping systems are widely practised in plantations, little is known about how they function. Post-harvest processing operations are often insufficiently mastered to market a product that meets increasingly strict quality requirements.

Many countries experience problems in raising funds for research into perennial tree crops, particularly when the prices for most commodities are enduringly low. Donor support for these research projects has generally been limited, as the emphasis for most donors is on food crops that directly contribute to food security rather than on commercial agriculture as a whole. Many donor agencies consider that research into tree crops must be funded by the industrial sectors that make use of their products. They are reluctant to invest public money in what they consider produces private goods (although this may be changing: the World Bank for example is developing a tree crop strategy for Africa). On the other hand, the private sector only contributes funding for specific projects that are closely linked to the competitiveness of its industry, especially in the downstream/post-harvest part of the chain, and many producers' concerns remain neglected or even ignored by the industry.

Quality requirements

Product quality requirements are both a constraint and an opportunity for producing countries. Draconian technical and sanitary standards, often associated with the importing country's health concerns, have to be respected, but can be difficult to achieve for developing countries. However, they can be of benefit if meeting them provides the producer with a distinct quality advantage that can be promoted.

Unfortunately, many low-income countries cannot rapidly adopt the new technologies required to meet exacting export standards, and lose out to better-prepared medium-income countries. The situation is exacerbated by the previously discussed State withdrawal.

One way to promote quality that is available to developing as well as developed countries is to introduce the *terroir* concept, whereby a specific crop (in France it is wine) is only produced by a particular region. Similar products from areas outside the region cannot be given the same name. A study in Honduras laid the foundation for possible coffee *terroirs* (Avelino 2002). Similar studies have been undertaken in other countries such as the Dominican Republic, Indonesia, Kenya and Rwanda. It has also been shown that local consumers can appreciate different qualities, as demonstrated with red palm oil in Côte d'Ivoire

(Cheyns 2001). And there is growing worldwide demand for fair trade and sustainable production, which bring new requirements to producers. A good example is the recent creation of the RSPO – the Roundtable for Sustainable Palm Oil (http://www.sustainable-palmoil.org) – that gathered together many stakeholders from the sector. Some commodities are obviously more advanced than others: coffee quality, for example, has more consumer recognition while few know about different types of rubber.

However, promotion of the *terroir* concept and other certification processes often faces opposition from downstream industrial sectors where the feeling is that end-product quality depends exclusively on their know-how. They do not accept the idea that the location, crop variety and technical skills of the farmer can play a role in the quality offered to consumers. At the moment farmers are not organized, end-consumers know virtually nothing about the commodity chains involved (except perhaps for coffee), and it remains to be seen if the costs of various certification processes can be justified by price improvements.

The way forwards

Although perennial tree crops are only part of the economic tapestry of national and local development, they possess unique characteristics and it is worth paying attention to how they can better contribute. This section suggests policy options and financial and technological actions that will ensure that tree crop systems play an increasing role in sustainable development.

Political and financial mechanisms for sustainability

There are three essential aspects to improving the tree crop sector: land tenure regulations, taxes and the funding of activities.

Firstly, it is important for the sustainability of tree crop-based farming systems that the relationship between land tenure and perennial tree crop development be considered. This relationship is not straightforward: local conditions are diverse and complex and simple models cannot be extrapolated. But public authorities need to be aware of how formal and informal tenure arrangements play a role in the tree-crop sector.

Secondly, as with many goods, the tax rate applied to tree crops destined for export is a decisive element in the sustainability of the production chain. A satisfactory balance must be found between a low rate that encourages commodity chain vitality and a higher rate to meet the State's requirements. As perennial crops are often one of its most visible and lucrative resources, the State has tended to over-tax in the past.

Finally, farmers' access to financial resources relies on two things: production earnings and access to credit. As discussed earlier, wide variation in product prices creates income instability; itself a factor in production insecurity. Several options have been developed to help including one by the World Bank, which has taken the initiative to set up an international task force to examine the feasibility of commodity price risk management. This involves offering producers risk-management instruments, implemented by local transmission mechanisms, cooperatives, agricultural banks or exporters. The first step has to be to strengthen the financial institutions in many countries otherwise these funds will be wasted.

Access to credit is often difficult for poor farmers. In order to facilitate such access, land tenure regulations could be changed to give perennial tree crops a guarantee value to help secure a loan. However, this might also lead to a rise in land speculation and land being appropriated by the rich, increasing rural landlessness. Hence a holistic and forward-thinking strategy that includes attracting medium-scale industrialization of tree crop industries has to be envisaged.

Overall what is needed is a clear demonstration of how tree crops contribute to food security and poverty reduction at both household and national levels. The problem is that there persists a simplistic notion that food security is mainly to do with household food production; in fact it depends upon the ensemble of strategies that people use to get food and allocate their land and labour (for food and also for education). There is evidence that tree crop income, coming regularly throughout the year, contributes greatly to the formation and maintenance of social capital, going towards school fees, house building and social stability (e.g. marriage payments and health costs; Russell and Tchamou 2001). Social capital creates a safety net that buffers communities against risk.

Tree crops and other plants, such as those with medicinal value, intercropped in plantations are a source of income and nutrition. These crops may provide jobs for a rural labour force that is desperately underemployed. The addition of small enterprises such as tree nurseries and primary processing of tree products adds stability to fragile rural economies. In some cases the local value of intercrops can exceed the value of the traditional tree crop (Gockowski and Drury 1999).

Organization of producers

With small farms and limited financial resources, isolated smallholders hold no more sway over product prices or commodity chain balances than they do over the agricultural policies of their countries, especially in a context of globalization.

Producer organizations enable farmers to exert a true negotiating influence and to take part in drawing up agricultural policies, i.e. to become fully fledged stakeholders, not only in the commodity chain but also in the sustainable development of their country.

There are also research and development (R&D) implications: farmer groups can become involved with capacity building, increasing the emphasis on quality rather than quantity. They can push for the creation of quality zones and other certification mechanisms, and provide the demand for development of diversification options with high and sustained economic value. National and international support for these organizations should come in the form of training and information, to give the farmers the resources they need to exert negotiating power within a commodity chain. Social sciences research can help by analysing local situations and proposing approaches that have been tried and tested elsewhere in similar circumstances.

There are many types of farmer organization. These include shareholding schemes, where producers buy a share of a downstream business (e.g. bulking or primary processing); cooperatives, which do not involve financial transactions, instead the focus is on sharing information, training and advocacy; or bulking centres that are linked to farmers and farmer groups, which is being proposed, for example, in the Kenyan dairy industry.

Whatever form the group takes, it is important that the impetus comes from the farmers themselves. Groups created by non-governmental organizations (NGOs) or governments are often doomed to failure because the farmers joining are not necessarily the best representatives of their communities, and their motives for joining may be coloured by the expectation of handouts. Perhaps the best way for NGOs and governments to help is by networking and building the capacity of existing groups that have stood the test of time (Tanui 2003).

Integrating tree crop and agroforestry extension could enhance benefits to farmer groups and reduce risks by introducing a range of options. Agroforestry groups could provide an additional platform of action that is perhaps less politicized than tree crop commodity chains. Better land management can also be integrated. The challenge is to maintain or even increase the quality of the tree commodity.

Cooperation within commodity chains

In the short term, the interests of the different stakeholders in a commodity chain may diverge and take the form of a power struggle, but in the long term it is the prosperity of the entire chain that is everyone's main concern. If certain categories of stakeholders systematically lose out, they will leave that field of activity, which can be fatal to the commodity chain (this happened to castor oil producers a few decades ago).

Most commodity chains have either formal or informal structures in which stakeholders meet, exchange information and sometimes implement joint projects. Ramping up such cooperation could guarantee more equitable relations between stakeholders and promote services that ensure the smooth running of commodity chains.

The Global Forum on Agricultural Research (GFAR) has an initiative to promote global research programmes for perennial tree crops, in a move to strengthen cooperation among commodity chain stakeholders. In the context of financial restrictions that are seriously affecting research structures in developing countries, better cooperation within commodity chains (and sometimes even between commodity chains) could help in putting all these assets to more effective use, so as to concentrate resources on what needs true scientific and technical innovations. The GFAR Global Programmes (GPs) are a step in that direction. GPs consist of coordinated sets of activities, carried out by a wide range of programme participants or partners, and directed towards specific problems or sets of problems identified at a global level. ProMusa, for banana and plantain, and Procord for coconut are the two existing GPs. The cocoa sector is discussing the feasibility of a sustainable cocoa production GP, and other approaches are being developed for different commodities (Frison et al. 2000; GFAR 2002; Omont and Frison 2002).

These stakeholder meetings and processes are important steps, but a great deal remains to be done to harmonize research across a large number of countries, many of which have weak research and extension systems. The most crucial next step is to design a range of options at the interface of environmental and market imperatives that will reduce the cost of certification schemes to smallholders and poor countries, and to find cost-effective ways to support better land management. These could include environmental service payments or special arrangements between localities producing high-value tree crops that border fragile or protected areas. Stakeholder groups need to address the proliferation of certification and quality standards and also build internal markets for some crops where certification schemes such as EurepGap and others present a formidable barrier.

Scientific and technical innovations

When markets were booming, technical and scientific innovation was primarily geared towards achieving higher yields and greater productivity. Today we have a more complex situation. The success of scientific and technical innovation can no longer be assured without the involvement of all the stakeholders and a clear understanding of social and political contexts. The complex behaviour of those stakeholders and the shifting policy environments at many levels mean that social and policy sciences have to be much better integrated into technology research.

The fact that most perennial tree crops are produced on smallholdings means that social concerns must be taken as seriously as the economic and technical aspects. It is essential to know more about the stakeholders in commodity chains: their motivation; the reasons for their choices; the scope of their decisions; and how new technologies can be adapted to their requirements and effectively transferred to them.

In terms of raising production and productivity, numerous technical possibilities already exist: new varieties, disease control methods, crop management sequences and post-harvest technologies for instance; some of which need to be adapted to new or different socioeconomic contexts. But such possibilities are not always available for the areas where they would be most useful, and those who need them do not always have the relevant information. For some commodity chains that are overproducing, such as coffee, it is no longer necessary to raise production, though it remains relevant for other commodity chains that expect a shortage such as cocoa and natural rubber. However, translating improved productivity into increased producer incomes remains a priority for many commodity chains. Quality, be it in terms of industrial technical standards or health standards, is becoming the main concern.

On top of all these concerns, environmental issues must also be integrated into the R&D process. This will require a change in the prevailing attitude and paradigm, not to mention specific scientific and technical innovations. Perennial tree crops can have a positive impact on the environment, but assumptions about how to improve landscape connectivity and hence biodiversity through agroforestry and growing tree crops need to be rigorously tested. There are also many serious questions about animal habitats, choice of tree species, flow of pests and diseases, and tree genetic diversity on a landscape scale that need answering (Schroth et al. 2004).

Agroforestry approaches

For producers, the aim is to share risk by diversifying crops, either in separate patches or intercropped within the trees. It is a matter of making better use of land, financial resources and farm labour as well as attempting to maintain (or even improve) the fertility of cultivated ecosystems.

If there are no severe land occupation constraints, diversification can take the form of a succession of monocultures without intercrops. However, in many countries, farming systems already use several plants or crops, often in complex combinations. Growing food crops in rows within a young tree crop plantation is a common practice (known as the *taungya* system). Several research centres are working on rationalizing these approaches with systems of biomass transfer and improved fallow with coppicing and/or quick growth shrubs. More recently, long-term intercropping of perennial crops has been tested in several countries with apparent success from a technical aspect (Erhabor et al. 2002; Herath and Takeya 2003; Maheswarappa and Nanjappa 2000; Ndeayo et al. 2001; Ollivier et al. 2001; Osei-Bonsu et al. 2002; Rajasekharan and Veeraputhran 2002; Suja et al. 2003). Indeed, in intercropping terms, the only limit appears to be the imagination of the farmers.

To assist diversification efforts, research institutions need to make examples of successful diversification available (e.g. coffee diversification in Ethiopia and India , timber and coffee in Costa Rica, fruit trees and cocoa in Cameroon, etc.), provide guidelines, focus more on meeting demand in local and regional markets, and link diversification to certification. The CASCA project (sustainability of coffee agroforestry systems in Central America [http://www.casca-project.com]) is a good example of what R&D could bring to the issue. Another example comes from the rubber sector – jungle rubber – where a multi-stakeholders' project is being developed in Indonesia, with the aim of improving the yield of rubber trees while maintaining the good environmental achievements of the jungle rubber agroforests (Herath and Takeya 2003).

The private sector may be encouraged to invest more in R&D for smallholders is if it helps maintain or increase quality. When quality is declining dramatically, high-end producers lose out. This is the case for coffee in Kenya, considered to be among the most valuable in the world. Some companies are also concerned about their reputations, for example in the wake of the coffee crisis that devastated smallholders but created record profits for manufacturing companies such as Nestlé. The use of child labour in tree crops is another concern that has reached world attention. M&M Mars, the chocolate manufacturers – a family-owned company, has a goal of substantially increasing farmer revenues within the next 5 years through quality improvements and diversification (Shapiro and Rosenquist 2004). They are embarking on diversification efforts into medicinal commodities that can be grown in smallholder cocoa plantations. Reducing child labour and increasing the use of integrated pest management (and therefore reducing chemical use) was the motivation behind the creation of the Sustainable Tree Crops Programme (STCP) in West Africa, which is backed by US chocolate manufacturers. Chocolate producers are also interested in such commodities as shea butter, which is used in chocolate manufacture and thus may sponsor research to improve these tree products.

Local consumers could stand to benefit greatly if important local trees and plants are integrated into tree crop plantations in such a way that both supply and quality increase without adversely affecting the quality and supply of the main commodity. This is the tree crop/agroforestry challenge.

Conclusion

Perennial tree crops have numerous assets that need to be highlighted to ensure sustainable development.

- They play a fundamental role in the economy of numerous producing countries; the additionalmonetary incomes contribute towards poverty alleviation and the maintenance of social balances.
- They play a role in structuring societies, e.g. by bringing in capital at different levels that enable investments, allocation of land and organization of commodity chains.
- They play a decisive role in maintaining a forest-type cultivated ecosystem, both in terms of fixing carbon and preventing soil erosion.

But the future of these crops is threatened by several negative factors:

- The volatility of product prices leads to chronic insecurity within commodity chains, which can be especially bad for smallholder farmers in the absence of regulatory mechanisms.
- Increased industrial concentration within certain commodity chains is worsening the imbalance of power, that particularly affects producers who are poorly, or not at all organized.
- The total withdrawal of State support from some commodity chains is just as detrimental as its over-involvement with some of them in the past.
- The weakness of public research efforts, in both developed and developing countries is not being compensated for by private research efforts.

The political, economic and social context of tree crop farming is undergoing profound changes, with the emergence of new issues centring on the sustainable management of territories and natural resources, quality, food safety and ethical issues (e.g., child labour).

The development of environmentally sustainable and competitive production systems for these crops, including agroforestry, and the availability of long-term incentives for smallholder producers will require new approaches and a concerted effort on the part of the international agricultural community, but it will also involve all commodity stakeholders.

Agroforestry research for its part has to strongly embrace the tree crop R&D agenda. Agroforestry systems that comprise these high-value crops but also provide a range of products and services can be true engines of future sustainable development. The common agenda that is emerging focuses on:

- Studying technical, economic, and social issues in diversification of tree crop plantations.
- Focusing on commodity quality and agronomic questions related to shading of tree crops.
- Building capacity of farmer groups in integrated plantation-agroforestry.
- Strengthening farmer groups and associations technically and organizationally.
- Testing approaches to certification and local value addition, including *terroir* that strengthen farmers' capacity, improve their negotiating power and maintain market value over time.
- Determining local demand and need for agroforestry and tree products that can be integrated into plantations.
- Networking information on sustainable management, diversification and value addition across the continents.

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Chapter 4

Trees and Markets: Working Group Report

Introduction

ICRAF's Trees and Markets theme created working groups to discuss the enhancement and future of the four focal areas that comprised the theme in 2003 (a fifth was added in 2004). These were: TM1 – market analysis and support for tree product enterprises; TM2 – developing sustainable seed and seedling systems and sound management of agroforestry genetic resources; TM3 – tree domestication with intensification and diversification of tree cultivation systems; and TM4 – farmer-led development, testing and scaling up of tree-based options.

Each group was given five questions:

- What is your 2015 vision for the focal area?
- What are main problems, opportunities and assumptions in the focal area?
- What new partners and partnerships do you suggest?
- Can you suggest promising new project ideas?
- What types of deliverables or outputs are needed to accomplish the results we seek?

These are the conclusions that the groups reached.

TM1 – market analysis and support for tree product enterprises

Although ICRAF has organized many discrete market-oriented projects in the past that have focused on this subject, TM1 is still a relatively new direction. In 2003, there were only a few staff working in this focal area and outputs were limited. Despite this, it became clear that people had quite different visions for this field, and the first question yielded a wide range of answers. One member of the group stated: "ICRAF and partners should, by 2015, have identified a 'resilient set' of diversified tree crops (by region) with markets with characteristics that are capable of buffering each other in the face of market fluctuations." Another mentioned that it would be important to see strong federated farmer groups in diverse tree crop sectors. Others put the emphasis on buffering risks (by keeping prices stable, dealing with diseases and pests, and retaining or creating diversity), building cottage industries, the importance of tree domestication, and on finding new products to diversify traditional tree plantations.

In terms of the main problems and opportunities that need to be tackled in the focal area there was more consensus. The working group identified:

- A lack of credit, capital and private sector involvement
- A lack of clarity about which market level should be targeted
- The existence of regulatory and trade barriers
- Unequal access to opportunities
- A lack of 'cottage industry' know-how
- A need for more institutional capacity, and
- A lack of focus on which products to develop.

The working group identified new partnership opportunities that would help to advance the focal area, including with the Global Forum on Agricultural Research (GFAR), the Underutilized Crops Unit of the International Plant Genetic Resources Institute (IPGRI), developed-country consumer groups, national and international private enterprise, fair trade groups, the World Business Council for Sustainable Development (WBCSD), and appropriate technology institutes.

Project suggestions within TM1 spanned the entire range from helping farmers to start producing, to developing niche markets for new products. For those farmers who do not have enough capital to start production, the group suggested that it would be a good idea to start a credit scheme. Further en route to market, it is the post-harvest processing of produce that is crucial – and something that can easily be overlooked. However, to achieve real success in the global market, there should be product differentiation and ways of ensuring that goods are unique and of a high quality. One project the group suggested would test the *appellation* concept for agroforestry products. This is a scheme employed in Europe to identify regions of excellence for certain products. Another way to create a niche market is to promote indigenous or local products; for example essential oils or craftwork. All these developments need to be supported by the right agroforestry policies, and therefore starting a discussion and maybe even lobbying on policy improvement for agroforestry products would be a step in the right direction.

To reach these visions, ICRAF would need a product development strategy that included production of enterprise development manuals, market development guides, consumer surveys for at least six products (preferably worldwide), periodic market bulletins and databases of products, prices and other market information. Some of this could be accomplished by including market information on existing websites. Scientific publications, policy briefs and reports on lessons learned are also important outputs. Some members of the working group felt that a big media promotion campaign would help to get products and marketing processes rolling.

TM2 – developing sustainable seed and seedling systems and sound management of agroforestry genetic resources

The group discussing TM2 felt that it was hard to predict the desirable situation in 2015. However, they agreed that flexibility is the key as demand for seeds and seedlings is always changing, particularly in terms of the quality, quantity, variety and diversity of agroforestry products needed.

The main problems the working group identified included:

- Intermittent demand that is unpredictable and often disappears totally
- Lack of marketplace intelligence
- Inadequate information and training
- Inadequate or expensive seed supply in villages
- The existence of free handouts that constrain private sector development
- Farmers not knowing their options, and
- Inadequate policies and institutional arrangements.

Partnerships (both new and old) with various institutions were suggested by the group as ways of countering these problems. Those mentioned included communities, national seed centres, non-governmental organizations (NGOs), research centres, local governments, private entrepreneurs (nursery owners, seed growers), and ministerial-level government officials. To raise awareness and money it was suggested that grammar/primary schools could sell tree seed and that ICRAF could publish a seed calendar. ICRAF should make people aware of the availability of germplasm outside their area.

To build up knowledge and expertise in the TM2 area, a lot of research needs to be done, and the working group suggested that one useful project would be to look at the tree seed sector as a whole to gain sound background knowledge. This could lead to the development of small-scale strategies with regional benefits, for example where locally grown seed was sold to local farmers and not necessarily grown for a large, national programme. Tying in with the question on partnerships, the working group felt that developing strategies under the umbrella of national agroforestry networks, who could then take the ideas further with their own task forces and would also enhance our knowledge of the field.

In order to ensure that these ideas are brought to fruition, the working group thought that what is needed the most is more information, which can be taught by ICRAF or shared between farmers. ICRAF should also play a major role in the sharing of tree germplasm – either by organizing exchanges itself or by helping to develop germplasm supply strategies at the national level.

TM3 – tree domestication with intensification and diversification of tree cultivation systems

The working group noted that farmers who grow many different types of crops/trees reduced their environmental and economic risk and this contributed to poverty alleviation. However, sustainability – both of livelihoods and of traditional ways – is the important factor. Therefore, the the group's vision for TM3 included using domestication strategies to capture indigenous knowledge for future generations. In a similar vein, it was suggested that by 2015 we will have learnt to appreciate natural products (e.g. natural dyes) and to recognize the untapped commercial potential in intact ecosystems.

On-farm, the group predicted that there would be more cultivation of particular tree species and intensification of fodder systems, especially for those trees that can provide foods for famine times in drought-prone areas. Furthermore, improvements to be made to tree domestication would come from using a combination of participatory and biotechnology approaches rather than depending on one or the other.

Because there are lots of opportunities within agroforestry to improve farmers' incomes and choices while reducing their exposure to risk, it is vital that the full impact of farming decisions are known and considered up front. There is a serious risk that relying on only one, or a handful of agroforestry species could reduce choice and push the less popular trees towards extinction. Some indigenous trees are already in decline, particularly those with recalcitrant seeds that are hard to grow ex situ, which will reduce natural biodiversity as well as degrade the indigenous knowledge that goes with them. It is therefore important to determine the best trees that can be grown in any situation, whether for general or niche consumption, and what the economic returns of each are. Furthermore, the group highlighted the fact that fruit trees should be well managed (appropriately spaced, well fed, etc.) as well as genetically improved to get the best results, and these two processes should feed off each other. Other important problems, opportunities and assumptions identified include:

- Raising community awareness of agroforestry practices and benefits
- Priority setting for species selection
- The need for landscape planning, and
- Establishing subsidised or free local nurseries so that fruit trees can interact beneficially with crops, inputs (especially chemicals) are kept to a minimum, and diversity (ethnic, landscape and species) can be managed.

There is a lot of opportunity for new partnerships within TM3, and the working group recognized that the retention of old partnerships (e.g. with Ministries of Agriculture, Forestry, Health, Science and Technology) is just as important as forging new ones. Any new partnerships within tree domestication should involve heightened access to market information and also to specialist knowledge, for example in medicinal trees.

Bearing these factors in mind, the working group suggested some areas where new projects would come in useful. Some of the most important areas concern the removal of social or economic constraints, such as gender inequality or lack of micro-credits or subsidies for small-scale farmers. There are quite a lot of untapped opportunities that could be investigated, such as growing wood for small dimension, high quality cabinet making, as well as the extension of existing tree growing and craft-making. Overall there is a need to keep communities involved and to focus on local, small–medium-sized enterprises. Other suggestions include:

- More collaboration between tree users and molecular biologists/other scientists
- Identification of new technologies that can help with creating demand for tree products (e.g. in areas such as milling or fermentation), and
- Establishment of an 'endowment tree' in each environment, consisting of a tree or set of trees that will mature in around 15 years and add value each year at an above-interest rate.

The working group perceived that one of the requirements to meet this future include developing a participatory toolkit so that communities can undertake participatory domestication activities. This would include information on species characteristics, cultivation methods, products and uses, quality control and market data.

TM4 – farmer-led development, testing and scaling up of tree-based options

Empowering farmers is one of ICRAF's major aims; consequently the working group had many grand visions for TM4. One of the recurring themes from the panel was that of inclusion, that everyone in a community – women, HIV/AIDS sufferers, special-interest groups and those living in marginal areas – can participate in agroforestry advances. And the numbers being considered are quite substantial as well: one working group member predicted 10 million farmers would adopt agroforestry technologies by 2015.

Such a wide-scale and widespread adoption should become internally sustainable as empowered farmers start to demand more services. Scaling up would become a natural course of action as farmers participate more fully in 'bottom up' research and development, even establishing and running their own nurseries. This in turn would create a range of new technologies that would be reflected in a more diverse landscape. Farmers will be able to choose which type of agroforestry system was best for them, and adapt it as necessary. By 2015, the panel envisioned that agroforestry would have advanced so far that it could reach 20% of farmers in countries where ICRAF operates.

To develop in this way, there needs to be a supportive policy environment that is regularly reviewed to identify any constraints. To further its promotion, agroforestry should be brought into the syllabus and institutionalized. The end product of all this home-grown technology would, the working group predicted, be improved livelihoods – better health, more security, better education and more money.

To reach a future with such a high potential, the working group suggested many new project ideas. A lot of them are long-term, multi-strata projects that can take ideas further and deeper than before. To really make progress in this field, it is important that the fundamentals are understood. This means a lot of basic work is required to create inventories of useful plants (e.g. medicinal plants), document them (i.e. ethnobotany), study what works and what does not, and examine participatory communication tools used when scaling-up. There need to be adequate resources for scaling human, physical and financial capital. There should also be adequate supplies of seed and planting material, and that the germplasm from threatened species is identified and protected. At the institutional level it is important that there is the right degree of protection for intellectual property, tenure rights and partnerships and that the best policies exist for boosting membership of the agroforestry community.

Carrying on the principle of inclusion, it is vital that local and indigenous knowledge and conservation issues are integrated into scientific knowledge. Projects that focus on gender issues are also a step in the right direction. Furthermore, ICRAF should focus on projects that build on and foster local innovation and which promote participatory communication – as well as investigating other ways to disseminate ideas.

To really achieve the widespread adoption of agroforestry, the very way in which R&D is carried out needs to be examined. This includes looking at the nature of partnerships within agroforestry R&D, conducting surveys of innovations in integrated natural resource management and assessing farmer-trainer systems – who carries them out, who they are aimed at and how their development can be facilitated. Above all, the working group decided, there is a need for people to understand the usefulness of linking agroforestry products to the appropriate markets – locally, regionally, nationally and internationally.

Land and People

"Trees influence landscape scale dynamics more than any other organisms (although, of course, humans have now appropriated this claim). Investigation of this keystone role must remain not just a major part of the Centre's research agenda, but at the very heart of it, because of the huge number of secondary interactions that flow from the incorporation of trees within any land use system."

Swift et al.

Keywords:
Integrated natural resource management, scales, holism, institutions

Chapter 5

Confronting land degradation in Africa: Challenges for the next decade

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Abstract

This chapter presents five challenges for integrated natural resource management research at the World Agroforestry Centre within the theme of Land and People:

1. What are the determinants of the adaptive and adoptive advantages of the available technological options for sustainable soil fertility management?
2. How can the functions of the soil community be optimized with respect to different ecosystem services?
3. What are the trade-offs between the storage of organic matter in the soil (to counter climate change effects of gaseous emissions) and its use to drive nutrient cycling, crop production and other ecosystem services?
4. What are the key questions arising from interactions in the chain linking resource management–system intensification–market access–policy?
5. What are the rules governing cross-scale transitions in natural resource management?

These issues will require both holistic and reductionist interdisciplinary methodologies working across a range of scales, but many of the necessary tools have been put in place during previous work.

Introduction: land degradation in Africa

The purpose of this chapter is to identify some of the major challenges facing the research community concerned with combating land degradation in Africa and its effects on human welfare. This purpose can be rephrased in the form of a question: What type of science, to do where, and for whom? There is no intent to review in detail the problem of land degradation and its multiple causes, or the scientific response in terms of methods and results. These have been documented in exhaustive detail elsewhere and reference is made to the key sources where appropriate. Five major challenges for future research have been identified, but the most central issue for the World Agroforestry Centre remains that of investigating the keystone roles of trees as regulators of landscape dynamics and providers of goods and services for human welfare.

Land degradation has many characteristics, including soil erosion and nutrient depletion, decreasing quality and quantity of available water, and loss of vegetative cover and biological diversity. These have knock-on effects on the prevalence of disease – of plants, animals and humans – and, most importantly, on human welfare and well-being by the disruption of food production and other ecosystem services. The causes of land degradation are multiple and interactive. This complex chain of cause and effect has been analysed and documented in detail; most recently in the proposal by the Forum for Agricultural Research in Africa (FARA) for a Challenge Programme for sub-Saharan Africa and its many supporting documents (FARA 2003). The bottom line is that problems of this complexity require holistic solutions.

The challenge of scales and emergent properties

In proposing a holistic response to the problems of land degradation, one of the major structuring features must be a multi-scale approach, embracing both space and time. Learning to work across scales (plot, farm, land use type, landscape) with the associated human perspectives (farmer, farm family, community, district planner, forestry manager, etc.) is already one of the major concerns of the Consultative Group on International Agricultural Research (CGIAR). The World Agroforestry Centre has made major contributions in this respect and Chapters 7 and 10–13 illustrate many of the innovative and successful advances that have been made as well as addressing many of the most important methodological issues (see for instance the scalar approaches in the work of the Alternatives to Slash and Burn (ASB) Programme as described in Palm et al. 2000). Nonetheless, our facility in moving between scales, and in translating results learned on one scale into possible implications on scales above and below, remains limited.

At different scales in space the associated interests of different sectors of society become dominant and the issues of importance to these stakeholders also change (Figure 1). It is at the plot and farm scales that the natural resources of soil, water and biota are often most intensively managed and their dynamics altered by the interventions of humans. For the farmers, therefore, the availability, quantity and quality of resources at this scale, and the factors influencing their capacity to convert these resources into food and marketable products, is their major (but not their only) concern. At higher-level scales, moving through the hierarchy of catchments across the landscape to the aggregate of river basins, additional issues become the concern, not only of farmers and other direct land users, but also of urban society. These include ecosystem goods and services beyond food production, such as the impact of land management on water availability and quality. At a global level, the effects of land use on climate and biodiversity have become issues of significance. Resource

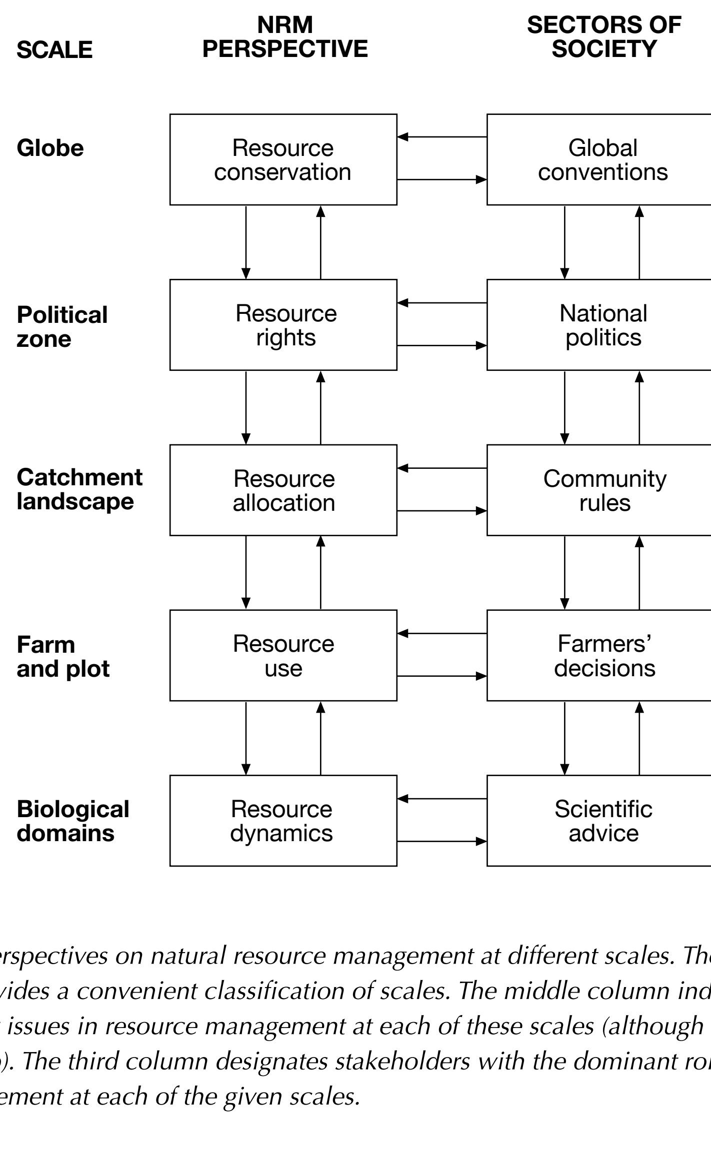

Figure 1. *Perspectives on natural resource management at different scales. The left-hand column provides a convenient classification of scales. The middle column indicates some of the major issues in resource management at each of these scales (although of course they overlap). The third column designates stakeholders with the dominant role in tropical land management at each of the given scales.*

protection becomes a feature of decision making at these higher scales, sometimes conflicting with the aspirations of the farm-level land users with respect to rights of allocation and use. Likewise, forests can be harvested by private enterprise or government, and the resultant land cover changes can influence the availability of water to local people.

In the following discussion we deal successively with challenges at the scales of plot and farm (the most common level of concurrence of agricultural practice and scientific exploration); the scales below the plot where biological dynamics in the soil influence agricultural productivity and other ecosystem services; and finally with the 'landscape', an aggregation of scales above the farm. It is perhaps necessary to note that this chapter is predominantly concerned with biological aspects of the management of natural resources. Those to do with the economic, social, cultural and institutional aspects are covered in Chapters 7: 'Scaling up the impact of agroforestry' by Franzel et al. and 8: 'Policies for improved land management in smallholder agriculture' by Place et al. in this volume. This is simply a matter of convenience and, hopefully, it does not need to be said that the biological problems associated with ecosystem service provision and those of the sociology of need and acceptability are inseparable and must be tackled holistically.

Plot and farm

The degradation of soil fertility, specifically the capacity of the soil to support agricultural production, has been identified as one of the main causes of Africa's agricultural failure (Buresh et al. 1997). It has been recognized that the problem of soil fertility degradation is a microcosm of that of land degradation as a whole. TSBF/ICRAF (2002) states: 'The soil fertility problem remains intractable largely because of the failure to deal with the issue in a sufficiently holistic way. Soil fertility decline is not a simple problem. In ecological parlance it is a slow variable, which interacts pervasively over time with a wide range of other biological and socioeconomic constraints to sustainable agroecosystem management. It is not just a problem of nutrient deficiency but also of inappropriate germplasm and cropping system design, of interactions with pests and diseases, of the linkage between poverty and land degradation, of often perverse national and global policies with respect to incentives, and of market and institutional failures such as lack of extension services, inputs or credit opportunities.' Tackling soil fertility issues thus requires a long-term perspective and a holistic approach that integrates biological and social elements (e.g. Swift and Palm 2000). As expressed in the African Highlands Initiative, integrated natural resource management embodies the following (Stroud and Khandelwal 2001:

- principles for improving livelihoods;
- inclusion of the perceptions, needs, opportunities and positions of multiple stakeholders;
- formulation and adoption of strategies to better balance the differing goals of those primarily concerned with environment, economic growth, equity or governance;
- facilitation of institutional arrangements and linkages within organizations and between various actors so as to achieve better coordination;
- fostering of synergies and information exchange between stakeholders to promote sustainable development;
- promotion of institutional and technological innovations and policies that contribute to local ownership and stewardship; and
- building upon local assets (financial, physical, knowledge and skills) to promote self-determinism and limit dependency.

For more than two decades, the Centre and its partners have focused on developing technological options for sustainable soil management that are biologically effective, economically viable and socially adoptable (Raintree 1987). This work has produced a substantial database of empirical knowledge, including a series of books, e.g. Young (1997), Buresh et al. (1997), Bergstrom and Kirchmann (1998), Tian et al. (2001), Vanlauwe et al. (2002), Gichuru et al. (2003), Schroth and Sinclair (2003) and Bationo (2004). From this work, a number of general lessons have emerged, with significant success in adoption and impact (see Jama et al. Chapter 6, this volume). Most of this success has been centred round the recognition that combined use of inorganic and organic sources of nutrients has greater benefit than either alone (Figure 2). As described in these publications, the menu of available technologies is broad and the potential for identifying the appropriate one under a given set of conditions is now high. The cropping designs that promote integrated nutrient management include integration of legumes as grain or cover crops, rotations and intercrops, improved fallows, integration with livestock (i.e. use of manure) and conservation tillage. Agroforestry has contributed successful options to many of these generic systems. A key feature of the success in soil fertility research in Africa over the last decade has been the integration of ecological and participatory social science research.

The focus on integrated nutrient management as the basis of soil fertility management is, of course, a relearning of an old lesson, but one that has been accompanied

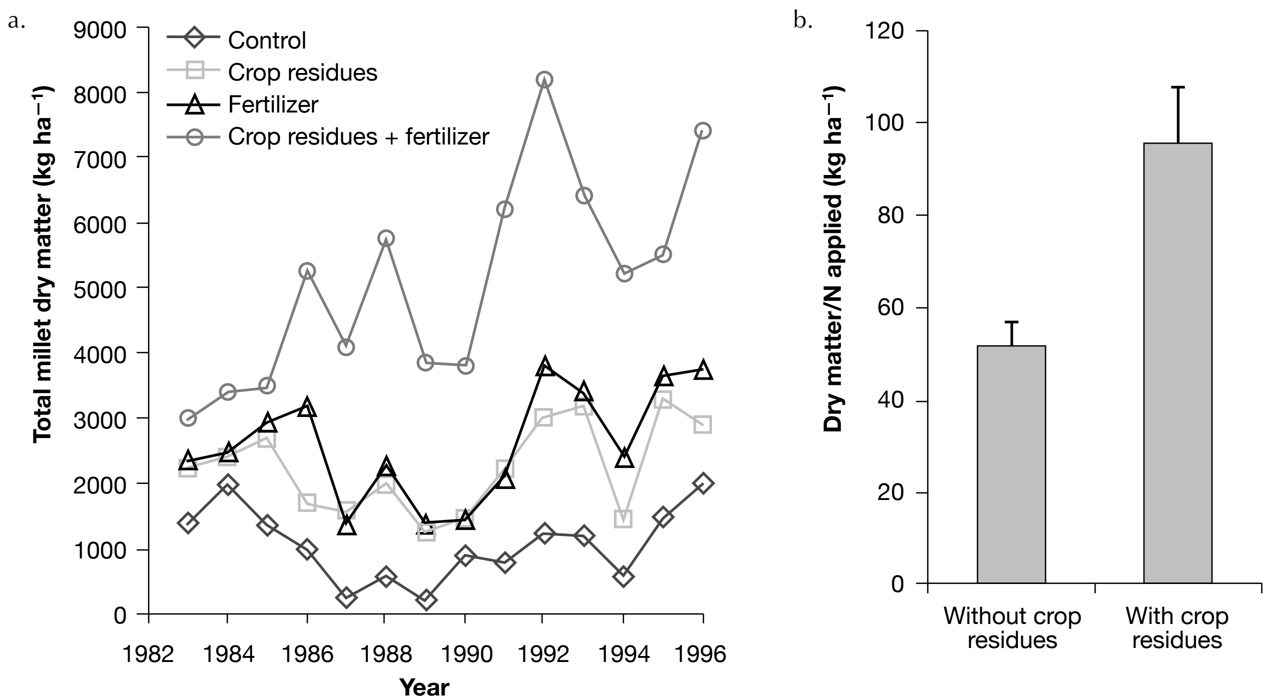

Figure 2. *The effects of crop residues and nitrogen fertilizer on (a) total millet dry matter yield and (b) nitrogen use efficiency at Sadoré, Niger (modified from Bationo et al. 1999).*

by significant advances in scientific understanding and practice. These include high-precision fertilizer management (e.g. Baidu-Forson and Bationo 1992) and the development of knowledge-based organic matter management practices (e.g. Palm et al. 2001 and 2002; Vanlauwe et al. 2003). The target of the these practices is, of course, not only to replenish soil nutrients and improve crop yields but also to (re)build soil fertility for long-term sustainable soil management. This has always been a target of soil fertility management but has gained additional impetus with realization of the wide range of ecosystem goods and services that stem from the maintenance of high levels of organic matter in the soil. In particular, the sequestration of carbon in soil as a means of alleviating the climatic impacts of excessive greenhouse gas emissions has become a global objective (Feller et al. 2001; Albrecht and Kandji 2003). Significant questions remain, however. It is still unclear how to predict the optimum quantitative mix of fertilizers and the various qualities of organic inputs. Such models must take into consideration the substantial site variability commonly found on farmers' fields, as well as the characteristic heterogeneity of tropical climatic conditions. Furthermore, while good formulae exist for the provision of nitrogen and phosphorus, the interaction with other nutrients, particularly micronutrients, remains largely undefined. A significant opportunity for development exists in this area of research now that very high priority is being given internationally to plant breeding for micronutrient provision. Most significantly, all the successes tend to remain disappointingly local in scale. The major challenge remains that of determining the necessary actions to multiply the local successes to achieve impact at a continental scale (FARA 2003). This requires better insight into the relationship between the technology performance and the prevailing conditions of the biophysical, institutional and socioeconomic environments. The first challenge therefore addresses both the adaptive range of the technological menu and the social and economic circumstances that influence farmers' willingness to adopt.

Challenge 1: *What are the determinants of the adaptive and adoptive advantages of the available technological options for sustainable soil fertility management?*

Below the farm: harnessing the biosphere

The community of organisms in the soil perform many essential processes. They act as the primary driving agents of nutrient cycling; regulate the dynamics of soil organic matter, soil carbon sequestration and greenhouse gas emission; modify soil physical structure and water regimes; enhance the amount and efficiency of nutrient acquisition by the vegetation through mycorrhiza and nitrogen-fixing bacteria; and influence plant health through the interaction of pathogens and pests with their natural predators and parasites. These processes also provide a range of services to humans, including maintaining the availability and quality of water resources, erosion control, biological control of pests, climate regulation and, of course, food production.

The status and activity of the soil community has only rarely been taken into account in modern approaches to soil management. Any form of integrated nutrient management nonetheless relies on the capacity of the decomposer community to process the organic inputs. Similarly, the benefits of conservation tillage rely on regulation of the soil's physical condition by earthworms and other biological ploughs. There is thus increased awareness of the need to understand the functioning of the living soil community, as expressed in the 'second paradigm' for soil fertility management proposed by Sanchez (1994) (see also Swift 1998), i.e. for improved crop growth, 'rely on biological processes by adapting germplasm to adverse soil conditions, *enhancing soil biological activity* and optimizing nutrient cycling to minimize external inputs and maximize the efficiency of their use' (our emphasis). The second challenge directly addresses the central, but largely unrealized, clause in this paradigm.

> ***Challenge 2:*** *How can the functions of the soil community be optimized with respect to different ecosystem services?*

One of the major reasons for the slow progress in understanding the functional biology of the soil biota has been the lack of sensitive methods for investigating soil micro-organisms. This problem has come closer to solution since the advent of molecular methods for identifying and tracking specific soil organisms and for assessing changes in overall biodiversity (Amman and Kuhl 1998; Amman and Ludwig 2000). The Centre has already embarked on innovative studies of this kind (e.g. Bossio et al. 2005). Combining such work with continuing studies of the keystone role of trees in agroecosystems (see following section) offers great promise as a means of linking the driving functions of ecosystem services across scales from below the plot to the landscape.

Beyond the farm: landscapes and institutions

The biggest challenges for the management of natural resources probably lie at the broadest scales and can be placed under the inexact term of 'the landscape'. At these scales, predictions of effects derive not so much from specific biological processes, but from their aggregate and interactive effects. The main driver of these effects is the nature and location of different land-use systems on the landscape, including their history and management. Trees influence landscape scale dynamics more than any other organisms (although, of course, humans have now appropriated this claim). Investigation of this keystone role must remain not just a major part of the Centre's research agenda, but at the very heart of it, because of the huge number of secondary interactions that flow from the incorporation of trees within any land use system.

One specific feature that is strongly influenced by the presence of trees is the abundance and quality of soil organic matter. This, in its turn, influences both soil fertility and all the other ecosystem services derived from soil. It is therefore both a major resource and an indicator of soil status. The work of Shepherd and Walsh in developing methods for remote sensing and mapping of soil carbon status and its linkages to other soil properties at different scales has provided extremely powerful tools for both assessing and predicting the environmental effects of land use change (Shepherd and Walsh 2002).

Soil carbon is now of global interest because of the opportunity to utilize sequestration as a mechanism for correcting the imbalances in emissions of carbonic gases that are believed to be driving climate change at an unacceptable rate. However, organic matter is not an inert component of soil. It is the substrate for many soil organisms and thence contributes energy for many of the essential biological processes that support plant production and soil structure maintenance. There is thus a major challenge to assess (for different types of land use) how to optimize the use of soil carbon. This is fundamentally an issue of balancing the needs of the farmer (at the scale of the plot) to exploit soil organic matter energy for crop production with the needs of society in general (at the scale of the landscape) to conserve carbon (Tomich et al. 2005). It is possible to hypothesize that these two goals may be mutually incompatible or have significant quantitative limits under some conditions. Izac and Swift (1994) argued, for instance, that a sustainable agricultural landscape might necessitate a balance between areas of exploitation of resources and areas in which they are permitted to accrue. This relates to the third challenge.

> ***Challenge 3:*** *What are the trade-offs between the storage of organic matter in the soil (to counter the climate change effects of increased gaseous emissions) and its use to drive nutrient cycling, crop production and other ecosystem services?*

Socio-biophysical interactions are apparent at all scales, but primarily at the landscape scale where the impacts of decisions made by different stakeholders across a range of scales interact (Figure 1). The two Systemwide Programmes managed by the Centre (the African Highlands Initiative and the Alternatives to Slash and Burn Programme) have been at the forefront in developing approaches and methods for assessing the interactions between environmental, economic, social and political factors in natural resource management (Stroud 2001; Stroud and Khandelwal 2003; Palm et al. 2005). The proposal for the Challenge Programme for sub-Saharan Africa drew upon these lessons by picturing an interactive chain of cause and effect in land degradation and unsustainable agriculture. This chain links the degradation of natural resources to failures in market access and performance, thence to inappropriate pathways of system intensification, and finally to inadequate policies (FARA 2003). The analysis provided in the Challenge Programme documentation serves in particular to direct attention to the 'interactions' between these sectors of the research enterprise as well as to the issues within each of them (the fourth challenge).

> ***Challenge 4:*** *What are the key questions arising from interactions in the chain linking resource management–system intensification–market access–policy?*

Integrating across scales

The rules governing resource management, and the institutions making them, change as scales change. For example, rules (or the lack of them) made from the national perspective can strongly influence local behaviour and may result in significant feedback effects (Figure 1). This complexity is compounded by changes in dominance of the factors determining natural resource dynamics at different scales (e.g. van Noordwijk et al. 2004 with respect to hydrological flows and Swift et al. 2004 in relation to the significance of biodiversity). The type of management (communal or individual, government or private) apparent within the land use types and the gender and wealth dimension is also important. Thus, a range of social parameters enters the equation. These issues have been analysed by the CGIAR Taskforce on Integrated Natural Resource Management and the reports and papers emanating from that group (e.g. Campbell and Sayer 2003; Sayer and Campbell 2001) together with the framework developed by Izac and Sanchez (2001) offer some of the best analyses of the methods, approaches, successes, opportunities and challenges that face a scientific community committed to issues of 'Land and People'.

In a recent study of watershed management issues that cut across scales and social perspectives in the East African Highlands (reported by German 2003 and Stroud 2003), five main categories were identified:

1. Issues involving the management of common property resources which compromise either the quantity or quality of these resources.
2. Issues involving limited access and inequitable distribution of resources (absolute and relative shortages).
3. Trans-boundary effects between neighbouring farms and villages.
4. Areas in which collective action could significantly enhance farm productivity, either through increased access to productive resources (natural resources, labour, capital) or through cooperation to conserve resources that are under threat (biodiversity, local knowledge).
5. Areas in which collective action is currently needed to enhance income or livelihood more broadly (public works, governance of existing resources, marketing).

Of equal interest to variation across spatial scale is the influence of change over different scales in time. Crowley and Carter (2000) provided a detailed and perceptive analysis of the historical factors that have influenced the current state of natural resources and agricultural practice in western Kenya. Such analysis influences an important debate in natural resource management research. It is often asserted that the characteristics of the natural resource base and its management are highly site-specific, an observation largely derived from the huge biophysical variation that is commonly seen between neighbouring fields with respect to soil fertility status and other biological properties. These observable differences may derive, in some cases, from variations in underlying materials, but are more frequently a product of the history of human management of the natural resources of the plots, farms and regions concerned in response to risks posed by weather, market, food and feed needs, energy and land use policies, etc. This paints a potentially chaotic picture resulting from dynamic evolution over time. The evolutionary biologist, Stephen Jay Gould, has made an eloquent plea for scientists to appreciate the importance of historical analysis as an integral tool in the biological sciences (Gould 2000). In particular, he points to the importance of understanding the degree to which present conditions are contingent on events that occurred in the past. Whilst his arguments are largely concerned with the processes of biological evolution, they surely also apply to the development of ecological systems over time, particularly those influenced by agriculture.

The recognition of site specificity at the plot level has led to the pessimistic assertion that there is therefore no opportunity for generic scientific or technological solutions to natural resource management problems. This is a confusion of principle and practice. It is certainly now generally accepted that monolithic zonal technology recommendations (e.g. for fertilizer dosage) are ineffective. They have been largely replaced by menus of multiple options, and the choice of option is determined by local conditions. However, the origins of the menu options are no less based on scientific principles than are (for example) those created by producing different crop genotypes. Indeed, it could be argued that failures in realizing the potential of genotypes have often resulted from failure to recognize the environmental variations that are taken for granted in natural resource management research.

This brief analysis of multiscale issues in space and time serves to emphasize four cross-cutting issues:

1. Recognition of the hierarchical linkages across scales and their interactions in terms of problems and potential solutions (Swift 1999).
2. The value of understanding the historical basis of present conditions.
3. The importance of merging biological, social and institutional analyses in order to understand the dynamics of influence both across and within scales.
4. The value of identifying 'entry' points for research and intervention, i.e. simplifying access to the complexity of interactive effects within any natural resource management problem by tackling them through accessible and influential components.

These issues can be summarized as a fifth challenge.

Challenge 5: *What are the rules governing cross-scale transitions in natural resource management?*

Conclusion: what type of science, to do where, and for whom?

The five specific challenges presented above provide a response, but by no means a complete answer, to the question posed in the opening paragraph. The greatest challenge for any institution whose role is science for development is that of choice: choice of one scientific topic versus another; choice of criteria for research locations; choice of what type of scientific approach to use; and choice of which of the myriad stakeholders to work directly with, in what manner and across what scales in space and time.

The scientist in any development-related topic will always be faced by decisions as to where to place her or his activities in the research-to-adoption spectrum. Whether to concentrate on relatively basic research, removed from the ultimate client but generating knowledge that may open up areas of progress hitherto inaccessible; or to focus on actions to disseminate knowledge and technology that interact directly with, and provide identifiable benefits for, a selected group of such clients. This dilemma is far from peculiar to international agricultural research. The Nobel Prize laureate, immunologist and incisive writer on the philosophy of science, Sir Peter Medawar, pictured two 'Conceptions of Science' that exist in the popular imagination (Medawar 1982). He described the 'Romantic Conception' with the words of the English poet and essayist, Samuel Taylor Coleridge: "The first man of science was he who looked into a thing, not to learn whether it could furnish him with food, or shelter, or weapons, or tools, or play-withs, but who sought to know it for the gratification of knowing." Medawar contrasted this concept with what we may term a 'Pragmatic Conception': "Science above all else [is] a critical and analytical activity; …scientific research is intended to enlarge human understanding, and its usefulness is the only objective measure of the degree to which it does so." Medawar acknowledged that these two descriptions were caricatures and concluded that: "Anyone who has actually done or reflected deeply upon scientific research knows that there is in fact a great deal of truth in both [conceptions]." International agricultural research must indeed serve both these pursuits. By choosing to work for the poorest of the poor we have already chosen to follow the Pragmatic Conception. But our contribution is likely to be greater by applying what we are most suited to do – to exercise our curiosity and imagination to empower people with the best that the scientific adventure can provide.

The discussion in the preceding sections argues in almost every part for a holistic approach to agricultural research for development – and this is perhaps the most exacting scientific challenge of all. The obvious danger in any broad approach, however, is that of working on absolutely everything and losing all useful focus. Ecosystem ecology is helpful in this regard, for it has become clear that, whatever the level of complexity, there are always some features of the system that are more influential in its regulation than others. This existence of keystone organisms and processes is particularly good news for agroforesters, because asking the question 'what is the role of the tree(s)?' in any given ecosystem is unlikely to be distant from asking 'how does this system work?' Likewise, the disciplines of anthropology and sociology draw upon knowledge of repeated patterns in social behaviour and actions that can be linked to bio-political processes. The key for the resource management scientist in agricultural research is thus to identify key features of the system during the diagnostic phase of a research programme, and to derive appropriate entry points to the research that will enable manipulation of these keystone organisms, processes or properties.

In seeking to wade in the 'bathwater' of holistic science we should not, however, cast out the 'baby' of reductionism. As mentioned above, Stephen Jay Gould argued forcefully throughout his career for a wider and less mechanistic concept of what constitutes the scientific method than mere reductionist experimentation. Yet, in so doing, he also said: "Only a fool or an enemy of science could possibly deny the extraordinary power and achievements of reductionism…" (Gould 2004). It is thus surely not a question of *either* reductionism *or* holism, but the challenge of when and in what manner to employ the power of the former within a framework of the latter. As outlined above, the tools to assist such choices are already part of the World Agroforestry Centre's armoury – what remains is how we choose to use them.

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Keywords:
Agroforestry, improved fallows, trees, biomass transfer, nitrogen, phosphorus

Chapter 6

Agroforestry innovations for soil fertility management in sub-Saharan Africa: Prospects and challenges ahead

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Abstract

Improving soil fertility is a key entry point for achieving food security, reducing poverty and preserving the environment for smallholder farms in sub-Saharan Africa. Given the high cost of inorganic fertilizers, an integrated approach that combines promising agroforestry technologies – particularly improved fallows and biomass transfer – with locally available and reactive phosphate rock – such as the Minjingu of northern Tanzania – is described in this chapter. Leguminous tree fallows of several species can accumulate significant amounts of nitrogen in their leaves in the short duration (from 6 months to 2 years). Incorporating these leaves into the soil before planting can increase crop yields several-fold. Improved fallows can also contribute to the control of weeds (including *Striga hermontheca*) and provide wood for energy and for staking climbing crops. Some of the species also have fodder value that can improve manure quantity and quality. For biomass transfer, use of *Tithonia diversifolia* is the most promising because of its high nutrient content and rapid rates of decomposition. This plant is now being used more widely for high-value crops such as vegetables. To facilitate the scaling up of these fertility options, future research and development needs to address recommended application rates, impacts at both farm and landscape levels, and the method by which high-value trees, crops and livestock can be intensively farmed to provide a natural progression out of poverty.

Background

Land degradation and declining soil fertility are increasingly being viewed as critical problems affecting agricultural productivity and human welfare in tropical Africa. It is estimated that an average of 660 kg of nitrogen (N) ha^{-1}, 75 kg of phosphorus (P) ha^{-1} and 450 kg of potassium (K) ha^{-1} have been lost during the last 30 years from around 200 million ha of cultivated land in 37 countries in sub-Saharan Africa (SSA) (Stroorvogel et al. 1993). The estimated value of such losses averages about US$4 billion per year (Drechsel and Gyiele 1999). This figure is probably higher than the annual official development assistance given to the agricultural sector in Africa during the last three decades.

The underlying socioeconomic causes of nutrient depletion, their consequences and the various strategies for tackling this constraint are fairly well known (Buresh et al. 1997; Smaling 1993). It is important, however, to underscore that the spatial distribution of nutrient depletion in Africa is not uniform at regional or farm scales. Regions that have not been subject to intensive, continuous cultivation, or which have a widespread history of fertilizer use, do not exhibit this problem (Scoones and Toulmin 1999). Localized differences in farmer wealth ranking, field-use history and the use of organic additions (typically in fields close to the homestead) generally produce 'islands' of high soil fertility (Shepherd and Soule 1998.

Given the acute poverty and limited access to mineral fertilizers, a promising approach is one that integrates organic and inorganic fertilizers. Organic fertilizers include the use of improved fallows of leguminous trees, shrubs, herbaceous legumes and biomass transfer. The improved fallows system is the product of more than 10 years' of agroforestry research and development efforts by the World Agroforestry Centre (ICRAF) and its many partners in SSA. Both research and development dimensions are discussed in this chapter. We do this by drawing particular reference to the Centre's collaborative work in three regions of Africa – East and Central Africa, southern Africa and the Sahel. Declining soil fertility is a major concern faced by smallholder farmers in all these regions (Franzel 1999; Sanchez and Jama 2002).

Improved fallows

The concept and practice

Although neither the idea nor the research on improved fallows is new (Nye and Greenland 1960), critical examination of the practice, and the wide-scale evaluation of suitable species, is relatively recent (Sanchez 1995). Planted fallows of leguminous trees or shrubs can biologically fix considerable amounts of N – for example, between 60–80 kg ha^{-1} – in above-ground biomass (Gathumbi 2000). The rest of the recycled N in such leguminous trees or shrubs is accessed from sub-soil N – Oxisols and Oxic Alfisols – which is unavailable to crops (Mekonnen et al. 1997). Under conditions such as those in western Kenya, where the soils possess substantial anion exchange capacity, net N mineralization exceeds N uptake by crops and high rainfall carries nutrients to the sub-soil, resulting in a build-up of sub-soil N that ranges from 70 to 315 kg ha^{-1} (Hartemink et al. 1996). Nitrogen that accumulates in the above-ground biomass of planted tree fallows is returned to the soil upon clearing; the fallow biomass is incorporated into the soil for subsequent cropping. Additionally, fallows increase the amount of labile fractions of organic soil matter, which supply nutrients to crops following fallows (Barrios et al. 1997). They can also contribute to improving soil structure, build up of soil organic matter and its carbon (C) stocks, thus contributing to C sequestration.

The choice of which species to plant in the fallow period is influenced by both biophysical and socioeconomic conditions. The ideal tree species is typically fast-growing, N-fixing and efficient at nutrient capture and cycling. Examples of promising species include *Crotalaria grahamiana*, *Tephrosia vogelii, Cajanus cajan* (pigeonpea) and *Sesbania sesban* (sesbania). Coppicing species can also be used, and *Gliricidia sepium* (gliricidia) and *Calliandra calothyrsus* (calliandra) are becoming increasingly popular with farmers in Kenya, Malawi and Zambia because they are perennial and, unlike the non-coppicing species, there are no costs involved in replanting them once they are cut back.

Agronomic and economic benefits

Several agronomic studies demonstrate that improved fallows of 1–3 seasons (8–21 months) can increase soil fertility and improve yields considerably. For instance, Kwesiga and Coe (1994) in premier field studies demonstrated that 2- and 3-year sesbania fallows can increase maize yield, compared to unfertilized maize monoculture, for at least three cropping seasons after harvest of the fallows on an N-deficient soil in Zambia. This was confirmed later in multilocational trials in eastern Zambia (Kwesiga et al. 2003). In western Kenya, similar observations have also been made with use of several species and fallow durations (Jama et al. 1998a; Niang et al. 1996a; Rao et al. 1998). Recent trials in the Sahel that were conducted within the subhumid region of Mali also demonstrate the ability of several species to improve soil fertility and crop yields considerably (Figure 1). These studies have led to the general conclusion that total farm production can be greater with improved fallow–crop rotations than with continuous cropping, even though crop production is skipped for one or more seasons with improved fallows (Sanchez et al. 1997).

In areas such as southern Malawi with low rainfall and sandy soils, gliricidia fallows that coppice when cut back perform better than those of sesbania, which does not coppice well. This has been demonstrated through long-term trials that also show that the highest yields are obtained when improved fallows are used in conjunction with repeated application of the recommended rates of inorganic fertilizers (Figure 2).

In soils that are severely depleted of nutrients, the addition of inorganic fertilizers increases the productivity of improved fallows. In western Kenya, for instance, there is increasing evidence that 1–2 season-long fallows do not overcome N deficiency in highly degraded soils, especially when deficiencies of other nutrients are overcome and when high-yielding crop varieties are used. Fertilizer use is, however, limited by

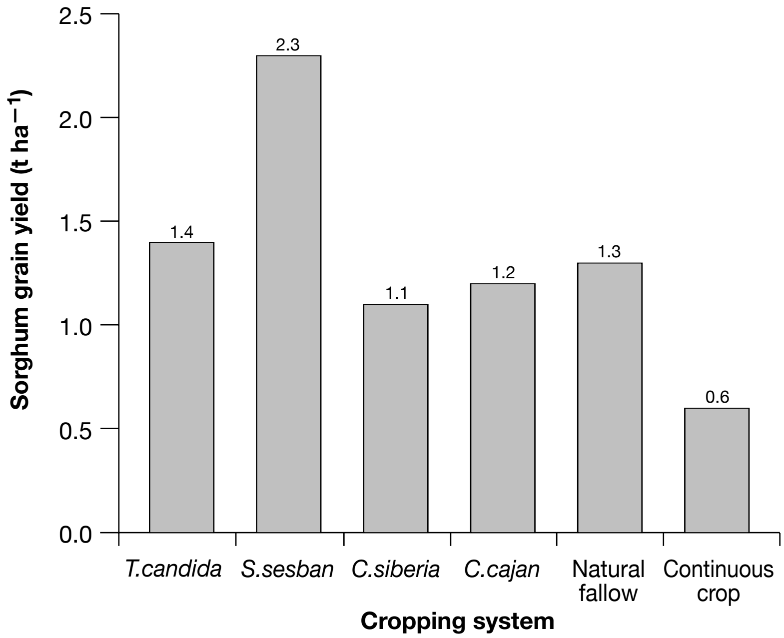

Figure 1. *Effect of improved fallows using different species on the grain yield of sorghum at Bamako, Mali.*

Source: Niang (unpublished data).

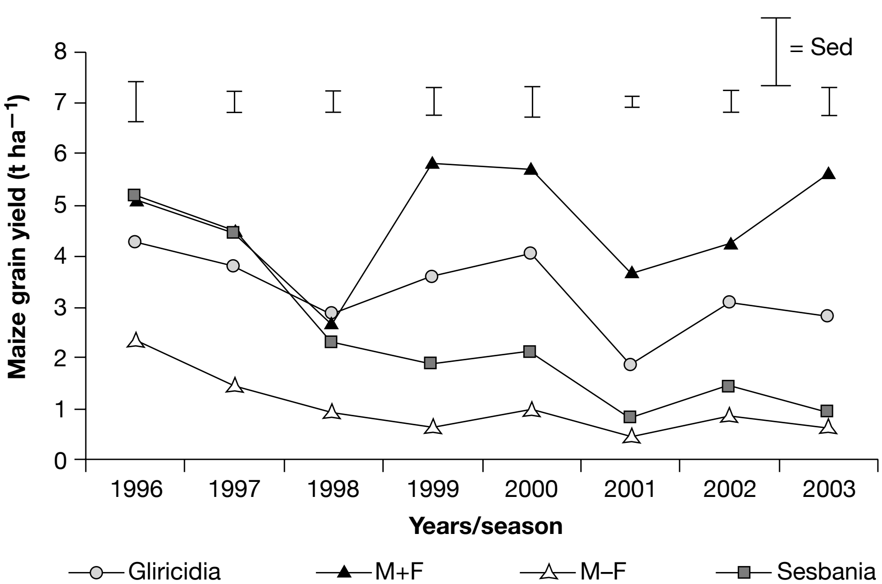

Figure 2. *Maize grain yield for eight seasons using* Sesbania sesban *and* Gliricidia sepium *fallows. Sed = Standard error of difference of means. M+F = Maize that was fertilized with 200 kg ha^{-1} of a compound fertilizer (N = 100 g kg^{-1}, P = 90 g kg^{-1} and K = 80 g kg^{-1}) at sowing, and 92 g N ha^{-1} as urea 4 weeks after emergence; M-F is maize not fertilized.*

Source: Kwesiga (unpublished data).

its high cost. In SSA, fertilizers cost around 3–4 times the international price largely because of poor roads and the associated high transport costs in many countries. However, fertilizers are needed for the integrated nutrient management approach proposed for replenishing soil fertility in Africa, and hence should be made affordable to farmers.

Economic analysis indicates that improved fallows are generally attractive (Franzel et al. 1999; Swinkels et al. 1997). According to sensitivity studies conducted by Place et al. (2000) in eastern Zambia, which is prone to droughts, this is the case even under drought conditions. In western Kenya, however, economic benefits are marginal. Even though the soils in this region are P-deficient and require application of P-rich fertilizers, that are prohibitively expensive (costing more than US$500 t^{-1}).

Other benefits

Control of *Striga hermontheca*, a parasitic weed of many cereal crops, is an added benefit of the repeated use of improved fallows (Barrios et al. 1998; Gacheru and Rao 2001). *Striga* causes large yield losses in the Lake Victoria area of the East and Central Africa basin. Although the processes are not well understood, it is suspected that the fallow species excrete substances that cause suicidal early germination of *Striga*.

The provision of fuelwood is another benefit of improved fallows. Depending on the species and fallow duration, considerable amounts of wood can be obtained from improved fallows. For instance, in western Kenya, calliandra, which produces wood with good fuelwood properties, can generate more than 10 t ha^{-1} of wood from as early as the third year of establishment. This is enough to meet the fuelwood needs of a typical rural household with 6–7 members for 6–8 months. The wood can also be used to support climbing beans and other climbing crops.

Limitations

Two important factors that need to be considered with short-term improved fallow systems are: how much leaf biomass the fallow species produces and the quantity of nutrients recycled with it. Several factors influence biomass production. In degraded sites (nutrient-depleted and eroded), most fallow species grow poorly and produce little biomass. This is also the case in dry areas and those with Vertisols (heavy clays) that drain poorly during the wet season. Such conditions prevail around the Lake Victoria basin where leaf biomass yields are typically less than 1 t ha^{-1}. This will give less than the 80–100 kg N ha^{-1} required to produce a 2 t ha^{-1} maize grain yield (Palm 1995). There are options that can be explored to increase biomass yield without necessarily increasing the fallow period. These include the use of coppicing species, and under-sowing the tree fallow with herbaceous green manure legumes such as mucuna (*Mucuna puriens*) and macroptilium (*Macroptilium atropurpureum*). In P-depleted soils, trees respond to P application and can benefit from having P applied to crops planted within them (Jama et al. 1998b).

The incidence of pests and diseases is another important limitation and there are two aspects to this problem. Firstly, there are pests and diseases that affect the trees themselves and limit their productivity. For example, sesbania is damaged, sometimes severely, by the defoliating beetle *Mesoplatys ochroptera*. *Crotalaria grahamiana*, until now a promising species for improved fallows in western Kenya, is attacked and defoliated severely by lepidopterous *Amphicallia pactolicus* caterpillars. Controlling these pests is vital to ensure that the productivity of species used and promoted for improved fallows is maintained. Secondly, there is need to understand and control the effects of these pests on the crops that succeed the fallows. A case in point are the root-knot nematodes associated with sesbania that also affect beans and tomatoes (Desaeger and Rao 2000).

There is also the potential for some of the species used in fallows to become invasive weeds – although no such occurrence has been reported so far. Prolific seeders like crotalaria and leucaena species are examples of the types of fallow plants most likely to become problematic. Other species may start to seed prolifically when taken out of their ecological range. Thus control mechanisms, including prevention, early detection and rapid response, need to be developed. This requires cross-regional collaborative efforts.

Biomass (green manure) transfer

Apart from improved fallows, existing hedges on farm borders are another source of organic nutrients for biomass transfer. More than 10 species with potential for this purpose have been screened in western Kenya (Niang et al. 1996b), and the most promising of all is *Tithonia diversifolia* of the family Asteraceae (tithonia). Although it is not a legume, the fresh leaf biomass of tithonia has levels of N as high as those found in many N-fixing legumes. This common shrub is also rich in P and K: the fresh leaves contain 3.5% N, 0.3% P and 3.8% K. The leaf biomass decomposes rapidly with a half-life of about one week especially during the rainy season (Gachengo 1996).

Many field studies report that the application of tithonia biomass results in higher crop yields than application of inorganic fertilizers, and it has longer residual effects (Gachengo 1996; Jama et al. 2000). Part of the yield benefits associated with tithonia could be due to increased availability of nutrients. Phosphorus release from tithonia fresh-leaf biomass is rapid, and the supply of plant-available P from tithonia can be at least as effective as an equivalent amount of soluble fertilizer. Nziguheba et al. (1998) reported that incorporation of green tithonia biomass equivalent to 5 t dry matter ha^{-1} to an acid soil in western Kenya increased P in soil microbial biomass and reduced P sorption by soil (Table 1). In this study, the plots were kept free of weeds and not cropped in order to eliminate plant uptake of P as a factor affecting soil P fractions and processes. Increased P in soil microbial biomass 2 weeks after tithonia incorporation presumably indicates enhanced biological cycling and turnover of P in labile pools of soil P. Enhanced microbial biomass P following integration of tithonia with triple superphosphate, and not with sole application of triple superphosphate, supports the hypothesis that tithonia increases soil labile P. Soil microbial P before maize planting has been shown by Buresh and Tian (1997) to be directly correlated to maize yield on a P-deficient soil in western Kenya.

Availability of sufficient quantities of tithonia biomass and the labour required to harvest and transport it to cropped fields are likely to be two major constraints to the wide-scale adoption of this technology by farmers. Recognizing these limitations, most farmers in western Kenya are using tithonia on small parcels of land and on high-value crops such as tomato and kale (*Brassica oleraceae* var *acephala*; ICRAF 1997). They are also experimenting with tithonia in maize–bean (*Phaseolus vulgaris*) intercrops, where it could be more financially attractive than in sole maize because

Table 1. *Effects of 15 kg P ha^{-1} as either green tithonia biomass or triple superphosphate (TSP) on increase in microbial biomass P and decrease in sorbed P at 0.2 mg P L^{-1} solution.*

Weeks after application	Increase in microbial biomass P (mg P kg^{-1})			Reduction in sorbed P (mg P kg^{-1})		
	Tithonia	TSP	Tithonia + TSP	Tithonia	TSP	Tithonia + TSP
2	4.3 **	1.8	7.8 **	49 **	41 **	30 *
16	1.6	0	3.7 **	27 *	10 *	20

* indicates significance at $P = 0.05$ and ** at $P = 0.01$. All values are relative to a control with no added TSP or tithonia.
Source: Nziguheba et al. (1998)

beans are of higher value than maize. In Zambia, farmers are doing the same in the 'dambos' (wetlands) during the dry season (Kuntashula et al. 2004). In Mali, it is increasingly being used for vegetable farming in urban and peri-urban agriculture. Indeed, economic analyses indicate positive returns from the use of tithonia on high-value vegetables but not for low-priced maize (ICRAF 1997).

Based on feedback from farmers, research on tithonia is now focused on several issues of practical importance: i) identifying ways of increasing its production on-farm by growing it in small niches such as around farm boundaries and in soil conservation structures; ii) integrating it with inorganic fertilizers to reduce the required quantities of each material; iii) using it to complement low-quality organic materials such as crop residues and farmyard manure that are used as fertilizers; iv) identifying the minimum acceptable quantities of tithonia for application to vegetables and cereals; and v) optimizing its use efficiency through timely application and appropriate placement.

Livestock manure

For smallholder farms, farmyard manure is a major source of nutrients. However, quality is poor and quantities available are often low, especially in densely populated regions like western Kenya where farmers keep few animals (Kihanda and Gichuru 1999). Quality can be improved through better management, including feeding nutrient-rich tree fodder to cattle. Manure from livestock fed with calliandra fodder can be especially high in P, for example, as demonstrated through studies in western Kenya (Jama et al. 1997). Application of this manure at rates typically used by farmers in the area more than doubled maize yields in P-deficient soils, and effects were even greater when it was spot applied (placed in the planting hole) instead of broadcast. However, much more assessment is needed on improvements in tree fodder and manure quality, including a better understanding of their interaction with inorganic fertilizers and how they affect overall household economic conditions.

Need for phosphorus inputs

Phosphorus deficiency is widespread in SSA. This is particularly pronounced in western Kenya where, for instance, more than 80 percent of the farms are severely deficient in P, with less than three parts per million of available P when analysed by the Olsen procedures. As a consequence, crop yields remain low. Under these conditions, P input is a must if crop yields are to be improved. Although trees can add some P to the soil, this is mostly by recycling what is already there and not through new additions. The exception is biomass transfer. Even then, the amounts that can be added through the biomass of trees are often low.

Options for P inputs are phosphorous fertilizers and phosphate rock (PR), depending on which is cost-effective. There are several PR deposits in Africa that could be of agronomic use (van Straaten 2000), for example the Tilemsi in Mali and the Minjingu in northern Tanzania. The agronomic effectiveness of Minjingu rock phosphate was examined in long-term (5-year) field trials in western Kenya. Two different strategies of phosphorus application were compared – a large one-time application (250 kg P ha^{-1}) that is expected to provide a strong residual effect for at least 5 years, and annual applications of 50 kg P ha^{-1} applied to the rainy-season maize crop. Over the 5 years of the study, cumulative maize yield was significantly increased by P fertilization, and the cumulative grain yields were almost the same, regardless of which P source or application method was employed (Figure 3). This clearly demonstrates the utility of Minjingu and other reactive PRs in soil fertility management approaches in SSA.

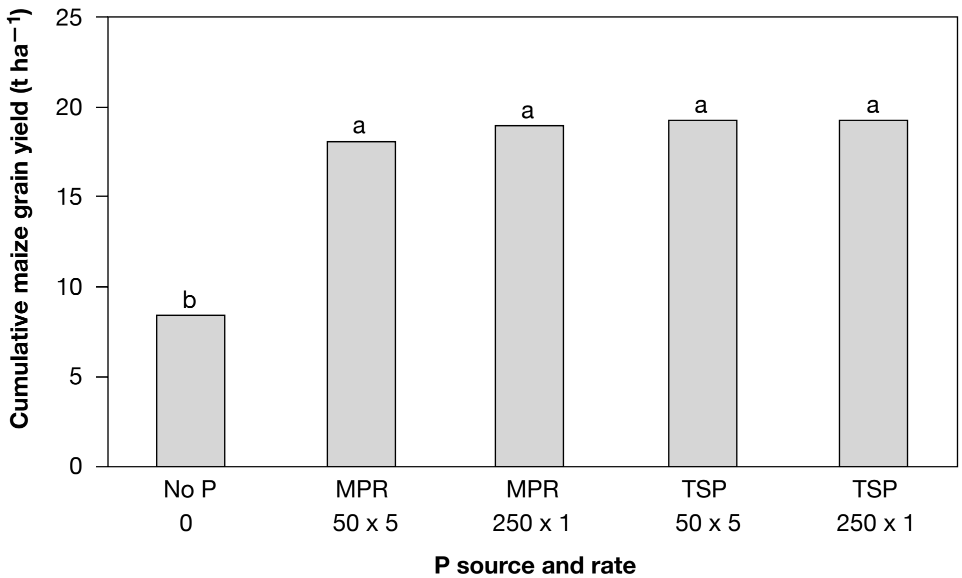

Figure 3. *Cumulative maize yields over 5 years (five crops, 'long rains' cropping season only) in western Kenya. Nitrogen (N) and potassium (K) were supplied. Minjingu phosphate rock (MPR) or triple superphosphate (TSP) fertilizer were added, either once at 250 kg P ha^{-1}, or at a rate of 50 kg ha^{-1} each year for 5 years. There was also a control plot with no added P.*
Source: Sanchez and Jama (2002).

Conclusion and way forward

Improved fallows of leguminous species and biomass transfer are both promising agroforestry techniques that can contribute to integrated soil fertility management practices in smallholder farms. They can also provide other benefits such as control of pests and diseases, and in the case of improve fallows, provide fuelwood that is in short supply in many rural settings. To enhance the impact of these technologies, there are a few remaining challenges that need to be addressed. These include:
1. Determining the recommendation domains (geographic areas and household types where the technologies are feasible and profitable), something that is necessary given the large biophysical and socioeconomic variability that exists within and between farms. 2. Developing strategies to make fertilizers affordable, especially those containing P that organic produce cannot supply adequately. 3. Promoting widely synergistic technologies such as biological soil and water conservation measures. 4. Promoting the keeping of livestock to produce manure, and developing best management practices for its use. 5. Developing strategies for wide-scale dissemination of the options available, particularly those that deal with overcoming the prevailing constraints of germplasm supply and information on their use. 6. Assessing ecological benefits of fallow plant species while mitigating potential problems of them becoming invasive weeds. 7. Determining ways in which high-value trees, crops and livestock can be more intensively farmed, providing a natural progression out of poverty.

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Keywords:
Extension, farmer-centred research, fodder shrubs, landcare, natural vegetative strips, tree fallows

Chapter 7

Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia[1]

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Abstract

This chapter assesses recent lessons learned from attempts to scale up agroforestry improvements, drawing on three case studies: fodder shrubs in Kenya, improved tree fallows in Zambia and natural vegetative strips coupled with the Landcare movement in the Philippines. Currently, more than 15 000 farmers use each of these innovations. Based on an examination of the main factors facilitating their spread, 10 key elements of scaling up are presented. These include: taking a farmer-centred research and extension approach; providing a range of technical options; building local institutional capacity; sharing knowledge and information; learning from successes and failures; and strategic partnerships and facilitation. Three other elements are important for scaling up: marketing, germplasm production and distribution systems, and policy options, although the three case study projects had only a marginal reliance on these. As different as the strategies for scaling up are, they face similar challenges. Facilitators need to develop exit strategies, find ways to maintain bottom-up approaches as innovations spread, assess whether and how successful strategies can be adapted to different sites and countries, examine under which circumstances they should scale up innovations and under which circumstances they should scale up processes, and determine how the costs of scaling up may be reduced.

Introduction

During the past two decades, researchers have worked with farmers throughout the tropics to identify and develop improved agroforestry practices that build on local indigenous knowledge and offer substantial benefits to households and the environment (Cooper et al. 1996; Franzel and Scherr 2002; Place et al. 2002; Sanchez 1995). Research and development projects have demonstrated in many instances that agroforestry increases household incomes, generates environmental benefits, and is particularly well suited to poor and female farmers. But in most cases these success stories have been confined to localized sites, often with unusually concentrated institutional support from research and development organizations.

As a consequence, considerable attention has been devoted in recent years to 'scaling up' the benefits of research, that is, 'bringing more quality benefits to more people over a wider geographical area, more quickly, more equitably, and more lastingly' (IIRR 2000). The issue of scaling up is particularly important

[1] This chapter is a shortened version of a longer published paper: Franzel, S., G.L. Denning, J.P.B. Lillesø and A.R. Mercado 2004. Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. *Agroforestry Systems* 61–62(1–3): 329–344.

to agroforestry and natural resources management innovations, because they are relatively 'knowledge intensive' and, unlike Green Revolution technologies, may not spread easily on their own. Drawing on a range of expertise, Cooper and Denning (2000) identified 10 essential elements for scaling up agroforestry innovations: farmer-centred research and extension approaches, technology options, building local capacity, germplasm, market options, policy options, knowledge and information sharing, learning from successes and failures, strategic partnerships, and facilitation (Figure 1).

The objective of this chapter is to assess recent lessons learned in scaling up agroforestry benefits, drawing on three case studies in Kenya, Zambia, and the Philippines. Two of these, from Kenya and the Philippines, were reported in Franzel et al. (2001a), but this chapter will show important developments since then. Firstly, concepts and definitions of scaling up are reviewed. Secondly, the case studies are presented, followed by a discussion of their use of the 10 fundamental elements. Finally, conclusions are drawn and research challenges are discussed.

Scaling up: Definitions and concepts

There is a proliferation of terms to describe scaling up (Gündel et al. 2001; Uvin and Miller 1996). For instance, Uvin and Miller's typology involves 17 different kinds of scaling up, focusing variously on structure, when a programme expands its size; strategy or degree of political involvement; and resource base, referring to organizational strength.

In this chapter we follow Gündel et al. (2001), who adopt the IIRR (2000) definition of scaling up, which notes that the 'scaled-up state' can either occur spontaneously or because of the deliberate, planned efforts of governments, non-governmental organizations (NGOs) or other change agents. Much can be learned from studying how spontaneous dissemination of innovations takes place, and in particular the role of farmer-to-farmer dissemination. Scaling up is a communication process, and change agents have to understand how farmers receive, analyse, and disseminate information in order to facilitate it. There is emerging literature on agricultural knowledge and information systems, exploring how those involved in the creation of agricultural knowledge acquire, transmit and exchange information (Garforth 2001).

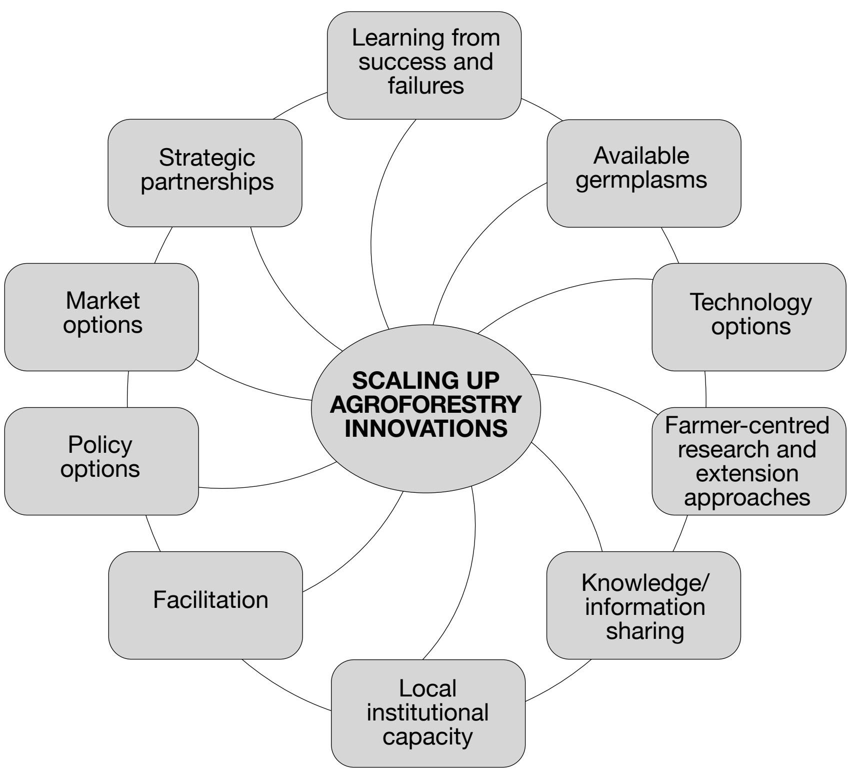

Figure 1. *Essential elements for scaling up agroforestry innovations.*
Source: Cooper and Denning (2000).

Case studies from Kenya, Zambia, and the Philippines

1. Fodder shrubs, Kenya

The low quality and quantity of feed resources is a major constraint to dairy farming in central Kenya. Most farmers also grow Napier grass as fodder, but it is insufficient in protein and the daily yield of cows fed on it is only around 8 litres. Commercial dairy meal is available but farmers consider it expensive and most do not use it (Franzel et al. 2003).

Development of the innovation

In the early 1990s, researchers (from the Kenya Agricultural Research Institute – KARI, the Kenya Forestry Research Institute

– KEFRI, and the World Agroforestry Centre – ICRAF) and farmers around Embu, Kenya, tested several fodder shrubs. Most of the trials were farmer-designed and managed. *Calliandra calothyrsus* emerged as the best performing and most preferred by farmers. It was found to grow in a range of 'neglected niches' on their farms, including in hedges along internal and external boundaries, around the homestead, along the contour for controlling soil erosion, or intercropped with Napier grass. When pruned to a height of 1 m, the shrubs did not compete with adjacent crops. Growing 500 shrubs increased farmers' incomes by around US$98–124 per year. By the late 1990s, two other shrub species, *Morus alba* (mulberry) and *Leucaena trichandra,* were introduced to farmers following successful on-farm testing (Franzel et al. 2003).

Scaling up

By 1999, 8 years after the introduction of fodder shrubs, about 1000 farmers around the research sites had planted them. However, there was limited scope for reaching all the 625 000 dairy farmers in Kenya; seed was scarce, and the farmers, extension staff and NGOs away from the on-farm trials were not aware of the work. During 1999–2001, KARI, ICRAF and the International Livestock Research Institute (ILRI) collaborated in a project to scale up the use of fodder shrubs in central Kenya. An extension facilitator, working with a range of government and NGO partners, assisted 180 farmer-development groups (comprising 3 200 farmers across seven districts) to establish nurseries and plant fodder shrubs. This approach proved to be very effective: by 2002, each farmer had an average of 340 shrubs and had given information and planting material to an average of six other farmers. Sixty percent of participating farmers were women.

Beginning in 2002, a project financed by the Forestry Research Programme of DFID (the UK's Department for International Development) and implemented by the Oxford Forestry Institute and ICRAF helped a range of partner organizations to increase the adoption of fodder shrubs. By early 2003, there were about 22 000 farmers planting fodder shrubs in Kenya and several thousand in four other countries. Facilitators are helping to train the extension staff of a range of different organizations, including government, NGOs, churches, community-based organizations, farmer groups and private-sector firms. The project is also helping to facilitate the emergence of private seed producers and dealers, and to help link them to buyers in areas where seed demand is high (Franzel et al. 2003; Wambugu et al. 2001).

2. Improved tree fallows, Zambia

The plateau area of eastern Zambia is characterized by a flat to gently rolling landscape, with annual rainfall around 1000 mm. Approximately half the farmers practice ox cultivation, the others cultivate by hand hoe. Maize is the most important crop, and sunflower, groundnuts, cotton and tobacco are also grown.

Surveys identified soil fertility as the farmers' main problem; fertilizer use had been common during the 1980s but was in decline as farmers now lacked the cash to purchase it (Franzel et al. 2002; Howard et al. 1997; Kwesiga et al. 1999).

Development of the innovation

In 1987, a Zambia–ICRAF agroforestry research project began research on improved fallows, using *Sesbania sesban.* By 1995, several hundred farmers were involved. In researcher-led trials, farmers chose among three different species and two different management options – intercropping with maize versus growing the trees in pure stands. In farmer-led trials, farmers planted and managed the improved fallows as they wished. Most farmers opted for a 2-year fallow and planted their main food crop, maize, for two seasons following the fallow. *Tephrosia vogelii, Cajanus cajan* and *Gliricidia sepium* were the main fallow species used. Maize yields following improved fallows averaged 3.6 t ha^{-1}, almost as high as for continuously cropped maize with fertilizer (4.4 t ha^{-1}) and much higher than maize planted without fertilizer (1.0 t ha^{-1}).

Scaling up

Extension activities began in earnest in 1996 when an extension specialist in the Zambia–ICRAF project set up demonstrations, facilitated farmer-to-farmer visits, and trained staff from the Ministry of Agriculture, several NGOs and development projects in Eastern Province. The project helped launch an adaptive research and dissemination network, consisting of representatives from several organizations, farmers' associations and projects (Katanga et al. 2002). The extension effort received a big boost with the start of a United States Agency for International Development (USAID)-financed agroforestry project in 1999, covering five districts. The Centre also facilitated the visits of farmers from Malawi, thus helping to launch the practice there (Böhringer et al. 1998). Scaling up objectives included sensitization, building grassroots capacities, developing effective partnerships, promoting policies more conducive to adoption, monitoring and evaluation, and conducting research on the scaling up process (Böhringer et al. 2003). By 2001, more than 20 000 farmers in eastern Zambia had planted improved fallows (Kwesiga et al. 2003).

3. Natural vegetative strips (NVSs) and Landcare, the Philippines

The upland municipality of Claveria is located in northern Mindañao, the Philippines. Annual rainfall of 2 200 mm allows a farming system of two maize crops per year. However, with this high rainfall, coupled with cultivation of sloping fields and use of animal tillage, soil loss through erosion had degraded lands and led to declining maize yields.

Applied research began in 1985 on contour hedgerow systems using nitrogen-fixing trees to minimize erosion, restore soil fertility and improve crop productivity. But adoption of this system was slow, and many hedgerows were abandoned owing to the high labour requirement to maintain them, poor adaptation of leguminous trees to acid soils, and competition between the trees and the maize crop.

Development of the innovation

Through participatory on-farm experiments, ICRAF researchers concluded that the *concept* of contour hedgerows remained popular and that farmers were concerned about soil erosion and loss of productivity. Researchers observed that farmers often ploughed along contour lines, leaving crop residues and/or natural vegetation in strips between ploughed fields. The latter innovation evolved into natural vegetative strips (NVSs) and emerged as a crucial entry point for reversing land degradation on sloping fields.

Over several years, the NVS technology, coupled with contour ploughing, spread spontaneously among farmers. This innovative farmer-based system and its components were the subjects of intensive on-farm research. Farmer innovations such as the 'cow's back method' (using the view of the ox's backbone when ploughing to maintain a reasonable trajectory for laying out contour lines) were identified as acceptable alternatives to the more technical 'A-frame' technique (ICRAF 1997). For the strips, some farmers demonstrated interest in such cash crops as fruit, timber and coffee; others preferred improved fodder grasses and legumes. In all cases, these innovations built on and enriched the foundation of the NVSs.

Scaling up

With the spontaneous visible spread of NVSs in and around ICRAF's applied research sites, considerable interest emerged from communities, local and provincial government agencies, and NGOs to learn more about this innovation. In 1996, the Centre responded to communities' requests for technical support and training by introducing and testing the appropriateness of Landcare, a participatory, community-based approach from Australia involving the development of groups in partnership with local government to promote conservation-farming practices (Campbell and Siepen 1994; Catacutan et al. 2001; Mercado et al. 2001). Farmers' interest led to the formation of the Claveria Landcare Association, which has emerged as the platform for widespread dissemination of conservation farming based on NVSs. In 1999, Landcare was extended to another ICRAF research site in nearby Lantapan municipality, and by 2002 there were an estimated 500 Landcare groups, involving more than 15 000 farmers in the Philippines.

Comparing the key elements of scaling up

Farmer-centred research and extension

Participatory research, in which farmers play a critical role in the design, implementation, and evaluation of research, has been shown to improve the effectiveness of research and to reduce the time between initial testing and uptake (CGIAR/PRGA 1999).

Farmers were involved in the early stages of the development of technologies at all three sites. In both Kenya and Zambia, researcher-led and farmer-led trials were conducted simultaneously: the former primarily to assess biophysical response, the latter for socioeconomic assessment (Franzel et al. 2001b). Encouraging farmers to experiment with the new practices as they wished led to new innovations and greatly improved the practices at both sites – reducing costs, promoting adoption and making scaling up more rapid.

In the Philippines, it was a farmer innovation – leaving crop residues along the contour, where they revegetate forming NVSs – that proved very popular. Researchers later proved that these strips were effective in controlling soil erosion and required little maintenance. The use of NVSs spread rapidly and farmers continued to innovate (Mercado et al. 2001). Also, establishing a long-term field presence in Claveria enabled researchers to identify and validate farmers' innovations, such as the cow's back method, and to help farmers adjust the NVS system to better reflect their interests, in particular by introducing such cash-generating enterprises as timber and fruit.

There was some variation in extension strategies among the three case studies. In Kenya, extension facilitators provided training to government extension and NGO staff and representatives of village-based farmer development groups, resulting in a significant amount of farmer-to-farmer extension. A similar strategy was implemented in eastern Zambia, except that facilitators established a network of farmer-trainers. In the Philippines, partnership with farmers in on-farm research paved the way for active farmer participation in the scaling up of both the technical innovations and the Landcare approach.

Technical options

Offering a range of options to farmers rather than a specific recommendation is important for several reasons (Franzel et al. 2001c):

- Diversification minimizes production and market risks, and allows for different preferences.
- Farmers' resources vary and different options often have different resource requirements.
- Different options allow for a variable environment.

In all three sites, researchers and farmers quickly developed a range of options for the technologies in question. In Kenya, farmers have the choice of three fodder shrubs and a herbaceous legume, which can be planted in a range of different niches and arrangements on their farms. Moreover, they can feed the leaves to their animals fresh or dry, or store them.

In Zambia, farmers choose from four different species and a range of management options for their improved fallows, depending on their preferences and available labour. They can plant the crops in pure stands or intercropped.

In the Philippines in the early 1990s, farmers and researchers began with a single innovation – the NVS. But by the end of the decade, farmers had introduced 31 different perennials, on their own initiative or with advice from facilitators. These different options included fruits, timber trees, fodder grasses and legumes. Many planted with the intention of earning cash (Mercado et al. 2001).

Local institutional capacity

Empowering local communities to plan their own development and mobilize resources is fundamental to any successful development strategy (Binswanger 2000). The three case studies used different approaches to building local institutional capacity. In central Kenya and eastern Zambia, extension facilitators provided training to village-based groups on the technologies they were promoting, but there were few direct efforts to otherwise build the capacities of these groups.

In Eastern Province, Zambia, in the mid-1990s, ICRAF assisted partner organizations to form an adaptive research and dissemination network to plan, implement and evaluate on-farm research, training and dissemination activities. The network facilitates the involvement of local groups in the plans and activities of research and development organizations, which enhances their capacity and feelings of ownership of the network and practices (Katanga et al. 2002).

In the Philippines, Landcare has gone further in building local institutional capacity. It has enabled communities to share knowledge and experience, influence the agenda of researchers and local policy makers, and mobilize financial resources. Mercado et al. (2001) noted that the "greatest success of Landcare" was the change in the attitudes of farmers, policy makers, local government and landowners with respect to land use and environmental management.

Germplasm

The lack of planting material is repeatedly identified as one of the most important constraints to the wider adoption of agroforestry innovations (Simons 1997). National Tree Seed Centres have been unable to deliver seed to large numbers of smallholders and, as with crop seed, "the seed demand–supply relationship in a large proportion of Africa's smallholder farming systems appears to represent a situation of market failure" (DeVries and Toenniessen 2001).

Successful production and distribution of quality tree seed to resource-poor farmers depends on a number of factors, some of which are biophysical, for example, identifying adapted provenances and seed sources or ensuring sufficient genetic variation, while other factors are economic, organizational and institutional, such as the protection of and ownership of seed sources, and cost-efficient production and distribution networks.

The Kenyan calliandra case study shows a typical dilemma: farmers unfamiliar with the new practice cannot be expected to buy seed, yet provision of free seed discourages them from harvesting it and undermines the emergence of private-sector marketing systems. ICRAF and KARI are trying to improve the situation in four ways:

- Helping link dealers in western Kenya to buyers in other parts of Kenya.
- Assisting fodder shrub growers and private nurseries in central Kenya to produce high-quality seed and seedlings and become seed dealers.
- Working with an NGO, Farm Input Provision Services, to help private dealers to package and sell seed through stockists.
- Encouraging private firms to produce fodder shrub seed or to buy seed from seed dealers.

The situation of improved fallows in Zambia has many similarities. One solution tried here through a USAID-financed project is to loan seed to farmers in return for a promise to give back double the amount they took. The sustainability of this system is uncertain; no private seed dealers have yet emerged, despite the wide-scale adoption of improved fallows.

In the expansion of Landcare, hundreds of communal and private individual tree nurseries have been established to provide seedlings for fruit and timber species. In Lantapan, farmers organized themselves to create the Agroforestry Tree Seed Association of Lantapan (ATSAL), a farmer-operated seed collection, production, processing and marketing association. The organization has trained more than a thousand farmers in both exotic and indigenous tree species and has extended its operations to other areas of the country.

Marketing

Linking farmers to markets and adding value to raw products have great potential for improving the incomes of smallholders and facilitating the scaling up process (Dewees and Scherr 1996). All three of the main practices promoted in the case studies produce inputs: fodder for increased milk production, and soil erosion control and soil fertility for crop production. However, only one of them, fodder, can be sold, explaining the relatively low emphasis given to marketing and product transformation in the case studies. Nevertheless, the uptake of the new practices depends on the availability of markets for the final products.

As mentioned above, efforts are needed in all three cases to promote the marketing of seed and seedlings. Moreover, there are also options for increasing the marketing of fodder from shrubs, which could be promoted as a cash crop for farmers who do not own livestock. In Kenya, there is also great potential for selling leaf meal as a protein source to millers producing dairy concentrates, who currently import protein in the form of fish meal, soybeans and cottonseed cake.

For thousands of low-income farmers in the Philippines, the NVS system has evolved as a means to graduate from subsistence maize farming to cash cropping. Claveria is well connected by road to the large port city of Cagayan de Oro, opening up potential markets for a range of agroforestry products. NVS adopters in Claveria are now observed to be growing a wide range of timber and fruit trees and are increasingly expressing interest in backyard livestock enterprises to diversify and stabilize their incomes. Market access has been critical for the intensification and diversification of the NVS system.

Policy options

Policy affects scaling up operations in several different ways: policy constraints may limit adoption of new practices, policy incentives help promote adoption, and policy makers themselves may be engaged to promote or even finance scaling up activities – a relatively untapped resource (Raussen et al. 2001).

In Zambia, local leaders played important roles in promoting improved fallows in two ways. Firstly they helped sensitize and mobilize their constituents to plant improved fallows. Secondly, they passed, and in some cases, promoted the enforcement of bylaws to remove two of the main constraints to agroforestry adoption: the setting of uncontrolled fires and free grazing of livestock (Ajayi et al. 2002).

The Landcare movement has benefited from and, in turn, reinforced the Philippine government policy of decentralization and devolution of responsibilities to local government. The local government units (LGUs) are now seen as important partners in local natural resource management initiatives, providing policy support for institutionalizing Landcare and conservation farming practices, training staff, and financing Landcare activities (Catacutan and Duque 2002; Catacutan et al. 2001).

Knowledge, information sharing and learning from successes and failures

The dissemination of knowledge and information about scaling up among stakeholders is necessary for making effective decisions. Monitoring and evaluation systems, both formal and informal, ensure the generation of such information at a range of different scales and from the perspectives of different stakeholders (Cooper and Denning 2000).

In Kenya and Zambia, monitoring and evaluation have been conducted in several different ways. Village workshops enabled researchers to gain an up-front understanding of farmers' assessments and expectations of the technologies they are using. In both Zambia and Kenya, Centre staff and partners engage in collaborative monitoring and evaluation. These studies include economic analyses, impact assessments and assessing factors affecting adoption. The system in both countries is not without problems, not all organizations involved in scaling up participate and some are unable to collect even the minimum data required. But the collaborative mechanism gives partners a greater sense of ownership and buy-in as well as access to more information and feedback (Nanok 2003).

Knowledge sharing and learning are priorities at all three sites. As highlighted earlier, Landcare groups have proved to be an effective vehicle for knowledge sharing in areas of conservation farming and livelihood improvement. This institutional platform for knowledge sharing is especially valuable in heterogeneous biophysical environments and dynamic local economies where farming systems are constantly evolving.

Strategic partnerships and facilitation

When scaling up, partnerships offer high potential benefits. Organizations with complementary strengths, resources and 'reach' can improve the efficiency and effectiveness of scaling up efforts (Cooper and Denning 2000). However, these need to be weighted against such potential risks as high costs in terms of time and resources, compromised impact, and loss of identity (Jacquet de Haveskercke et al. 2003).

Landcare in the Philippines is based on a strategic partnership of farmers, LGUs and technical facilitators (such as ICRAF and government line agencies). These alliances are an important aspect of the Landcare movement as they strengthen the influence of farming communities on policy formulation and resource allocation decisions. One concern is that ICRAF continues to play a seemingly indispensable role in facilitation; more effort is needed to develop local skills, preferably in the community or with NGOs that have a long-term commitment to the local communities.

Conclusions: Research challenges

The review of the three case studies highlights the fact that there is no single recipe for scaling up (Table 1). Different approaches can all be successful, depending on the innovation, the environment and the resources at hand. The key elements contributing to improved impact in the case studies were: taking a farmer-centred research and extension approach; providing a range of technical options; building local institutional capacity; sharing knowledge and information; learning from successes and failures; and creating strategic partnerships and facilitation. Three other elements are important for scaling up: marketing, systems of germplasm production and distribution, and policy options, but the performance of the cases on these was, at best, mixed.

Although the facilitators in the three case studies used many of the same elements, their scaling up strategies were very different. The case of fodder shrubs in Kenya offers the simplest approach, in which a focus on on-farm research and facilitating extension services, NGOs and farmer groups reaped surprisingly high benefits. Certainly the limited scope of the innovation – it being one among several important management practices in the dairy enterprise – prevents certain scaling up approaches from being used.

Table 1. *Agroforestry practices, extension strategy, policy options and institutional innovations promoted in the three scaling up case studies.*

Technology		**Extension strategy**	**Policy options**				**Institutional innovations**		
Type	Origin	Facilitating extension services, NGOs, farmer groups	Engaging local govern-ment in facilitative role	Obtaining local government financing	Lobbying for local policy changes	Lobbying for national policy changes	Capacity building of farmer groups	Facilitating the creation of federations of farmer groups	Promoting consortia of partners
Fodder shrubs, **Kenya**	Researcher- and farmer-led trials	X					X		
Improved fallows, **Zambia**	Researcher- and farmer-led trials	X	X		X		X		X
Natural Vegetative Strips/ Landcare, **the Philippines**	Farmer innovation with research inputs	X	X	X	X	X	X	X	X

Improved fallows in Zambia is an intermediate case, in which a more complex management practice relevant to several enterprises is being scaled up. Facilitators are using several strategies in addition to those used by fodder shrub facilitators, including engaging local government in a facilitative role, lobbying for policy changes, and promoting a network of partners. These have greatly added to the success of the innovation and to its spread across eastern Zambia.

The case of NVS/Landcare in the Philippines presents the most extensive set of innovations, a technical one accompanied by an institutional one. The technical innovation is simple, yet serves as a platform for a multiplicity of other technical innovations and, indeed, a transformation of the farming system. The institutional innovation, Landcare, has had far-reaching ramifications, as federations of farmer groups can wield not only increased economic power but political power as well. In addition to the strategies used by those promoting fodder shrubs and improved fallows, facilitators in the Philippines have obtained local government financing and have facilitated the establishment of federations of groups. Moreover, they have persuaded policy makers to incorporate the Landcare approach into local and national policy.

But as different as the case studies are, they face five similar challenges:

- Articulation of a clear exit strategy, to leave farmers on their own to continue to implement and disseminate the innovations, with limited local backstopping.
- Maintaining the bottom-up, participatory nature of the scaling up process, which contrasts with the top-down approaches of many government services and NGOs.
- Adapting the scaling up innovations and processes from one site or country for use at another site or country.
- Deciding under what circumstances facilitators should seek to scale up technologies, and under what circumstances to scale up the process by which adoption and adaptation have taken place. In other words, is a scaling up strategy applicable only for a particular technology, or can it be used for several innovations, for any type of agricultural innovation or for agriculture in general?
- Making sure that the benefits of scaling up out-weigh the costs. This includes promoting or formalizing farmer-to-farmer information systems, and encouraging farmer organizations such as Landcare to take on some of the functions of these systems

All of the above issues are at least to some extent researchable. For example, careful assessments of the costs and benefits, and advantages and disadvantages of different strategies can be made. Simple planned comparisons of different scaling up mechanisms can be undertaken. Just as learning and knowledge sharing are critical functions in the scaling up of innovations, they are critical for identifying effective and efficient scaling up strategies. Investment in understanding scaling up processes will reap important rewards leading to improved livelihoods of beneficiaries.

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Policy, land management, agriculture, agroforestry, research

Chapter 8

Policies for improved land management in smallholder agriculture: The role for research in agroforestry and natural resource management

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Abstract

This main purpose of this chapter is to identify significant research areas for the World Agroforestry Centre (and other natural resource management research centres) that will contribute to improved policies for land management. To do this, the chapter first describes the nature and extent of land degradation and argues why this is a major policy issue. It then applies a conceptual framework to identify the proximate and underlying causes of land degradation. Special attention is paid to the effect of policies, especially those related to land tenure, soil management, and research and extension. It concludes by reviewing the Centre's experiences in policy research and advocacy and proposing three key areas for intervention in the future: identification of land management problems and opportunities, design of investment/response priorities, and monitoring the impact of policy reforms.

Introduction

It is well documented that smallholder farming areas throughout the developing world are beset by high poverty rates, suffer from low (and sometimes declining) productivity, and have increased occurrences of land degradation. For example, about 50 percent of rural households in India, and about 60 percent of those in sub-Saharan Africa (SSA) are living below the poverty line (World Bank 2000). In fact, in SSA, about 85 percent of the all the poor reside in rural areas (Mwabu and Thorbecke 2001). Some South American and East Asian countries have succeeded in significantly reducing poverty through urban growth, but this is decades away from being feasible in many South Asian countries and almost all African countries (United Nations 2003). Thus, coinciding with the recent heightened attention on poverty and the setting of the Millennium Development Goals (MDGs) (United Nations 2000), there has been renewed debate on how policy reforms can spur investment in smallholder agriculture to increase food security and income. These debates pay particular attention to the impact of such policies on sustainable land management, which is increasingly being recognized as a necessary step along the path towards meeting the MDGs in rural areas.

The major aim of this chapter is to suggest a set of priorities for research into improved land management in smallholder agricultural landscapes, which will potentially inform policy decisions. The section that follows will show why smallholder land management is an issue meriting public policy attention: examining the

[1] The opinions expressed in this chapter are those of the author and not of the World Bank.

extent of land management problems, their proximate and root causes, and their consequences for society. The third section will then examine how past and current policies have contributed to such land management problems. The fourth section of the chapter discusses positive policy reforms that have taken place along with those that require further attention. Finally, the contribution of research to the process of policy reform is discussed, and priorities for natural resource management (NRM) and agroforestry research centres are proposed.

Land degradation as a public policy issue

Extent of land degradation in the world

Many researchers, for example Oldeman et al. (1991), estimate that severe land degradation is already pervasive. Significant damage has been observed in the Balkans, eastern Europe, much of Southeast Asia, the farming areas bordering the Sahara Desert, and the central United States, while there is substantial but patchy degradation in areas of South Asia, eastern and southern Africa, and the eastern Amazon. In their paper, Oldeman et al. estimated that around 25 percent of land in developing countries is degraded, rising to 65 percent when focusing solely on African agricultural land. However, the severity of such large-scale land degradation is contentious. A recent study by Kaiser (2004) for example, supported by Wiebe (2003), has tempered some of the earlier alarming national and global rates of soil loss. What can be said is that land degradation is found throughout the world, but it is a more complex problem in developing countries where it tends to reinforce and be reinforced by poverty.

Why land degradation is a public policy issue

The vast extent of degradation indicates that it is a major problem, but does not by itself imply that it is a public policy issue. However, there are complementary reasons that clearly make it a policy issue of importance at local, national, regional, and global scales. Firstly, there are significant social costs and benefits (externalities) associated with bad and good land management (for example, more dust or carbon sequestration respectively). Externalities can have local/regional effects, such as the sedimentation of Lake Victoria from degraded upland agricultural communities, or global impacts, such as dust clouds moving from the desertified Sahel to North America. Secondly, poverty reduction and food security are the major goals of most developing-country governments, and the poor are overwhelmingly rural. Helping the poor, which is a public policy issue, therefore must involve some attention to the land resource. This is important for overall economic growth as well as for equity considerations. Finally, future generations have rights to a viable soil resource and governments, as ‘custodians’ of the land (and, indeed, as owners of much of it), have an obligation to ensure that this happens.

Reasons for land degradation in smallholder farming systems

There are some causes of land degradation that are either not possible to prevent or are too costly to prevent at farm or landscape scales. These include climatic catastrophes such as major storms that bring forth massive rain and wind erosion, environmentally induced droughts, fires, major pests or diseases that destroy vegetative cover, and human-induced or perpetuated degradation such as massive health calamities or wars.

But many other types of degradation can be prevented or at least mitigated through land management. Under similar physical and climatic conditions, some communities are found to manage their land resources much better than their neighbours (see Pretty 1995 for a number of examples). Likewise, within the same village location, some farms will have intact soils while others exhibit considerable types of erosion. So what explains the differences in land degradation or, more specifically, why are large areas of lands not being invested in and managed sustainably?

In their 1994 paper, Scherr and Hazell offered six main reasons why smallholder farmers may not invest in NRM or adopt NRM technologies. These reasons are listed in a similar order to a decision-making process, from first consideration to last:

1. Lack of recognition of a natural resource problem
2. Lack of importance of the natural resource or its problem
3. Lack of willingness to invest in the resource
4. Lack of capacity to invest in the resource
5. Lack of economic and other incentives to invest in the resource
6. Lack of information and support services that are necessary to implement investments.

We will now briefly discuss these reasons specifically in terms of land management by smallholders (although these reasons are also quite valid when considering collective management of landscapes).

Lack of recognition of a natural resource problem. Resource degradation processes, such as nutrient leaching or more subtle sheet erosion of topsoil, are not always easy to detect. Even if productivity shows signs of weakening, a farmer may not attribute this to eroded resources. In other cases, a farmer may realize that the resource base is declining in quality, but it does not yet have a measurable impact on productivity. So, for example, cumulative sheet erosion may be taking place, but not be posing a 'problem' on deeper soils.

Lack of importance of the natural resource or its problem. There are several reasons why smallholders who can observe a natural resource problem may feel that it is unimportant. Firstly, it may be occurring in a small or insignificant area, such as a remote corner of the farm. Secondly, even though the magnitude may be significant, a rural household may place more attention on livelihoods that do not depend on the degrading resource, for example, if the household derives more of its income from services, processing, or wage employment, its priorities for investment will not be on farming natural resources. Thirdly, lack of appreciation of the natural resource or problem may be due to a lack of awareness or education, or due to historical or cultural factors. For example, immigrants may not attach a high value to tree resources because they lack awareness of their potential values.

Lack of willingness to invest in the resource. Willingness does not refer to capacity, but rather one's interest in investing. This hinges significantly on smallholders' property rights and time horizons. For example, if a farmer cannot gain long-term rights to land, there is little incentive to make investments in that land, irrespective of the potential effectiveness of the investment. Furthermore, households that rent land, or female farmers who do not control the benefits from investments they make, are also unlikely to be willing to invest time and effort on improvements. In terms of time, some smallholders may have very short time horizons because of high risk aversion or extreme poverty, and in such cases will not even consider a number of types of investments. In particular, the discount rates of the poor are very high due to immediate survival needs; they therefore steeply discount benefits that may accrue from long-term investment.

Lack of capacity to invest in the resource. Some households may recognize a problem and have the potential to benefit from investments to solve it, but simply cannot assemble the resources required to make the investment. Setting aside land for permanent cover or long fallows is not attractive to households with very small farms. Often, labour shortages prevent significant soil and water conservation investments from being undertaken, especially in areas ravaged by malaria or HIV/AIDS. But perhaps the most serious constraint is lack of financial capital, since in theory households with cash can obtain labour or other resources needed for investment.

Lack of incentives to invest in the resource. In this situation, farmers may have access to the resources required to make investments in natural resources, but the payoff from doing so appears to be unattractive. This can be a result of the (in)effectiveness of the investment. For instance, few profitable investments may be available in the more arid or sandy environments. But incentives are also highly related to prices, access to inputs and markets for outputs. Where output markets are lacking, farmers are discouraged from purchasing inputs. Even where markets exist, in many areas of rural Africa the ratio of farmgate input costs to output prices is so high as to discourage all but the minimum of investment.

Lack of information and support services to implement investments. While some types of investments are straightforward, others may require a degree of technical knowledge. Without basic training, farmers may not fully understand how and why certain types of investments will work. Likewise, some types of investment require materials (e.g. shovels or seedling pouches) that may not normally be available locally. More significant public investment to support improved land management is clearly vital for impoverished rural areas so that this type of vicious circle of poverty and land degradation can be broken.

Many of these circumstances may be felt at the household level, but are actually affected by larger-scale cultural, economic and political factors. Some of these are:

- lack of crop/agriculture insurance to protect against climatic risk;
- almost complete absence of rural credit systems;
- weak healthcare systems, including low availability of medicines;
- weak extension systems in terms of personnel, transportation and motivation;
- poor infrastructure and markets leading to unattractive prices for outputs and inputs; and
- poor or non-existent rights to land for women, migrants, settler communities on state land and in a variety of other situations.

Some of these large-scale factors stem from market or even social failures, but all of them are driven by policy and are therefore also policy failures.

Policy factors contributing to poor smallholder land management

In this section, we explore in more detail some of the policy problems related directly to land management and needed reforms. This list is not exhaustive, but does reflect the priorities noted by several other recent authors (Dorward et al. 2004; Hazell and Johnson 2002; Lee et al. 2001). We also recognize that in fact there have been positive reforms undertaken in many sectors that support smallholder agriculture in general and land management in particular, for example, policies with a focus on poverty, decentralization and new land legislation.

Enabling incentives for the agricultural sector

It goes without saying that incentives provided to rural communities and agriculture are critical in promoting improved land management. Policy incentives can cover such areas as market, pricing, infrastructure and credit. In some cases, even with growing pressure on resources, getting these policies right can lead to improved land management (this has been the case in Machakos, Kenya, for instance). However, in many cases, merely putting well-intentioned broad policies in place is not sufficient to ensure sustainable land management, as witnessed by low nutrient inputs throughout much of Africa. While acknowledging the importance of these enabling policies, we do not discuss them in detail, instead devoting more time to specific land management policy issues. Readers may refer to the studies noted in the introduction to this section for more information.

Land tenure policy

There is no disagreement that property rights are important in shaping incentives for investment, management, mortgaging and transacting in land (for investment in soil management, see Prudencio 1993, and Manyong and Houndekon 2000 for examples). There is no property rights system that is ideal for all circumstances, but there are many recognizable faults with some existing systems (see Deininger 2003 for a good summary). Some policy problems are an effect of unresolved struggles for authority between formal and informal tenure institutions (e.g. state versus chiefdoms in areas of western and southern Africa), or they may be caused by excessive state control over land and other resources (e.g. in Ethiopia, Indonesia and the Philippines), or overlapping or conflicting tenure administration across ministries (of lands, agriculture, natural resources, and so on). These situations contribute to poor formulation and implementation of tenure policies that can particularly affect the property rights of women and migrants (or in some case indigenous peoples). Each of these factors may have considerable impact on NRM. By increasing the uncertainty over any individual or group's claims to the benefits generated by the application of resources, these tenure problems reduce incentives for investment and management of natural resources.

While in many areas, indigenous tenure systems offer sufficient incentives for investment in land management, there remain some stubborn problems to resolve. As a general principle, the clearer the policies are (i.e. no overlapping inconsistencies or gaps), the better, all else being equal. Furthermore, there needs to be functional and fair property rights enforcement mechanisms in place to back up those policies. This calls for local services and for local and national administration to be linked. For the specific tenure problems that exist, transparent resolution processes need to be developed, substantiated by scientific information about the desirability of any specific new tenure arrangement.

One lesson that has been learned from recent reforms is that national policy alone will not necessarily lead to tenure change on the ground (for example, with respect to women's rights; Razawi 2003). Such change also requires interventions on a local scale, which may include policies but will also need such institutional reforms as a fairer judicial system and technological interventions such as practices that women will use. Also because tenure systems and tenure security respond to driving forces, indirect policies (e.g. on market liberalization) may lead to desired tenure changes in tenure institutions.

Land/soil management policy

Land management policy is often the amalgamation of dozens of laws and hundreds of regulations, established by several different ministries and possibly two or more administration levels. This may be unavoidable to some extent, yet the result is usually conflicting policies resulting in a lack of clarity at government level and certainly at the level of land manager. Most countries are attempting to consolidate policy making by forming Environmental Management Authorities, but they have not been given ample resources to tackle this colossal mandate. Indeed, the natural resources sector is often underfunded and must depend largely on externally funded projects.

It is unfortunate that policies concerning development and welfare goals are often detached from those focusing on conservation and the environment. This is evident in the significant lack of attention that is paid to land and soil management in the poverty reduction strategy papers (PRSPs) of African nations, such as Burkina Faso, the Democratic Republic of Congo, Kenya, Mozambique, Niger, Tanzania and Zambia.

To see how this lack of clarity affects land management, we can take the example of agroforestry. Land and tree property rights, which affect agroforestry investment incentives, are influenced to some degree by ministries of forestry, agriculture, lands, energy and water. In addition, in many countries, there is insufficient distinction between trees on farms and those in forests. Rules and laws are thus made to apply to all trees, and logging bans and protected species regulations have unintended disincentives for farmers to plant and manage the trees on their farms. Agricultural extension staff are increasingly active in promoting agroforestry enterprises for farmers, but tree seed is still mainly in the domain of forest departments. At the same time, forest departments do not have enough staff to interact sufficiently with farmers. So development programmes continue to struggle to build sustainable agroforestry systems.

Thus, the profile of land management needs to be raised, and new or existing institutions should become focal points or coordination units for land and soil. They would be responsible for assembling databases on soils, monitoring changes in land resources and championing improved land management practices to practitioners and policy units. There are many areas that require attention; here we discuss in more detail some policy reforms that could contribute to improved soil nutrient management by smallholder farmers.

Most countries' policies on sources and management of nutrients require attention. The starting point is generally fertilizer prices; in a country where markets and infrastructure function well, the ratio of input to output prices at the farm is sufficiently low to attract high demand and use of fertilizer. However, in much of the developing world these conditions are not met. To encourage the use of fertilizer, governments can try to alter the ratio (e.g. to entice farmers to cultivate higher-value crops) or try to directly influence prices (e.g. by subsidizing fertilizers). Fertilizer subsidization has been tried in the majority of countries, and remains in place in a few. In countries such as China and India fertilizer application rates are very high – even greater than those in some developed countries (FAO 2004), leading to environmental and human health concerns. Several governments that discontinued subsidies are considering other options to make fertilizers more attractive to farmers. Some, such as the governments of Malawi and Zambia, have embarked on limited subsidy programmes that are designed to be small starter kits or targeted to the poor. In other countries, such as Kenya, fertilizer import taxes have been lowered and competition encouraged so that there are now many large importers, which reduces profit margins at the importer level (Jayne et al. 2003). None of these policies by themselves will lead to desirable levels of fertilizer use because there are still high poverty rates coupled with poor rural credit availability. Thus, the exploration of other nutrient sources becomes important.

Organic sources of nutrients are gaining recognition as not only feasible and appropriate, but necessary in certain situations (Palm et al. 1997; Place et al. 2003). Crop–livestock farms are common throughout the smallholder sectors of developing countries, but little of the manure produced is used as an input to crop production because of lack of knowledge, lack of labour, use of manure for energy, and grazing systems that do not favour the concentration of manure near the farms. More attention needs to be paid to manure management and application as well as to the development of manure markets. In terms of plants, a number of herbaceous and woody legumes have been found to produce large amounts of organic matter and certain elements such as nitrogen. Moreover, they are cheap to establish and therefore attractive to the poor. However, policy makers continue to be unaware of these systems and thus have not made them part of mainstream development programmes. In places, such as most of sub-Saharan Africa, where multiple constraints to land investment exist at community and household levels it is likely that over the next 10–20 years the use of nutrients from all sources – mineral fertilizers, animal manure and green biomass – will become even more important.

Research and extension policy

Sound agricultural and natural resource research systems have emerged in Brazil, China, and India and in some of the other emerging nations of Asia and South America, but remain weak elsewhere. The reasons for weak systems are manifold and include under-appreciation and neglect by government, insufficient external funding, poor and rigid management, and low staff motivation. Another criticism of research systems, especially in Africa, is that they do not integrate well with extension systems. But sometimes it is the extension systems themselves that come under intensive scrutiny (World Bank 2003). Disseminating new information or fostering innovative processes through technical support are major challenges in rural areas of developing countries and are exacerbated by poor communication infrastructure, multiplicity of languages and high levels of illiteracy. The poorer countries have been unable to sustain investment in extension systems leading to failures and calls for change.

Until recently, national research programmes tended to be organized around commodity sectors, which hampered integrated research into land management issues. Now national research organizations need to attract funds to fulfil their new mandates in natural resources and land management research. The current orthodoxy is that for such research to be successful, it should embrace the following guidelines: be demand-driven through participatory research, be interdisciplinary in approach, be market-oriented, and help integrate technologies, institutions and policies. In doing so it will be able to offer farming communities a range of land management options that can overcome constraints and generate sustainable productivity increases. Governments, including those in developing countries, need to make long-term commitments to research funding, and must ensure that research results are better integrated into national policies and programmes. The experiences of Brazil, China and India are a testament to the extraordinary achievements that can result from making strong commitments to research, and these impacts are being felt around the world.

Extension systems must become more flexible in their approaches; farmers are increasingly demanding information on market opportunities and processing techniques in addition to their typical production questions. Agents or facilitators must have much larger information networks and must have adequate resources to access the information and then transmit it to clients. Farmers also demand different levels of service provision, from simple message transmission to more sustained technical support. To improve land management, it is necessary to promote knowledge-intensive practices such as integrated nutrient management as well as more simple transmission of information on output prices in different markets. Some signs of this are occurring, for example, participatory rural appraisal is becoming mainstream, but financial resources are often the binding constraints. There have also been attempts to reduce national governments' share of costs and to move towards a fee-for-service system, but the feasibility of this for poor smallholder farmers is a major concern. How to implement these concepts in practice has remained elusive for the most part.

The role of research in shaping land management policy reforms

Contributions by ICRAF and its partners in policy reform processes

Although the Centre has not emphasized a policy research programme, it has had modest success in contributing to positive policy change. One of the key policy areas in which the Centre has undertaken a significant amount of research is land and tree tenure in Africa and Asia (Fay et al. 1998; Otsuka and Place 2001; Place 1995; Tomich et al. 1997; Traore and van Dorp 2004). This has helped to generate knowledge on the effects of different tenure arrangements on NRM, and has led to several local tenure changes in Africa, the development of a pilot tenure reform in Indonesia (Tomich et al. 1998), and the provision of technical advice to global tenure reform processes (e.g. presentations at World Bank and UN-Economic Commission for Africa workshops on tenure issues for Africa).

ICRAF and its partners (national agricultural research institutes and universities) have undertaken a large number of studies related to understanding farmers' NRM decision-making processes and outcomes. This has also taken place throughout Africa and Asia and has helped to identify major constraints and opportunities on which new policies and programmes can be based (Barrett et al. 2002). These have been published in several different media, including policy briefs, and have found their way into some of the major development initiatives from the United Nations Millennium Project and the World Bank.

Apart from policy research per se, the Centre has invested significant effort into seeing that its broader research results reach policy makers. The Centre has helped to bring the concept of agroforestry into mainstream policy documents, research programmes, extension services and development projects. Examples include: the formation of agroforestry research programmes in many African national research institutions, where previously they did not exist; the creation of agroforestry curricula in more than a hundred universities and colleges throughout the developing world; generation of national agroforestry strategies and networks in some countries; the explicit mention of agroforestry in increasing numbers of global and national policy documents; and contribution to specific major policy and programmatic initiatives such as the New Partnership for Africa's Development (NEPAD) agricultural strategy (NEPAD 2003), the World Bank's Soil Fertility Initiative and the UN's Hunger Task Force strategy to reduce hunger in Africa.

Supporting future policy reforms

There are three major areas where research from an international organization such as the Centre can best support policy debates and reforms and improve smallholder land management.

1. Identification of land management problems and opportunities. This involves the understanding of how biophysical problems of land degradation vary and how they interact with poverty, policy and other drivers and incentives. Research work must therefore analyse not only land management problems but also the underlying policy and incentive structures that shape land management. In essence, this research will identify priority areas for intervention based on the significance of problems and opportunities for rehabilitation or enrichment. The Centre is well placed to do this since it can draw upon research from a range of settings.

2. Design of investment/response priorities. Research should identify the investments – in technological, institutional and policy reforms and programmes – that will lead to the greatest impact in sustainable land management for poverty reduction. Some of the crucial areas of research will be: synthesizing lessons learned from around the world; analysing trade-offs and synergies of different interventions or sets of interventions; identifying entry points or sequencing patterns of investments; and analysing alternative implementation strategies. It will be particularly important to assess interventions comprehensively in terms of their social, economic and environmental implications as well as implications at different spatial and temporal scales.

3. Monitoring the impact of policy reforms. This will involve collaboration with policy makers in the pilot testing of land management policy and programme reforms and the monitoring and assessment of these interventions. Governments of developing countries are generally weak in the area of monitoring, while an international centre is in a good position to develop comparative studies of reforms and other interventions across countries. Such studies will not only evaluate specific interventions in certain countries but should also be able to understand the factors associated with how successful an intervention is, and to identify beneficial modifications to reforms or interventions.

These are very broad research areas; the Centre will need to focus on areas connected to agroforestry or, more broadly, to natural resources in an agro-ecosystem. Building on strengths, the Centre should continue to give emphasis to issues such as: germplasm supply; property rights (including intellectual property rights); community and watershed management and regulation; the interactions between poor communities and farmers on the one hand and land management and degradation on the other, especially among the poor; research and extension; markets; commercialization; NRM; and the potential for promoting environmental services and improved land management in smallholder communities.

In order to have impact in these areas, the Centre will need to be active in two ways. Firstly, it should directly participate in research and advocacy activities in high-priority areas where it may generate global public goods. It will be most effective when attempting to learn or disseminate lessons across regions and countries, given its global position. Secondly, the Centre should be a champion for promoting policy research and dissemination on issues that are vital for improving land management. This will involve public awareness, such as the dissemination of technological success stories and presentations at key national and international fora. It will also require capacity building of research and advocacy groups so that they may integrate agroforestry issues into their own agendas. Clearly, the latter approach is going to be more critical in having policy impact in a large number of countries so that more and more smallholders might be able to benefit from improved land management.

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Chapter 9

Land and People: Working Group Report

After some discussion, four working groups were formed to brainstorm over priorities for the Land and People research and development agenda in the coming years. The four groups corresponded to the topics of the presentations: land and soil management, land management policy, scaling up of agroforestry interventions, and the scientific challenges for the Centre presented in Chapter 5.

Working group on land and soil management

This group identified two primary topics under land and soil management where it felt ICRAF should significantly increase its role. The first is to develop relevant and useful land-quality indicators. Within this, it was recognized that much research had already been undertaken that demonstrated the critical role of organic carbon (C) in soil fertility processes. However, more work should be done to understand the links between organic C and soil-quality indicators. Furthermore, soil biology databases and the links between different soil biota and soil fertility require strengthening. This work needs to be conducted within a strategic framework with the landscape as a key unit of research, which could have the additional result of describing land capability classes that can guide decisions about future land-cover dynamics.

The second area on which the Centre should concentrate is the greater application of geographic information systems (GIS) and remote-sensing tools. These can guide priority setting for research on agroforestry technologies for improved land management, assist the Centre in moving innovations to scale and allow the organization to identify strategic sites for testing that exhibit different soil problems. GIS can also be useful in informing current development efforts. In terms of geographical emphasis, the working group felt that there was a need for ICRAF to pay greater attention to the semi-arid and arid lands, where degradation and poverty hotspots occur.

Achievement in these two areas should produce ‘international public goods’, in particular publicly available information that can be efficiently stored in databases on soils and used in decision-support guides on technological options for different problem areas.

The working group identified three key roles for ICRAF in this research:

- contribute to better diagnosis of problems, and identify entry points for agroforestry;
- build capacity and develop human resources (including in civil society and for smallholder farmers); and
- produce research and development outputs in accordance with the Centre’s comparative advantage.

Working group on policy

This working group spent considerable time taking into account the internal processes under which policy research is identified and implemented at the Centre. The group felt that more discussion is needed to answer the following: How are policy research topics selected? What is the priority-setting process? Is this process based on existing global or national strategies or policy documents?

The working group concluded that the manner in which policy research themes and directions are selected at ICRAF needs to be more transparent and rigorous.

With regards to the output of policy research, there was considerable discussion within the group about whether it was preferable to focus on developing a process or a product. Some experiences show that leading with process work can have more of an effect and creates its own demands for specific research products. This approach should be considered throughout the institution. The next question was whether the Centre should therefore be proactive in shaping policy processes and agendas. The group felt that building up farmer representative groups as a voice for defining and lobbying for priority policy agendas would enable the organization to make better decisions.

The group also recommended that ICRAF gives due attention to the administrative level and position of the policy makers with whom it interacts. Although the organization is in the process of learning about appropriate levels of engagement, from local to international, nevertheless it is important to be aware that specific policy problems often require specific types of decision makers. The Centre can help to bring policy makers from different sectors and scales together with researchers to debate policy issues. Even here, there are many options and pathways to choose from. Therefore, it is important to spend more effort on identifying the policy makers with whom ICRAF wishes to influence and interact, what these policy-makers need, and how to communicate effectively with them.

Working group on scaling up, adoption and impact – reaching the vulnerable groups

This working group discussed lessons from its experiences both at the Centre and in other organizations. The group recognized that scaling up should not take a broad-brush approach. The critical, vulnerable groups should be identified and targeted, and different approaches are needed for each one. Reaching the most-vulnerable people can be difficult; some studies have found that they are less likely to belong to easily identifiable groups in villages. So is it possible to reach such solitary farmers? GIS tools and maps that have advanced our ability to target technologies to specific agroclimatic conditions may be useful in identifying these socioeconomic variables and targeting vulnerable groups.

Not only should scaling up efforts be targeted to particular groups, different situations require different approaches. And not all situations require elaborate scaling up mechanisms: the group noted that some technologies ‘sell themselves’ and undergo rapid spontaneous diffusion. Therefore, one lesson to learn is that we need to ensure that all new technologies work well in the eyes of the farmers.

The group agreed that ICRAF should invest more resources in learning from experiences of scaling up, especially those that involved different situations and technologies. Certain questions need to be answered: What are the widely applicable methods and lessons for dissemination processes? What is known about successful extension materials? How can cadres of local people be persuaded to share their experiences? Institutionalization of lessons is also important, to ‘cement them in’ and enable them to be built upon. Therefore, what are the best ways to take such lessons into mainstream extension, education and policy?

The diffusion of new innovations/modifications is a complicated process that faces many challenges. However, it can be strengthened by better horizontal and vertical feedback systems that spread information about innovations. This will also help to prevent negative consequences, such as where new information becomes diluted during the diffusion processes and leads to undesirable management practices.

For adoption and impact of new technologies, researchers need to look at a range of indicators that relate to poverty. This is because some indicators move slowly, while others may not show a significant effect from only one agroforestry improvement. This problem is exacerbated by a lack of understanding of the key drivers of adoption. More attention should be paid to studies of mature technologies. One particular research gap the group identified was how adoption of various practices is affected by human health.

An even weightier question the working group discussed was the balance between reach and impact. Is it better for ICRAF to try and reach a large number of farmers with little impact or fewer farmers but with larger impacts? For example, should it aim for broad productivity impacts or should it try to invest more in targeting the poor and vulnerable? The group agreed that the Centre has started on the right track by forming partnerships, but that it does not yet have all the right ones (i.e. improvements could be made in partnerships for research, education and development) and there is still too much fragmentation.

Finally the group concluded with a brainstorming session of what it considers to be possible international public goods outputs in the area of scaling up:

- methods that analyse scaling up experiences and which could be applied by partners;

- scaling up approaches that could be applied to many situations over wider scales;
- strategies for testing of unfinished technologies with farmers to fine tune their application;
- use and integration of high-level scientific approaches such as GIS and biotechnology;
- building capacity among national research and development organizations to enable ICRAF to effect exit strategies; and
- identification of the Centre's comparative advantage in dynamic research and development environment.

Working group on Mike Swift's challenges

The working group addressed many of the challenges presented in the opening session on Land and People which was led by Mike Swift, eminent soil scientist and former Director of the Tropical Soil Biology and Fertility Programme. Here is a list of the challenges followed by the responses of the working group that were more of a reflective brainstorm about the challenges.

What are the key determinants of the adaptive and adoptive advantages of the available technological options? What works, where do they work, when do they work, and for whom do they work?

- There is a need to be able to better predict the performances of different technical options under different conditions Explore whether the creation of target-zone domains for various options based on biophysical and socio-economic conditions is practical and beneficial.
- Test options across varying conditions so that limits of the options are known.
- Conduct risk analysis for various options.

What are the main questions arising from the interactions in the chain that goes from resource management to system intensification to market access to policy?

- Our analysis of natural resource management (NRM) programmes should start with determining what markets exist for goods and services in an area and this will drive our research agenda.
- Our approaches should take a holistic yet incremental approach (covering markets, policies, institutions and so on).
- Based on one aspect of a very complex problem, try to look at an integrated model of the situation and work in a multidisciplinary team.

What are the rules governing transitions across spatial scales (for example, how nutrient cycling processes or biodiversity-function linkages differ at plot, farm and landscape scales)?

- Be aware of the spatial scale of the work in both biophysical and socioeconomic research and be able to better link research that takes place at different scales.
- Some of the work within the Centre does deal with issues at various scales – this is very innovative science. These interactions and transitions are complex, which makes ICRAF's work in this area complex compared to research on crops. However this work has practical payoffs and should be continued, despite the difficulties.

What are the trade-offs between the storage of organic matter in the soil and its use to drive nutrient cycling, crop production and other ecosystem services?

- Much is known about nitrogen (N) and its role in crop production.
- We need to go beyond N and study other nutrients, issues such as soil acidity, and environmental services, and link this with price, policies, farmers' needs and the resilience of agroecosystems. This is an area that is largely unexplored.

How can the functions of the soil biological community be optimized with respect to different ecosystem services?

- Functional biodiversity (as opposed to species richness) is the key issue in relation to various ecosystem services as well as such issues as soil health, soil macrofauna, soil microbes, and soil physical properties.
- These components/systems need to be studied in relation to agroecosystem stability, productivity, and resilience of systems.
- This type of research should be pursued vigorously over the next 5 years.

Enhancing Environmental Services

"Forest conservation is no longer seen as the only appropriate means to achieve environmental conservation, nor is afforestation seen as the only way to reverse environmental damage."

Swallow et al.

Keywords:
Property rights, land tenure, buffer zones, forest classification, payments for environmental services, Africa, Asia

Chapter 10

Agroforestry and environmental governance

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Abstract

Environmental governance is in a state of change throughout the developing world. Power and authority are shifting from national offices to global and regional fora and to local user groups. Regulatory approaches to environmental management are gradually being augmented by incentive- and market-based approaches. Private organizations and firms are becoming more involved in the provision of such environmental goods as water, energy and timber, and environmental services like conservation and watershed protection. Forest conservation is no longer seen as the only appropriate means to achieve environmental conservationm, nor is afforestation seen as the only way to reverse environmental damage. Integrated approaches to ecosystem and landscape management, which include local residents as important partners, are being given more emphasis. These trends are creating new opportunities and constraints for agroforestry. While there are very few pieces of legislation or rural institutions that focus solely on agroforestry, there are many laws and rural institutions that shape farmers' incentives to plant and manage trees in their agricultural landscapes. This chapter reviews the five policy issues that have greatest impact on agroforestry: land and tree tenure, forest classification, biodiversity and forest conservation, environmental service reward mechanisms, and global environmental governance. Targeted applied research and engagement in local policy processes increases the beneficial impacts of agroforestry development within local policy terrains and contributes to policy reform at the national and global levels.

Introduction

Environmental governance – including all policies and institutions affecting the state of the environment – is in a state of change throughout the developing world, with significant consequences for on-farm tree planting and management. Changes are occurring in several dimensions. Formal authority is shifting from national forestry agencies to decentralized multistakeholder committees and local user groups. Rules and prohibitions are gradually being augmented by incentive- and market-based approaches to environmental management. Private firms are becoming more involved in the provision of such environmental goods as water, energy and timber and environmental services like biodiversity conservation and watershed protection. Integrated approaches to ecosystem and landscape management, which include local residents as important partners, are being given more emphasis in international agreements and the programmes of influential international organizations (Tomich et al. 2004).

While few developing countries have specific laws or policies on agroforestry, a range of environment and development policies and structures of administration and governance affect the practice. Here we follow the Leakey (1996) definition of agroforestry as a "dynamic, ecologically-based, natural resource management system that, through the integration of trees on farms and in the landscape, diversifies and sustains production for increased social, economic and ecological benefits". This definition has three direct implications for governance. First, agroforestry involves the deliberate management of trees, including tree planting and various intensities of farmer management of trees in multiple function landscapes. Second, it depicts agroforestry as a natural resource management system that includes land use practices and the institutions (including rules, regulations and norms) that shape those land use practices. Third, the definition explicitly recognizes agroforestry as a land-use system practiced at the farm and landscape scales. Institutions and policies that govern land use and environmental management at those scales will affect farmers' incentives to plant and manage trees.

At the farm scale, the most important institutional arrangement affecting agroforestry is property rights. Property rights to land and trees on farms shape farmers' expectations of whether and how they will be able to appropriate long-term benefits from investing in tree management and planting. Property rights are also important at the landscape scale since property rights regimes (state, common or open access) governing tree resources outside of individual farms affect the use of those resources and the incentives for farmers to plant trees on farm. One of the key determinants of property rights to trees outside of private farms is the system of forest classification and governance. State systems of forest governance generally reflect a combination of state control of valuable forest resources and concern for the public interest in the environmental services that they provide.

As property rights and forest governance systems have evolved over the last two decades, other governance arrangements have become important. The focus of biodiversity conservation has widened from looking solely at protected areas to including their boundaries and the surrounding landscape. Agroforestry is recognized as having unfulfilled potential to contribute to biodiversity conservation at the landscape scale. Environmental service reward mechanisms are being explored in some locations, with agroforestry often seen as a desirable land use from the perspective of biodiversity conservation, carbon sequestration, renewable energy production and reversal of land degradation. The growing importance of global environmental agreements is increasing motivation for some of these environmental service mechanisms. The widespread implementation and national 'domestication' of global environmental agreements provides a mix of opportunities for and constraints to agroforestry.

This chapter reviews evidence concerning links between agroforestry and the five components of environmental governance described in the previous two paragraphs: i) property rights to land and trees; ii) land classification; iii) biodiversity and forest conservation; iv) environmental service reward mechanisms; and v) global environmental governance. Table 1 summarizes information on the links between each of these components and agroforestry.

The World Agroforestry Centre (ICRAF) works with a range of partners to implement a three-pronged approach to address these policy challenges. Firstly, we seek to enhance understanding of the links between agroforestry, forestry, protected area management and social objectives related to the environment. In some cases, the results challenge conventional wisdom and conventional approaches to environmental management. Widespread dissemination of key principles and empirical findings is achieved through scientific publications and engagement in local, national and international policy fora. Secondly, we seek to broaden understanding of how policies and institutions affect the incentives of farmers to manage and plant trees in high-priority situations. Commonalities and contrasts tend to emerge across research sites, implying that there are no universal policy solutions. Thirdly, in high-priority situations we work with policy makers and policy shapers to promote reform or effective implementation of policies and regulations that have high impact on the effectiveness of agroforestry. The following sections summarize links to agroforestry, relevant research findings and policy impacts for the five components described in Table 1.

Property rights to land and trees

A large body of literature on the relationships between property rights and tree management has grown up during the 25 years since the Centre was founded. While economic theory indicates straightforward relationships between tree planting and land tenure security, the evidence indicates complex interrelationships between management of natural vegetation, tree planting, perceptions of land and tree tenure security, gender relations and the operations of customary and formal tenure arrangements. Uncovering the more complex relations requires research approaches that draw upon institutional economics, social and economic theories of innovation

Table 1. Characterization of the links between five components of environmental governance and agroforestry.

	Relation to farmer incentive to deliberately manage trees	Location of policy making relative to farmer	Trends in policy and governance context
Property rights to land and trees	Farmer assurance of future benefits from current investments; farmer incentive to obtain tree products on own farm or elsewhere in the landscape	Local norms; decentralized government agencies; national policies	Gradual individualization; decentralized state agencies generally becoming more important
Forest classification and governance	Farmer incentive to obtain tree products from forest areas; farmer incentive to manage and protect nearby forests	Decentralized forest agencies; national forest agencies	Decentralization of state agencies; some movement away from command and control approach
Buffer zone and landscape approaches to conservation	Incentives/disincentives to manage trees near protected areas; types of trees allowed and encouraged in different parts of the landscape	Decentralized conservation/forest agencies; national forest agencies; international conservation pressures	Mixed success with integrated conservation and development projects; landscape approaches still largely experimental
Environmental service mechanisms	Most environmental service mechanisms involve tree and vegetation management by individual farmers, groups and/or local governments	Regional dialogue for watershed services; national policies and international mechanisms for biodiversity and carbon	Becoming part of government approaches in many countries in Latin America; small experiments in other regions
Global environmental governance	UNFCCC[1], UNCBD[2], UNCCD[3] and GEF[4] all have significant forestry components, with inadequate provision for smallholder agroforestry; no specific forestry convention since the Rio conference in 1992	National ratification and domestication of global agreements and funding opportunities	UNFCCC has progressed furthest in explicitly considering potential of agroforestry and smallholders

Source: Authors' summary from this chapter and literature review.
[1] United Nations Framework Convention on Climate Change
[2] United Nations Convention on Biological Diversity
[3] United Nations Convention on Combating Desertification
[4] Global Environment Facility

and collective action, and a variety of quantitative and qualitative research tools. Much of this research has been conducted in association with the Collective Action and Property Rights Initiative of the Consultative Group on International Agricultural Research (CGIAR) (Meinzen-Dick et al. 2002).

In the 1980s and early 1990s, much of the evidence on the links between agroforestry and property rights in Africa emerged from joint efforts by ICRAF and the Land Tenure Centre at the University of Wisconsin–Madison (Bruce 1989; Fortmann 1985; Fortmann and Bruce 1988; Place 1995 and Raintree 1987). Bruce (1989) summarizes the results of these studies by noting that agroforestry projects may be associated with several problems of land and tree tenure. Firstly, a project may disturb or destroy rights to other important uses of the land or trees. Secondly, customary tenure systems that provide multiple uses of land and tree resources may make it difficult for individual farmers to protect tree seedlings. Thirdly, some categories of intended clients may be unable to participate in a project because they do not have the right to plant or own trees. This includes landless people and women in some societies. Fourthly, farmers may undertake tree planting as much to establish rights to land as for the direct products of the trees.

In the mid-1990s, ICRAF, the International Food Policy Research Institute (IFPRI) and Tokyo Metropolitan University engaged national partners from across Asia and Africa in studies of the effects of land tenure on tree management at the farm and community scales (Otsuka and Place 2001; Suyanto et al. 2001). Several important results have emerged from these and other similar recent studies. Firstly, most customary land rights systems provide sufficient tenure security to encourage deliberate tree management in at least some land use niches (although some state-imposed tenure systems have actively discouraged tree management or created de facto open access situations that encourage overuse and under-investment in long-term tree management). Secondly, land tenure security, tree planting and management of natural vegetation are interdependent in many customary societies in Asia and Africa. Because both clearance of natural vegetation and tree planting are markers of land improvement, it is possible to observe both reduced and increased tree cover as land rights become more individualized (Place and Otsuka 2002; Suyanto et al. 2001). Unruh (2002), for example, describes the importance of cashew trees for marking land claims in post-conflict Mozambique. Thirdly, many African and Asian societies and national governments have property rights systems biased against women planting and managing long-term agroforestry investments such as timber trees and woodlots (e.g. Fortmann 1998). Even in such systems, however, women are often able to benefit directly from short-term agroforestry investments such as improved fallows (Gladwin et al. 2002), processing and marketing interventions that add value to agroforestry products and intra-family allocation mechanisms that distribute the benefits and costs of longer-term investments. Agroforestry interventions targeted to particular niches of land controlled by women, such as home gardens, may be adopted in the short term, but in the long term may encourage men to try to wrest control of such lands (Schroeder 1999).

Property rights to land and trees have a large impact on farm tree management in the Lampung province of Sumatra, Indonesia. Suyanto et al. (2005) found that areas designated as protected forests had more frequent and devastating fires during the Suharto era than in the years since 1998, when the regime fell, implying that there now is less deliberate use of fire as a weapon to claim property rights. Fay and Michon (2003) describe part of the political motives and ideology underlying government expropriation of large areas of land previously used by individual families and governed by indigenous ethnic groups. Fortunately, the greater political freedom ('reformasi') and decentralization that have developed since the fall of the Suharto regime have created opportunities for enhancing farmers' tenure security and revitalizing customary institutions. ICRAF/AMAN/FPP (2003) describe the outcomes of these processes for the disenfranchisement and loss of land rights for millions of indigenous Indonesian people. Scientists from the Centre have actively contributed to the restoration of indigenous rights in Indonesia (see Box 1). In northern Thailand, Centre scientists and collaborators (e.g. Care–Thailand) are increasing recognition of the property rights of indigenous communities by helping upland tribal groups to develop accurate maps of their village domains. This active engagement in policy processes as a facilitator, supplier of empirical evidence and supporter of indigenous practitioners of agroforestry is a hallmark of the Centre's approach to agroforestry policy (van Noordwijk et al. 2001).

Box 1. Promoting indigenous rights in Indonesia

Scientists from the World Agroforestry Centre have actively contributed to the restoration of indigenous rights in Indonesia. Our research and engagement with policy processes in the mid/late-1990s contributed to the first community forest law in Indonesia: a historic decree by the Indonesian Minister of Forestry that recognized and protected the rights of the Krui community to collective rights to damar agroforests. We have also promoted the subsequent recognition of the right of the Government to designate a forest for such special purposes and facilitated dialogue among indigenous groups. The direct effect was that 15 000 households in the Krui area were granted more secure rights to over 35 000 hectares of agroforest land; the indirect effect was that it became easier for indigenous communities throughout Indonesia to register rights to agroforest lands.

Source: ASB 2001

Forest classification and governance

Classification of forestland is a related aspect of environmental governance. Throughout the developing world, large tracts of land have been declared as state forests. There are two key components of this designation: state and forest. Both have implications for farmer incentives to plant and manage trees. Centre research in this area is motivated by the general question: how can forest policies be reformed to harmonize the stewardship of trees in the landscape and on individual farms?

Colonial-era forestry was designed around the needs of the colonial state, i.e. promotion of exports and large industry and control over local communities. Policies of extraction and central control had their roots in the feudal systems of medieval Europe. Policies designed to protect the environmental values of forests by excluding people began in Europe only in the early 1900s and spread to colonial areas in the later stages of the colonial era (Fay and Michon 2003). Anthropologists such as Cronon (1996) have shown that many forested landscapes now considered to be pristine primary forests have, in fact, had long histories of human impact. Forced displacement of people from conservation areas has led to the impoverishment of tens of thousands of former forest dwellers in the Congo Basin (Cernea and Schmidt-Soltau 2003) and to long-term conflict between rural people and governments in much of Southeast Asia (Fay and Michon 2003; Tomich et al. 1998).

A large body of research and experience has accumulated on central forest management and the advantages and disadvantages of devolution to municipal governments and local community groups (Agrawal and Ostrom 2001; WRI 2003). Three major concerns have been expressed about state forest management: i) some state agencies and agents have used their positions as forest regulators as platforms for extraction of resources through concessions to commercial companies and/or bribes; ii) state agencies are accused of not understanding or respecting the ways that local communities and indigenous people use and manage forests; and iii) many state forests are highly degraded. As a consequence, there has been undue suffering for many forest dwellers. Although state forest authorities continue to operate in many countries, some countries have experienced real devolution of authority away from central authorities toward communal management and co-management regimes. Different variants have developed in different places: joint forest management in India, extractive reserves in Brazil, community forest user groups in Nepal, and community forests in Cameroon (see also Box 1).

In the last few years, Centre scientists in Indonesia have given more attention on the 'forest' part of state forest management. Fay and Michon (2003) argue that the forestry regulatory framework has been inappropriately applied to large parts of Indonesia and other countries in Southeast Asia. In many instances this classification has, in fact, been an a posteriori justification that suits the dominant political and economic interests and disenfranchises smallholders, while favouring large-scale plantations and forest concessions. Farmers practicing agroforestry have suffered as a result. Fay and Michon (2003) argue that the forestry regulatory framework should instead be reserved for areas that clearly protect 'public environmental services' such as watershed protection and biodiversity conservation. Areas that don't generate such environmental services should be reclassified under the less-restrictive agrarian regulatory framework.

The Forest Codes of francophone West Africa are renowned for the disincentives they provide for participatory forest management and agroforestry. Some of them have changed since the 1990s, with the pace of change varying from country to country (Russell et al. 2001). Cameroon introduced community forestry in the late 1990s and several lessons have been learned from its experience. Niger passed its new Forestry Act in April 2004. A new forestry code for the Democratic Republic of Congo is still under consideration with much discussion on the role of communities in a situation where all land and resources continue to be legally the property of the state. Ashley et al. (2005) shows that continued uncertainty about forest classification is creating disincentives for agroforestry and forest management in Cameroon and Mali.

Buffer zone and landscape approaches to conservation

There is now general agreement that conservation of valuable natural resources and biodiversity requires the designation of protected areas and better management of the land surrounding them. Agroforestry contributes to landscape approaches to conservation by enhancing the diversity of vegetation in farming areas, increasing the habitat value of land-use mosaics around protected areas, and reducing pressure on protected areas. Schroth et al. (2004) conclude their review of the potential for agroforestry to contribute to biodiversity conservation with the statement that "…the effective integration of agroforestry into conservation strategies is, however, a major policy and institutional challenge".

Attempts to address that institutional challenge have been undertaken in several countries, including Nepal and the Philippines (see Box 2). In 2003/4, Centre researchers conducted studies of the policy terrain affecting agroforestry in several protected areas (national parks or classified forests) in Cameroon, Mali and Uganda. Key conclusions from the studies were as follows (Ashley et al. 2005):

- policy and institutional support to agriculture and agroforestry in buffer zones tends to be very minimal;
- extension and development agencies that support agroforestry in buffer zones

tend to focus on a small number of exotic trees, putting little emphasis on the indigenous trees that would be better suited from an ecological perspective;
- reserved species laws, originally designed to conserve indigenous tree species, tend to provide disincentives for agroforestry; and
- the overall policy and regulatory terrain tends to have many inconsistencies between forestry, environment and land policies.

Centre scientists are following up these studies with targeted research and development projects around protected areas in several countries, including Cameroon, Indonesia, Kenya, the Philippines, Thailand and Uganda. The fundamental question still being asked is: where and how do the integration and segregation options for human–environment interaction have greatest potential to meet conservation and rural development objectives? (van Noordwijk et al. 1997.)

Environmental service mechanisms

During the past decade, there has been increased interest in mechanisms linking supply and demand of environmental services. The environmental services of greatest interest include carbon sequestration, watershed protection and biodiversity conservation. The different environmental services have largely different populations of demanders and suppliers. Carbon sequestration is a global environmental service being financed by emitters of greenhouse gases in the context of the United Nations Framework Convention on Climate Change (UNFCCC) (see next section). The global benefits of carbon sequestration are basically the same no matter where the carbon is sequestered. This contrasts with environmental service mechanisms for watershed protection. In any particular watershed, there may or may not be specific populations (e.g. urban water users) or individual actors (e.g. hydro-power companies) who demand watershed protection, and specific populations of land users who can supply those services. Biodiversity conservation falls somewhere between these two extremes; those who demand biodiversity conservation often demand conservation of species and ecosystems at both global and local levels.

Several factors account for increased interest in environmental service reward mechanisms. Firstly, many organizations are looking for new ways to finance conservation. Secondly, changes in the regulatory environment and liberalization of markets are resulting in increased private-sector participation in conservation, domestic water supply and carbon offsets. Private firms appear to be more interested in market approaches to protect the integrity of their resource base. Thirdly, international environmental agreements are creating space for more market-oriented approaches.

The Clean Development Mechanism (CDM) of the UNFCCC creates new opportunities for developing-country farmers to benefit from their contributions to carbon sequestration and renewable energy. Interest in agroforestry has increased since a report by the Inter-Centre Panel on Climate Change (IPCC 2001) indicated that changes in land use from annual crops to agroforestry is one of the most promising approaches for sequestering carbon through CDM-approved afforestation. Although the carbon sequestration value of agroforestry has received greater attention to date, there is also evidence that agroforestry has good potential to generate renewable energy in the form of biomass and biodiesel that could qualify for the CDM if it can be shown to replace non-renewable sources (Venema and Cisse 2004).

Simple calculations show that the monetary value of the carbon sequestration

Box 2. Buffer zone approaches in Nepal and the Philippines

In Nepal, the Worldwide Fund for Nature and the King Mahendra Trust for Nature Conservation created a rosewood plantation/agroforest around the Royal Chitwan National Park, a valuable conservation area for native forest and wildlife, including the endangered tiger. As part of the Biodiversity Conservation Network, this approach was monitored for its effectiveness in both conservation (reducing pressure on park resources) and contribution to local livelihoods. An additional benefit was empowerment of local communities in park management (WWF 1997).

In the Philippines, the World Agroforestry Centre was part of a group of organizations that conducted research and development around the Mount Kitanglad National Park, one of the most important biodiversity areas in the country. The Landcare approach to land management, which links community groups, municipal governments and research organizations, was tested in the conditions prevailing around the park boundaries. Hundreds of farmers joined sub-village Landcare chapters around the edge of the Park. After several years, this approach has led to improved agricultural production, increased tree cover, and a substantial reduction in encroachment into the Park (Garrity et al. 2002).

benefits of most tree production systems are small in relation to the value of the timber produced. However, Chaco et al. (2002) and Tomich et al. (2002) have used data from the Alternatives to Slash and Burn (ASB) programme in Indonesia to predict how carbon sequestration payments would change the relative returns to alternative land use systems. Their results indicate that carbon payments could be sufficient to increase returns to smallholder agroforestry systems to levels comparable to those generated by oil palm plantations. This makes agroforestry attractive to CDM since projects must be shown to add value to the existing situation. Pilot carbon sequestration schemes with smallholder farmers are currently in progress in several developing countries, with the most experience accumulated in Latin America. The Centre is currently involved in pilot carbon sequestration schemes in Kenya, the Philippines and Uganda.

Experience to date shows that institutional and governance factors determine the feasibility, performance and impacts of environmental service mechanisms. Formal institutions are often designed in ways that require market participants to incur transaction costs that cannot be feasibly met by individual smallholders (Landell-Mills and Porras 2002; Krey 2004; Chaco et al. 2002). Moreover, where land rights are unclear, environmental service mechanisms might compel powerful people to usurp otherwise marginal lands and evict poor land users (Grieg-Gran and Bann 2003).

The Rewarding Upland Poor for Environmental Services (RUPES) project was established in 2001 to address possibilities for environmental service mechanisms in Asia, with particular emphasis on potential for the upland poor to benefit from the mechanisms. The project conducts action research at pilot intervention sites across Asia to examine the provision of environmental services, decide who benefits and who pays, and determine the institutional and policy environment to enable fair and equitable distribution. An inclusive view is taken on payment, including rewards that provide upland farmers with enhanced land tenure security in exchange for following land use agreements (RUPES 2004).

Global environmental governance

The Rio Convention of 1992 marked a sharp increase in the importance of global environmental governance, including several conventions and mechanisms that have direct and indirect relevance for agroforestry. The United Nations Convention on Biological Diversity (UNCBD), the UNFCCC and the United Nations Convention on Combating Desertification (UNCCD) are the most important for agroforestry.

The UNCCD has a Thematic Program Network (TPN) in Asia and Africa on agroforestry and soil conservation. The World Agroforestry Centre has provided technical input on agroforestry to the TPN for Africa and is increasing its links with the TPN for Asia. The TPNs can also benefit from greater consideration of the links with environmental governance. In other words, while tree-based solutions have great technical potential for the problems of land degradation, harnessing that potential requires institutional arrangements that appropriately share benefits and costs, foster local collective action in tree management and provide individual farmers and farm communities with appropriate incentives. Comparative studies on agroforestry in the drylands of South Asia and Africa can provide valuable information. One success story that may be replicated is the ‘Ngitili’ system for farmer-managed natural regeneration (Barrow and Mlenge 2003).

The UNCBD has adopted an expanded programme of work on forestry that has many connections with agroforestry, including raising awareness of the problems of invasive alien species. Recent Centre research in the Baringo area of Kenya is exploring how policies and institutions can shape the benefits and costs associated with the alien invasive tree species *Prosopis juliflora*. One approach to more effective management of *P. juliflora* would be to organize collective harvesting and processing of charcoal made from its wood.

The Centre has been engaged in the UNFCCC for over 5 years. In 2001, the IPCC issued its third assessment report on climate change, with a strong endorsement of the potential for agroforestry to contribute to increased carbon stocks in agricultural lands, while contributing to the welfare of smallholder farmers: “Agroforestry can both sequester carbon and produce a range of economic, environmental and socioeconomic benefits. For example, trees in agroforestry farms improve soil fertility through control of erosion, maintenance of soil organic matter and physical properties, increased nitrogen, extraction of nutrients from deep soil horizons and promotion of more closed nutrient cycling” (IPCC 2001).

The Centre influences CDM policy processes in several ways. Firstly, we seek to provide scientific data and information on the relations between agroforestry systems and greenhouse gases, including carbon and nitrogen compounds. Secondly, we seek to understand the potential for agroforestry to buffer farmers against climate risks. Thirdly, we seek to evaluate how smallholder farmers could be involved in carbon sequestration projects, and the implications of alternative mechanisms for exploiting this potential. Finally, we provide relevant information to a variety of stakeholders at international, national and local levels.

Conclusions and implications for future research and development

Environmental governance shapes the context in which farmers make decisions about where and when to invest time and resources in planting and managing trees. Farmers are encouraged to protect existing vegetation and invest in new agroforestry systems when they have secure rights to the products generated by the trees, when there are certain markets for those products, and when they capture value from the positive environmental services that their trees generate. Land and tree tenure, forest classification, conservation policies, environmental service mechanisms and global environmental agreements are components of environmental governance that affect those incentives through various pathways. They are also policy levers that are used by governments to advance forest conservation, environmental protection, economic growth and other national objectives.

Most developing countries have had regimes of environmental governance that stressed forest conservation by central agencies without due regard for the value of the environmental services produced by those forests, the performance of the regulatory agencies or the negative impacts of forestry laws on farmers' incentives to practice agroforestry. Changes in environmental governance are unfolding in many developing countries, with some decentralization of governance institutions and more emphasis on the environmental effects of land use outside of forests. In many cases, the result is a very uncertain and uneven policy terrain, particularly regarding the relatively new discipline of agroforestry. The review presented in this paper suggests that additional research is needed on the following:

- The landscape and watershed level effects of different types of property rights in farm areas and different configurations of property rights in non-farm areas. Suyanto et al. (2005) has taken this approach to fire management in Sumatra; Swallow et al. (2001) outline a similar approach for watershed management; and Ashley et al. (2005) do the same thing for protected area landscapes.
- Appropriate negotiation platforms for multi-functional landscapes. van Noordwijk et al. (2001) have made major contributions to this with their work on negotiation support systems.
- The potential for environmental service mechanisms that enhance the supply of environmental services and the welfare of smallholder agroforesters in multifunctional landscapes. The Centre is gradually expanding work on environmental service mechanisms from specific locations in Southeast Asia to key locations in Latin America and South Asia.
- The ways that global environmental agreements can be modified or implemented to maximize the potential for agroforestry to synergize the objectives of the agreements with that of reducing poverty.

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Chapter 11

The potential for agroforestry to contribute to the conservation and enhancement of landscape biodiversity

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Abstract

Agroforestry is increasingly being acknowledged as an integrated land use that can directly enhance agrobiodiversity and contribute to the conservation of landscape biodiversity, while at the same time increase, diversify and sustain rural incomes. There are valid concerns, however, that the biodiversity benefits of agroforestry may be misunderstood and the risks to biodiversity understated. This chapter therefore reviews some of the growing literature on agroforestry and biodiversity in order to clarify key relationships, including factors and processes that amplify or limit the contributions of agroforestry to biodiversity conservation. Four propositions are presented, with reference to evidence for the propositions and caveats to them. We conclude that agroforestry generally produces higher biodiversity benefits than both annual and perennial monoculture crop production, and that agroforestry is of the greatest benefit to biodiversity when it is a component of an integrated approach to land use. Important knowledge gaps remain, however, regarding the ways in which tree domestication and agroforestry promotion can be designed to stimulate new agroforestry systems that have greater positive impacts on wild biodiversity.

Introduction

Agroforestry is increasingly being identified as an integrated land use that can directly enhance plant diversity while reducing habitat loss and fragmentation (Noble and Dirzo 1997). There are major concerns, however, that the deforestation benefits of agroforestry have been overstated (Angelsen and Kaimowitz 2004) and that the risks associated with agroforestry have not been adequately acknowledged. It is therefore more important than ever that both the scientific and development communities develop a more accurate and subtle understanding of the multiple links between biodiversity and agroforestry. This chapter reviews evidence that links agroforestry with biodiversity in an attempt to clarify key relationships. It also examines the factors and processes that may amplify and limit the contributions of agroforestry to biodiversity conservation. It is organized as follows: the first substantive section presents important organizing concepts; the second section reviews the available evidence for and against four propositions about the relationship between biodiversity and agroforestry; and the final section discusses a number of issues for follow-up research.

Organizing concepts

The United Nations Convention on Biological Diversity (UNCBD) defines 'biodiversity' as "…the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems." Spatial and ecological scales are therefore fundamental concepts in biodiversity studies. The UNCBD further defines agrobiodiversity as biodiversity that is important for agricultural production, including crop and livestock genetic diversity, wild biodiversity closely associated with domesticated species, and other wild biodiversity sharing the resources. 'Wild biodiversity' is biodiversity that has not been domesticated, while 'domestication' is the dynamic process of how humans select, improve, manage, propagate and integrate trees or other plants into land use systems. While ICRAF and its partners have conducted a great deal of work on below-ground biodiversity (e.g. van Noordwijk et al. 2004), we concentrate here on above-ground biodiversity at the landscape scale, explicitly focusing on the links between the planting and management of trees by farmers and biodiversity in the landscape.

Several definitions of the term 'agroforestry' are used in science and practice. Leakey's (1996) definition is used most frequently: "a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the landscape, diversifies and sustains production for increased social, economic and ecological benefits." Three aspects of this definition are important for the biodiversity value of agroforestry. Firstly, agroforestry involves the deliberate integration of trees with farms and landscapes, which may have direct and indirect effects on farm and landscape biodiversity. Secondly, there are trade-offs and complementarities between the social, economic, ecological and biodiversity benefits of agroforestry compared to other land use systems; indeed, the quantification of trade-offs has been at the heart of the research agenda of the Alternatives to Slash and Burn (ASB) Programme coordinated by ICRAF (Tomich et al. 2001). Thirdly, while some agroforestry practices in certain circumstances contribute greatly to diversification and sustainability, there are other circumstances where it contributes very little.

Propositions about relationships between agroforestry and biodiversity

A number of recently completed review papers suggest ways in which agroforestry contributes to the conservation and protection of biodiversity, including that of both wild species and species more directly related to agricultural production (Boffa 1999; Buck et al. 2004; Cunningham et al. 2002; McNeely 2004; McNeely and Scherr 2003; Schroth et al. 2004a; van Noordwijk et al. 1997). These and other studies suggest four key relationships between agroforestry and landscape biodiversity.

1. Agroforestry farmers and systems as promoters of plant diversity

Proposition: *While modifying natural vegetation for their productive use, farmers develop and maintain agroforestry systems that make substantial contributions to biodiversity in multi-functional landscapes.*

The proposition that agroforestry will result in 'substantial contributions' to biodiversity is supported by a good deal of evidence regarding the diversity of tree and vascular plant species across a variety of landscapes, including those containing agroforestry systems. There are important caveats to the proposition, however: i) there are large differences in the biodiversity value of different agroforestry systems; ii) some of the more diverse agroforestry systems may become less diverse under high levels of population pressure; and iii) the commodities that underpin many of the most diverse agroforestry systems are subject to fluctuations and declines in profitability when adopted on a large scale.

The ASB programme has evaluated the biodiversity associated with a range of typical land use types, including agroforestry, that are found at the frontiers of tropical forests in Southeast Asia, the Congo Basin, and the Amazon Basin. Methods used and results generated by this comprehensive set of studies are available on the ASB web page (www.asb.cgiar.org). Summary results are also presented in Tomich et al. (1998) and Tomich et al. (2001). In general the results show that multistrata agroforestry systems contain an intermediate level of plant biodiversity that lies between primary forests and monocrop perennials or field crops. For example, Murdiyarso et al. (2002) compared the number of plant species found in different types of land use in the Jambi area of central Sumatra. They found that continuously cultivated cassava had 15 species per 1.5-hectare plot, oil palm plantations had 25 species per plot, rubber agroforests had 90 species per plot, while primary forests had 120 species per plot.

Gillison et al. (2004) found that complex agroforestry systems and shade-grown coffee both had much higher levels of biodiversity than simple sun-grown coffee, although all coffee systems had lower biodiversity than primary or secondary forests.

Similarly high levels of tree diversity are also reported for complex cocoa systems found in West Africa and Central America (Schroth et al. 2004b) and the intense homegarden systems found in many parts of Africa and Asia (Khan and Arunachalam 2003; Michon and de Foresta 1995). However, recent data from the Chagga homegardens in Tanzania indicate that tree populations in established gardens may become less dense and more fragmented over time if population pressures rise to very high levels (Misana et al. 2003; Soini 2005).

An alternative approach to agroforestry/forest management that has proved particularly effective in parts of East Africa and the West African Sahel, is described by one analyst as farmer-managed natural regeneration (Chris Reij, seminar at ICRAF, Nairobi, September 2004). The agroforestry parklands of the Sahel are one example – for several generations, farmers across the Sahel have deliberately selected and protected valuable indigenous trees located in their agricultural fields (Boffa 1999). The 'Ngitili' system practised in western Tanzania is another example. The Sukuma people – as individuals and groups – have traditionally set aside parcels of land and managed them as biodiversity reserves and fall-back resources. After years of neglect, this system has been revived in large areas of western Tanzania. Additional value has been added to many 'Ngitili' exclosures through the planting and management of valuable timber and fruit trees (Barrow and Mlenge 2003).

Assessing the value of farmer tree management to biodiversity is challenging. On-farm surveys in Cameroon, Kenya and Uganda show that the diversity of tree species hosted on African farms is greater than originally thought (Kindt 2002). However, in these agroforestry systems, although there may be high species richness it is often accompanied by the infrequent occurrence of many species. For example, while 47 percent of species recorded in Uganda's Mabira Forest were found on surrounding farms, more than half of the identified species numbered 10 individuals or less (Boffa, unpublished data), which may not be sufficient to sustain genetic diversity in the long term. Equally important is the extent to which agroforestry systems specifically contribute to the conservation of rare or threatened forest species. Data from these three countries indicate that few vulnerable or threatened species have actually been observed in agroforestry systems. More research is needed on the important functions and roles that tree diversity plays in landscapes in terms of conserving lesser known aspects of biodiversity, providing other environmental services and benefiting livelihoods.

A crucial question is how agroforestry systems with increased biodiversity value can be stimulated or enhanced in new environments. Agroforestry systems have the potential to evolve through succession toward mature, productive systems to form a mosaic of patches on a landscape while producing marketable tree products for improved livelihoods. Leakey (2004) proposes that domestication of valuable indigenous trees is a key starting point. The proposition is that farmers who recognize and are able to capitalize on the value of indigenous trees will be impelled to plant and protect trees of various types. ICRAF's agenda of research on domestication, seed production and marketing of indigenous fruit and medicinal trees is largely based on this proposition. One of the challenges is to integrate domestication work with a broader conservation framework.

2. Agroforestry and pressures on forests and protected conservation areas

Proposition: *The increased uptake of agroforestry in multi-functional landscapes can reduce pressure on forests and protected conservation areas.*

This proposition is not supported by a large base of empirical evidence, but nonetheless has become the basis for including agroforestry in many integrated conservation and development projects. For example, one of the global champions for primate research and conservation, Jane Goodall, now supports agroforestry development as a way of protecting the remaining chimpanzee populations in the Gombe national park in Tanzania (http://www.janegoodall.ca/inst/inst_tacare_hist.html). There are four main caveats to this proposition: i) agroforestry will only result in reduced pressures on a protected area if the main pressure on that area is farmers' collection of tree products; ii) agroforestry has the potential to increase pressure on forests and conservation areas if it results in increased clearance of primary forest for agroforestry; iii) the potential impact of agroforestry on protected areas depends upon the policy and institutional context affecting tree management and protected area use; and iv) it is difficult to separate the effects of agroforestry from other elements of buffer zone management that successfully reduce pressures on protected areas.

The proposition that agroforestry can reduce pressure on conservation areas is mainly based on evidence of the productivity of agroforestry systems compared to more extensive systems of land management. For example, Ramadhani et al. (2002) found that 5-year-old woodlots of *Acacia crassicarpa* in the Tabora district of Tanzania produced five times as much wood as mature 'miombo' woodlands. Simple calculations show that if all the wood needed for tobacco drying came from woodlots instead of the 'miombo', then 8 675 hectares of woodland would be conserved each year in the Tabora district. Govere (2002) attempted to test this substitution hypothesis for the example of improved fallows in eastern Zambia. His results are mixed: in one village the adopters of improved fallows gathered less wood than non-adopters; in another village adopters and non-adopters gathered roughly the same amount of wood.

A study by Garrity et al. (2002) around the Mount Kitanglad Range National Park in Mindañao, the Philippines, provides support for a link between agroforestry and reduced pressure on protected areas. Farmers around this area of high biodiversity were educated about the use of natural vegetative strips to stabilize hillside farming areas, and improved germplasm and nursery techniques to enhance on-farm production of fruit and timber. The key institutional innovation was Landcare – farmer-led knowledge-sharing organizations inspired by the Landcare movement in Australia. After a number of years, this combination of technical and institutional interventions produced positive impacts in terms of increased maize yields, greater density of fruit and timber trees, reduced runoff and erosion, enhanced environmental awareness, reduced encroachments into the park, and restored stream corridor vegetation. By 2002 there were more than 800 households in Mindañao that belonged to village Landcare chapters around the park boundary.

Another study of the buffer zone of the Kerinci Seblat National Park, Indonesia highlights the relationship between farm diversification and reliance on adjacent national park resources (Murniati et al. 2001). Comparing a sample of rice-only farms, mixed garden farms and a combination of both, the authors found that farms practising both rice growing and mixed gardening had 80 percent lower dependency on park resources. Factors associated with a higher propensity to extract from protected forest resources were low farm income and low supply of on-farm tree-based products, suggesting that agroforestry systems were particularly relevant in the buffer zones. ICRAF research around the Mabira Forest Reserve in Uganda suggests that larger scale economic forces and forest policy can have greater impact on protected areas than agroforestry and other development interventions undertaken around them. While resource extraction by adjacent communities increased with proximity to the forest, agroforesry in the buffer zone could not have any significant impact on the quantitatively far more significant pressures originating from outside the buffer zone, particularly from fuelwood markets for sugar and tea processing, and for brick and charcoal making (Mrema et al. 2001a; 2001b; 2001c; 2001d).

Angelsen and Kaimowitz (2004) argue that the conservation benefits of agroforestry have often been overstated, particularly in places where the forest frontier is still open to settlement and harvesting. Angelsen and Kaimowitz (2004) and Tomich et al. (2001) point out there are likely to be trade-offs associated with profitable agroforestry: on one hand, there will be pressure to convert primary forest to profitable alternative land uses; on the other hand, degradation of agroforestry systems may lead to conversion to less desirable land uses. A classic case of these trade-offs is cocoa. Conversion of primary forest to cocoa production has been a major source of biodiversity loss in many parts of the humid tropics. However, compared to sun-grown cocoa or competing annual crops, shade-grown cocoa agroforests retain much higher levels of biodiversity (Donald 2004).

3. Agroforestry and habitat for wild species

> ***Proposition:*** *Agroforestry can create habitat for wild species in landscape matrices surrounding forest conservation areas.*

The integration of trees into multiple-use landscape matrices can contribute to wild biodiversity through the maintenance of landscape connectivity, heterogeneity and complexity of vegetation structure, integrity of aquatic systems, and cleaner water. Trees can contribute nesting sites, protective cover against predators, access to breeding territory, access to food sources in all seasons, and encourage beneficial species such as pollinators. Evidence of the nature of these relationships has been generated through a fairly large number of field studies, most of which have focused on birds. One caveat is that there have been limited studies to date on how the spatial configuration of trees on farms and in landscapes affects the conservation of different types of biodiversity.

Buck et al. (2004) reviewed 12 studies that found agroforestry systems to provide habitat for diverse populations of birds, with the greatest amount of evidence pointing towards the habitat value of shade-grown coffee and cocoa systems in Southeast Asia and Central America. However, there are also contrasting results: Soini (2004) found low levels of bird diversity in the multistrata Chagga homegardens of Kilimanjaro, Tanzania. Soini postulates that the very high levels of human population in those areas have created an inhospitable habitat for most bird species.

Naidoo (2004) presents a novel analysis of the relationship between forest types and bird types in and around the Mabira forest in Uganda. He analysed the diversity of songbirds along transects across different types of landscapes, from intact primary forest, to regenerating secondary forests and agricultural fields. Songbirds were classified as forest specialists, forest generalists, forest visitors and open habitat species. He found roughly similar numbers of total songbird species in each of the three land-use types, but marked differences in the percentages of different species groups. Forest specialists were not found in the agricultural area; open habitat species were not found in the intact forest. Statistical models of the habitat–species relationship showed that tree density and distance to intact forest had the greatest impacts on number of forest species. Model results indicate that greater tree density in agricultural fields could result in a sizeable expansion in the habitat of forest specialists within the forest and forest generalists in the forest margin.

Agroforestry can enhance connectivity and landscape heterogeneity in multi-functional conservation landscapes. Zomer et al. (2001) found that an agroforestry system involving *Alnus nepalensis* and cardamom contributed to the integrity of riparian corridors for wildlife conservation around the Makalu Barun National Park and Conservation Area of eastern Nepal.

Griffith (2000) suggests a different ecological mechanism by which agroforestry can contribute to biodiversity – by providing a low risk refuge in the case of fire. He assessed bird biodiversity in two agroforestry farms in the buffer zone of the Maya Biosphere Reserve in Guatemala in order to determine whether those farms had served as biodiversity refuges during the fires of 1998 that burned eight percent of the reserve. He found high numbers of bird species, including forest specialists and forest generalists – birds that are not usually found in agroforestry areas.

4. Agroforestry and the threats of invasive alien species

Proposition: *Agroforestry development can be implemented in a way that reduces the risk of alien invasive species to acceptable levels, if adequate precautions are taken.*

In the introduction to this chapter we noted that there are major concerns in the conservation community about the potential threat that farmer planting of trees may pose to biodiversity. For example, the UNCBD Thematic Programme of Work states: “Tree plantations and agroforestry are important sources of biological invasions… Of species used for agroforestry around seven percent are said to be weeds under some conditions, but around one percent are weedy in more than 50 percent of their recorded occurrences.”

Evidence from across the world indicates that agroforestry projects have contributed to the ecological problems associated with alien invasive species. News of impending ‘fuelwood crises’ a generation ago led to the creation of a large number of new agroforestry projects across the developing world in the late 1970s and early 1980s. While many of these projects undoubtedly contributed to increased energy supplies, they have also had negative consequences for welfare, biodiversity and water availability. Better design of the current generation of agroforestry projects should help to minimize negative impacts in the future. For example, ICRAF has adopted a policy that focuses on reducing the risk of introducing invasive alien species as part of new agroforestry research and development programmes. We are also conducting research on effective management of selected invasive alien species. For example, ongoing research on *Prosopis juliflora* in the Baringo area of Kenya indicates the potential benefits and limitations of effective management through sustained use.

Challenges for the future

The overall conclusion that emerges from this review is that agroforestry generally produces biodiversity benefits that are intermediate between monocrop agriculture and primary forests. The overall contribution of agroforestry to biodiversity conservation depends, therefore, on the type of land use that it replaces and on the attributes of the specific agroforestry system. The effectiveness of agroforestry in biodiversity conservation depends on the design of the system and the nature of the biodiversity to be conserved. Agroforestry is not a stand-alone approach to conservation. Rather, it needs to be seen as an element of conservation strategies, which also include policy and institutional changes, and spatial configurations that emphasize maintenance of natural habitats.

Additional research, including appropriate measurement, modelling and experimentation, is needed, contained within the following recommendations:

- Broaden the agroecological focus of agroforestry and biodiversity studies to include more drylands and annual crop-based systems.
- Identify the key features of agroforestry systems – species composition, configuration, management, landscape position – that are most critical to supporting biodiversity in the landscape and in multiuse areas around protected areas.
- Evaluate the conditions under which market-led domestication and on-farm husbandry of valuable indigenous trees can stimulate a sequence of increased tree planting, more intensive land use, and less pressure on forest and land resources.
- Assess the landscape-level effects of new agroforestry systems, such as the improved fallows and rotational woodlots promoted in southern Africa.
- Give higher priority to the challenges of alien invasive species, with special emphasis on the development of management plans for species that have been associated with agroforestry.
- Expand the use of agroforestry systems in degraded lands to help restore the productivity and biodiversity of marginal lands.
- Fully explore the refuge value of agroforestry systems, such as those studied by Griffith (2000).
- Conduct more research into the important functions and roles that tree diversity plays in landscapes for conserving lesser-known aspects of biodiversity, providing other environmental services, and benefiting livelihoods.

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Agroforestry, buffering water flow, coffee, criteria and indicators, litter layer, macroporosity, protective garden, soil bulk density, soil structure, watershed functions

Chapter 12

Watershed functions in productive agricultural landscapes with trees

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Abstract

Watershed functions are often discussed in terms of deforestation and reforestation, but require a more careful diagnosis of problems and solutions. Criteria and indicators that are based on the quantity, timing and quality of river flows are influenced by a combination of effects, including the green and brown cover provided by plant canopies and surface litter layers, the soil surface properties and soil structure, and the landscape-level drainage network. Opportunities for agroforestry and other forms of conservation farming to maintain and restore watershed functions are dependent on the relatively rapid options for restoring green and brown cover, the asymmetric (rapid degradation, slow recovery) dynamics of soil structure and on modification of landscape-level drainage. Data for the watersheds of Mae Chaem in northern Thailand and Way Besai in Lampung, Indonesia, indicate that land-cover change has a relatively small effect on low river flow. We focus here on the changes in soil structure as the 'slow variable' that tends to dominate the long-term opportunities for keeping watersheds productive as well as suppliers of quality water at the desired time.

Introduction

Watershed functions are nearly everybody's concern. Clearing natural forests to grow crops or build roads can reduce the amount of water that enters the soil and increase overland mudstream flows. Human habitation and industry can lead to streams becoming polluted while increasing the demand for clean water. Building on floodplains and wetlands can reduce water storage and buffer capacity and put the new developments at risk of flooding. New fast-growing crops and planted trees can use more water than existing vegetation. And governments can claim control of waterways and impose national solutions on them that do not take account of the local effects.

The end result of all these changes is that there are 'problems with watershed functions' that affect people one way or another. These problems will generally be attributed to deforestation, and reforestation is the default solution in public debate. The standard approach to 'rehabilitation of watersheds' is to plant trees, usually under the control of foresters, in the hope of recreating the benign conditions of a natural forest. Natural or planted forests, however, provide livelihood options only at low population densities, so reforestation cannot really solve current pressures on the land. Furthermore, tree planting in relatively dry areas may actually increase the problem: fast-growing trees with high water use will reduce dry-season flows of streams and rivers.

Agroforestry can make solid contributions to resolving the apparent trade-off between maintenance of watershed functions and productive agriculture, if it addresses the issues in a way that links patch, field, farm and landscape scales.

In this brief description of current approaches to agroforestry solutions to watershed problems, we will consider the following four basic steps, and discuss the concepts and tools required for each:

1. Diagnosis of problems at watershed scale.
2. Comparing land-use options on the basis of buffering functions.
3. Modelling physical degradation and rehabilitation processes in the analysis of trade-offs between profitability and watershed functions.
4. Negotiations between stakeholders of solutions on the basis of trade-offs.

Diagnosis of problems at watershed scale

Because there are many potential solutions to problems with watershed function, we need to be clear and specific about what the problem is, and this requires a common perception (criteria and indicators; Figure 1). A list of criteria for the contribution of watersheds to water quantity (the capacity to transmit water, buffer peak flows and release water gradually), water quality (reduce sediment loads and other pollutants and maintain aquatic biodiversity) and integrity of the land surface (control landslides and reduce loss of fertile topsoil through erosion), needs to be combined with criteria that relate to biodiversity conservation and to the social and economic welfare of the people living in watershed areas.

The relationship between full (as provided by a forest) and partial (agroforestry) tree cover and hydrological functions in terms of the five watershed functions listed in Figure 1 involves different time scales and trade-offs between total water yield and the degree of buffering of peak river flows relative to peak rainfall events. The role of land use can be analysed in terms of changes in evapotranspiration, linked to the presence of trees; infiltration, linked to conditions of the soil; and the rate of drainage linked to the drain network in the landscape.

van Noordwijk et al. (2003) completed a detailed analysis of both the 4000 km^2 Mae Chaem catchment in northern Thailand (mean annual rainfall 1500 mm, population density 20 km^{-2}; mean annual river flow 20–30 m^3 s^{-1}) and the 500 km^2 Way Besai catchment in Lampung, Indonesia (mean annual rainfall 2500 mm, population density 160 km^{-2}; mean annual river flow 15–20 m^3 s^{-1}). Daily rainfall and river flows for these two watersheds are shown in Figure 2.

The two rivers have very different patterns: the largely forested Mae Chaem shows a very strong seasonal pattern, falling nearly dry for a few months of the year; the Way Besai (only 15 percent forest) has approximately continual flow. These differences, of course, primarily relate to the rainfall pattern. They show, however, that commonly used indicators such as the ratio of maximum and minimum flow of the river, Q_{max}/Q_{min} cannot be used to analyse the condition of watersheds, without regards to rainfall.

The indicators of Figure 1 are all expressed in dimensionless form, relating river flow (discharge) to rainfall. For the analysis of the Mae Chaem and Way Besai situations, a new 'buffering indicator' was developed (van Noordwijk et al. 2003) that relates the frequency distribution of daily river flow to the frequency distribution of point-level rainfall. It can be used to test perceptions of increased flooding and peak flows. The Way Besai data relate to a 23-year period where forest cover was reduced from almost 30% to less than 10% in 2002. The main effect of this land-cover change was to increase the total water yield as a fraction of total rainfall. The total discharge in the month with the lowest flow, expressed as a fraction of annual rainfall, showed considerable variation between years but did not change along with total water yield. The buffering indicator was negatively correlated with the total water yield, but for

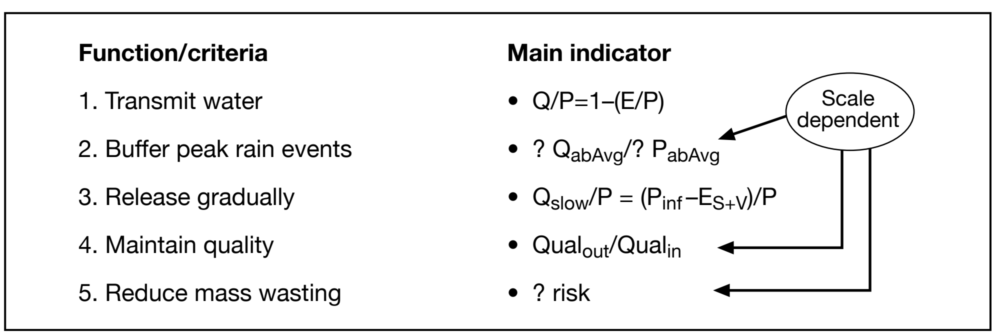

Figure 1. Indicators for the five criteria. The quantitative properties of river discharge change along the river course, and lead to scale dependence of three out of the five criteria. Q = river flow; P = precipitation; E_{S+V} = total evapotranspiration minus evaporation of canopy intercepted water; abAvg = sum of all above average values; inf = infiltration.

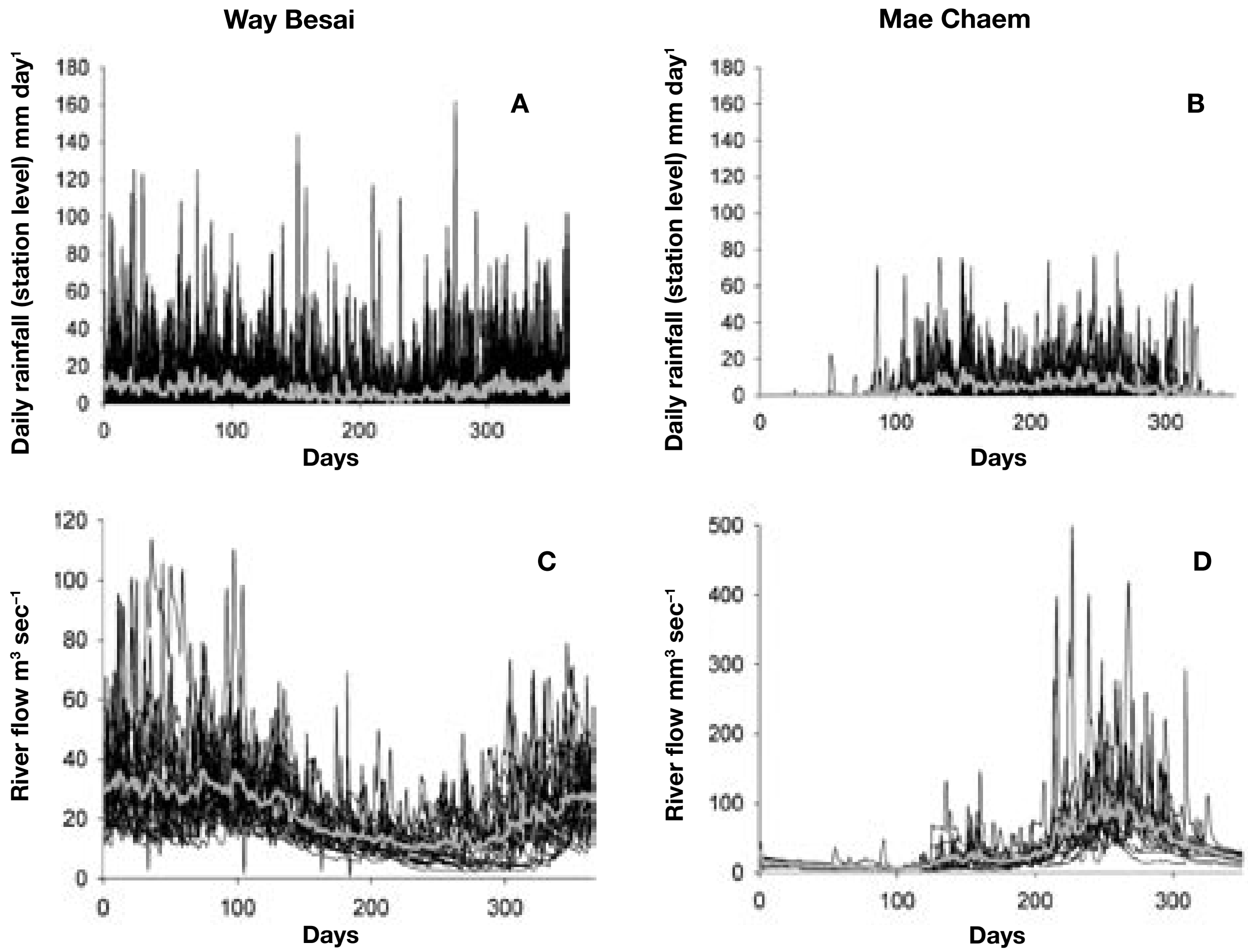

Figure 2. *The records of rainfall (A and B) and river discharge (C and D) of the Way Besai for the 1975–1998 period (A and C), and Mae Chaem for the 1988–2000 period (B and D). The thin dark lines trace the maxima and minima of daily values for the observation periods, the solid lighter line indicates the mean daily values (van Noordwijk et al. 2003).*

the other indicators the trade-off explained only a small part of the total variation. This suggests that in this catchment area the potential downstream benefits of more water are not associated with negative changes in river flow during the driest month or with less buffering of peak events.

A spatially distributed water balance model determined the current land cover situation as being between natural vegetation of forest on a porous soil, and degraded land with grassland on a compacted soil. Without fine-tuning of the model, an acceptable agreement between the model and actual measurements was obtained for the Way Besai (Table 1) and Mae Chaem (Table 2) catchment areas for each of the various indicators, within the range of forest to degraded lands.

This analysis, presented in very condensed form here, suggests that changes in forest cover can modify a number of quantitative characteristics of river flow, but that rainfall (and any change in rainfall characteristics between measurement periods) dominates the outflows. As rainfall tends to have complex patterns of variation over time, it is not easy to tease out a land-use change signal from the noisy background. Much of the attribution of change in river flow to land-cover change in public debate may not survive close scrutiny.

By comparing the results from the model with the measurements taken in the field we can conclude that models that link the space–time characteristics of rainfall via

Table 1. *Indicators of watershed functions for Way Besai, comparing actual data (averaged over 20 years) with simulations of different environments: the current LU (land use) mix; an 'all forest' approximation of natural vegetation; and a 'degraded lands' scenario with grass cover on a compacted soil. GenRiver simulations use rainfall data, soil information, land-cover type and sub-catchment structure of the watershed area (van Noordwijk et al. 2003).*

Indicators	Actual data	GenRiver		
	Current LU	Current LU	Natural vegetation	Degraded land
Total discharge fraction	0.61	0.53	0.44	0.62
Buffering indicator	0.79	0.82	0.80	0.68
Relative buffering indicator	0.66	0.66	0.55	0.49
Buffering peak events	0.86	0.81	0.76	0.78
Highest monthly discharge relative to mean rainfall	1.92	2.19	1.65	1.58
Lowest monthly discharge relative to mean rainfall	0.39	0.54	0.50	0.46
Overland flow fraction	*	0.11	0.00	0.36
Soil quick-flow fraction	*	0.10	0.02	0.00
Slow flow fraction	*	0.30	0.29	0.25

* indicates data not available.

Table 2. *Indicators of watershed functions for Mae Chaem, comparing actual data (averaged over 20 years) with simulations of different environments: the current LU (land use) mix; an 'all forest' approximation of natural vegetation; and a 'degraded lands' scenario with grass cover on a compacted soil. GenRiver simulations use rainfall data, soil information, land-cover type and sub-catchment structure of the watershed area (van Noordwijk et al. 2003).*

Indicators	Actual data	GenRiver		
	Current LU	Current LU	Natural vegetation	Degraded land
Total discharge fraction	0.21	0.19	0.13	0.32
Buffering indicator	0.89	0.90	0.93	0.81
Relative buffering indicator	0.49	0.45	0.54	0.40
Buffering peak events	0.91	0.88	0.91	0.79
Highest monthly discharge relative to mean rainfall	3.16	3.67	3.01	3.37
Lowest monthly discharge relative to mean rainfall	0.20	0.22	0.27	0.24
Overland flow fraction	*	0.00	0.00	0.00
Soil quick-flow fraction	*	0.08	0.03	0.17
Slow flow fraction	*	0.14	0.08	0.12

* indicates data not available.

the dynamics of macropores in the soil to the dynamics of river flow can fairly well reproduce the time series of data from intensively studied (sub)catchments.

Comparing land-use options on the basis of buffering functions

Long time-series with consistent data of land-cover change are scarce and much of the existing variation in land cover in agriculturally used landscape mosaics is not represented in empirical data. Further inference on land-use options has to rely on analysis of the various contributing factors and on synthetic models. Essentially, watershed functions that relate to the quantity, timing and quality of water flows can be understood by considering steps in the pathway of water through the landscape (Ranieri et al. 2004). The main factors are:

- Green cover – leaves intercept raindrops and modify the drip size (and therefore the splash power they have when they reach the ground), keeping a relatively small amount of water as water film on wet surfaces for rapid evaporation.
- Brown cover – the litter layer on the soil surface protects the soil from splash erosion, feeds soil biota that enhance soil structure, and acts as a filter for overland flow, reducing the sediment load.
- Soil structure – at the surface and in the soil determines the speed at which water can infiltrate and hence the amount of excess rainfall that travels over the soil surface as overland flow. Depending on slope and connectivity of the horizontal flow pathways (pipes) a substantial amount of water can be passed on to streams as interflow in a matter of hours after a rainstorm.
- Soil water deficit – water uptake by vegetation between rain events creates space in the soil pores to absorb water; if the soil structure allows this water to infiltrate fast enough, water use can thus reduce overland flow.
- The drainage network – the network of furrows, gullies, drains, roads, soil profile intersections along roads, temporary storage sites in ponds and wetlands, streamlets and streams determines how rapid overland flows and subsurface (inter)flows can reach rivers. Where land-use change affects the timing of flow at a minutes-to-hours scale, the significance of changes in pathways looses importance with increased spatial scale (say for distances more than 10 km), as the travel time in the river itself (and its influence by the degree of channelling, propensity for use of flood plains and riparian wetlands) starts to dominate.
- Properties of the riverbed – if the riverbed consists of stones and the river banks are stable, it can transport clean water at high velocity. Where the river flows through (or meanders in) a landscape with alluvial material, the river can pick up sediment along its way during peak flows and carry high sediment loads regardless of the degree of soil protection in the uplands. Landslides (linked, for example, to earthquakes, road construction or decrease in soil anchoring by decay of deep tree roots) and volcanic ash deposits can provide soil material for transport, over and beyond what comes from the hillsides.
- Point sources of organic and chemical pollutants – direct use of surface water for drinking and other domestic use is not generally safe downstream of human habitation. Water quality for other purposes, as well as for maintenance or restoration of the aquatic ecosystem, its biodiversity and use values, can be negatively affected by point sources of organic and chemical pollutants. Use of pesticides, imbalances between fertilizer inputs, uptake by plants (Cadisch et al. 2004) and deposition of harvested products or manure into streams by domestic livestock (or domesticated elephants in ecotourism areas in northern Thailand) can all make other efforts to maintain watershed functions useless from a user perspective.

Modelling physical degradation and rehabilitation processes in the analysis of trade-offs between profitability and watershed functions

A range of tools and models (e.g. Matthews et al. 2004; Ranieri et al. 2004) exist to relate the overall performance of a landscape to (subsets of) this list of influences, as well as to the 'natural capital' (including rainfall regimen, slope, intrinsic soil conditions and nature of the vegetation replaced by human land use).

For the specific analysis of agroforestry mosaics in Southeast Asia we use the WaNuLCAS (Water, Nutrient and Light Capture in Agroforestry Systems) model at plot level (Khasanah et al. 2004; van Noordwijk et al. 2004c), GenRiver and SpatRain for daily time steps at watershed scale (Farida and van Noordwijk 2004) and FALLOW (Forest, Agriculture, Low-value Lands Or Waste; Suyamto et al. 2004) to analyse longer-term trends in land-use change linked to internal drivers of change. In the remaining part of this chapter we will focus on the changes in soil conditions – as this may be the easiest part to manage for practitioners of agroforestry and other forms of eco-agriculture.

Using the soils under old-growth forest as a reference or baseline, soil degradation involves the loss of organic matter, a decline in soil nutrient reserves, a change in soil biota and below-ground food-webs, soil compaction and a change in water retention. The latter includes the capacity of soil to absorb water during rainfall events; release water during the first day(s) after a rainfall to groundwater and streams to reach field capacity; and retain water at tensions that are appropriate for plants to take up water (Figure 3).

The effects of compaction on these properties vary with soil type, but can be approximated by relating the actual bulk density (mass per unit volume) to a reference value that can be estimated from the soil texture (and which depends on sand, silt, clay and organic matter content) on the basis of large datasets for agricultural soils (Wösten et al. 1998). As a first estimate, we may expect topsoils under natural forest to have a bulk density (BD) of about 70 percent of this reference value, while severely compacted soils may reach 1.3 times the reference value (BDref).

Averaged over the 10 main soil groups represented in the database of Suprayogo et al. (2003), the decrease in water-holding capacity from a natural forest to a long-term agriculturally used soil will be 0.136 cm^3 cm^{-3}, equivalent to the ability to temporarily store up to about 25 mm of rainfall in 20 cm of topsoil. This is storage capacity that can be re-used in a rain event on the next day, as the water will by then have found its way to streams and rivers (or deep groundwater stores, if these are not yet saturated). Upon further degradation from agricultural to degraded lands, a further 0.081 cm^3 cm^{-3} (or the ability to absorb 15 mm of rainfall) can be lost. This loss of storage capacity is likely to induce overland flow conditions that can lead to flash floods and erosion.

The loss of plant-available water owing to soil compaction is small relative to the

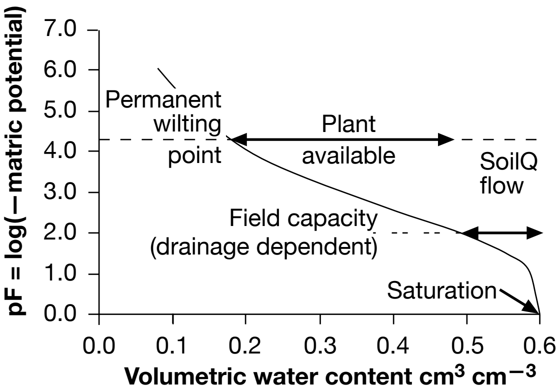

Figure 3. The main properties of the soil–water retention curve are the total water content at saturation, the amount retained one day after heavy rain (field capacity), and the permanent wilting point. Soil compaction primarily affects the soil close to saturation; the capacity for soil quick-flow (SoilQflow) or interflow depends on the difference between field capacity and saturated soil water content.

loss of temporary storage capacity. The consequences of soil compaction for the pathways of excess water flows (overland, subsurface lateral flow or deep groundwater pathways) are thus likely to be more pronounced than those for plant-water availability on site.

Compaction can, however, negatively affect the aeration of plant root systems, and a value of air-filled porosity at field capacity (numerically equal to the soil quick-flow capacity) of 0.1 is often interpreted as a critical threshold for sensitive crops.

A relatively simple method to visualize and analyse changes in soil macroporosity linked to land cover makes use of the infiltration of a dye (Figure 4). The infiltration patterns can be interpreted on the basis of the general macroporosity of the soil and specific impacts of cracks, old root channels and activity of earthworms or other soil biota.

Soil compaction can be rapid; bulldozers, cars, animal hooves and people can all apply sufficient pressure to compact a soil, especially when the latter is wet. In the absence of soil cover, detachment of fine soil particles and a process called 'slumping' also has the same effect. The reverse process, creation of macroporosity, is slow; it primarily depends on the activities of earthworms and similar 'engineers' and the turnover of woody roots. Once a soil is severely compacted, the recovery process may take decades or up to a century. Soil tillage is a poor substitute for biological structure formation: its effects are short-lived and by destroying biological structures it in fact creates an addictive effect – once tillage stops, the soil structure generally degrades rapidly. Strategic tillage-like interventions, such as planting holes or crust breaking can, however, set a long-term biological soil recovery process in motion.

Physical soil degradation can also have its primary effect via the reduction of the potential surface infiltration rate, through the formation of crusts on the soil surface. In relatively dry climates this may even be the primary effect that leads to overland flow

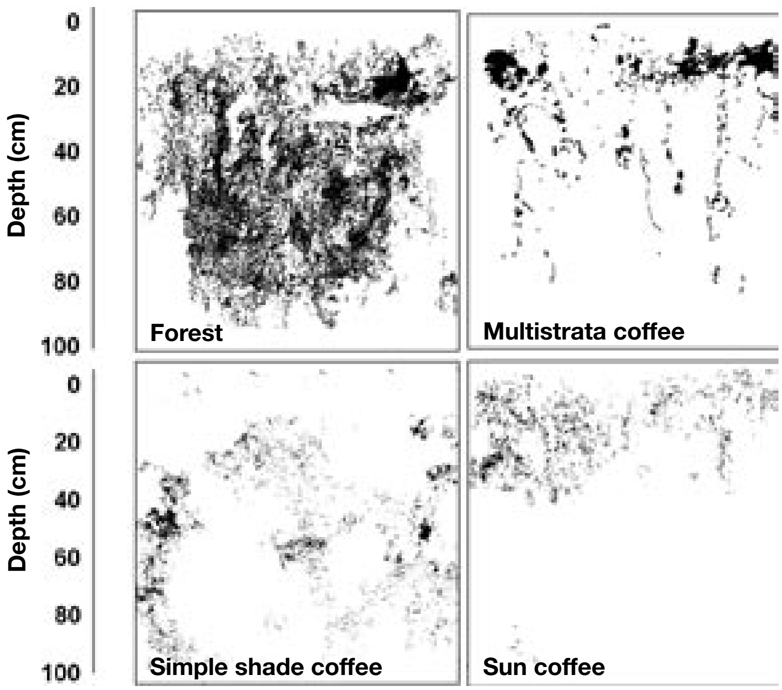

Figure 4. *Infiltration patterns for a dye that leaves a dark trace in all macropores it passes through. This simulates what may happen during heavy rainfall on four types of land use in the Sumberjaya benchmark area in West Lampung, Indonesia; see Hairiah et al. (2004) and Widianto et al. (2004) for details on the methods and sites.*

in conditions where the soil remains far from saturated. Where surface phenomena such as crusting rather than soil compaction dominate in the soil physical degradation process, recovery may be faster: any type of mulch that protects the soil from the direct impact of rain and sunshine and that stimulates soil biological activity may lead to recovery in a timeframe of months.

It is thus important to correctly diagnose what type of degradation dominates in a given location, as this will influence the timeframe for potential recovery. Avoiding compaction at sites that are still in a natural forest condition is probably more effective than trying to rehabilitate degraded sites. Where surface processes dominate, however, rapid gains by mulch-based restoration activities can be expected.

Standard soil physical textbooks and handbook of methods specify how BD can be measured – but not how the data can be interpreted. Bulk density is strongly related to soil texture and soil organic matter content (which in itself depends on texture), so for a valid interpretation in the context of compaction, we need to derive a reference value for a soil with the same texture. A simple scheme is available in spreadsheet form on www.ICRAF.org/sea as part of the ecological models that can be freely downloaded.

While the water, nutrient and carbon balance of soils are well understood, and the main processes are captured in simulation models that have reached considerable predictive ability, the dynamics of soil structure in terms of decay and recovery are still largely a black box, constraining further precision of models of water balance for example. The WaNuLCAS model (van Noordwijk et al. 2004c) uses the empirical reference value for bulk density, BDref , as a 'fall-back' value to which soil structure decay reverts in the absence of specific macropore creation activities, which create macropores directly (van Noordwijk et al. 2004d). This model description suggests that the most important parts of a tree for land rehabilitation are the dead leaves that it sheds and the fine and coarse root turnover it induces.

A further complication arises when we realize that surface litter, depending on its size and weight, is prone to be carried away by wind or overland flow of water, leading to a differentiation of the land into mutually enhancing zones of high infiltration with deposition of surface mulch, and zones of crusted soil with high runoff. Classification of litter sources by their propensity to transport is only just starting.

A macro version of the transport–deposition effect is known as the 'tiger bush' striped pattern in semi-arid lands – where the degraded zones act as water harvesting source areas for the vegetated parts. Land rehabilitation can aim at strategically modifying the scale of this pattern, but not at a fully homogeneous state.

For a full understanding of the tradeoffs between productivity (or profitability) of land use and the implication for watershed functions we thus have a reasonably well-equipped tool kit. There are complications, however, such as the differences in time course of profitability and the substantial variation in soil properties, often at short spatial range, with substantial differences between soils in susceptibility to compaction.

Negotiations between stakeholders of solutions on the basis of trade-offs

The basics of watershed functions are well understood in most local ecological knowledge systems that have so far been explored (Joshi et al. 2004), as well as in formal ecohydrological science. Their representation in general public debate and policy circles, however, leaves much scope for improvement.

Indonesia is rich in examples of landscapes where farmers have combined the use of trees and other elements of the natural forest that provide environmental services with areas that are used for intensive food crop production. These agroforestry mosaic landscapes can be seen as 'kebun lindung' (protective gardens) that offer great opportunity for combining development and environment targets (Pasya et al. 2004; van Noordwijk et al. 2004a). Yet, there are obstacles to the recognition of these systems, as they may not meet the legal definitions of forest or be in harmony with existing land-use regulation systems and policies – even though they could pass the test when functional criteria and indicators would be used.

In negotiating solutions to local problems, the following aspects may require specific attention:

1. Creation of local infiltration sites is often the first step required to break out from a soil degradation–surface runoff erosion cycle. Such sites will both reduce negative impacts on downhill neighbouring zones and allow for a positive feedback loop of vegetation that stimulates formation of soil structure, increasing infiltration and acting as a further stimulus to plant growth. Triggers of such a positive feedback can be remarkably simple: stone lines (as used in the Sahel), planting holes made for trees (that may be the best part, initially, of reforestation efforts and is often not considered as such) or small strips left to natural vegetation succession in between ploughed fields ('natural vegetative strips', see Chapter 7 this volume) as used in the Philippines and Indonesia.
2. Taking natural forest soil as a baseline, soil compaction will initially have a stronger effect on the lateral flows that affect watershed functions than on the on-site productivity of the soil. Where protection of forest soils is feasible by reduction of the drivers of degradation, it is likely to be much more effective than efforts to rehabilitate degraded locations. Unfortunately, environmental governance and reward systems tend to be reactive, and have difficulties in dealing with avoidance of degradation, while rehabilitation is considered worthy of public investment.
3. Enhancing soil organic matter levels has little direct influence on plant-available water, but a strong indirect effect via soil structure, depending on the texture of the soil and the rainfall regime. Susilo et al. (2004) discuss the relationship between total organic input in the agroecosystem and the various levels of the below-ground food-web.
4. The most important part of a forest from a perspective of soil and water flows is likely to be in the litter and root turnover effects, and that in turn supports soil biota to maintain soil structure. Half-open (agroforestry) land-use systems with trees can approach the same functionality while providing better livelihood opportunities and income (see van Noordwijk et al. 2004b, for discussion of trade-off between relative ecological and relative agronomic functions, or REF and RAF).
5. For assessment and monitoring purposes, new methods and models that provide internal controls in the form of reference values for soil carbon and BD can be used to deal with the inherent variation in soil properties and the relationships between lateral flow process across spatial scales.

The discussion so far has highlighted the ecological/technical side of soil structure and function. If agroforestry is to achieve its aims, understanding of and actions targeting these technical aspects at farm-management scale will have to be embedded in a structure of rules and incentives that relate both the downstream users of landscapes and the stakeholders in maintenance of watershed function to the decisions made on-farm. The past focus of watershed managers on forest cover per se may now give way to a more subtle view in which land uses such as the 'kebun lindung' in Indonesia get the recognition that they are due (Pasya et al. 2004; van Noordwijk et al. 2004a).

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Chapter 13

Opportunities for linking climate change adaptation and mitigation through agroforestry systems

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Abstract

Agroforestry systems not only provide a great opportunity for sequestering carbon, and hence helping to mitigate climate change, but they also enhance the adaptive capacity of agricultural systems in tropical and subtropical regions. Agricultural research over the last few decades has been driven by the quest to increase the productivity and resilience of agricultural systems. While increasing productivity relates directly to the ability of a system to accumulate and retain carbon, improving the resilience of agricultural systems is largely the result of enhancing the capacity of such systems to cope with adverse climatic changes. This chapter presents data that examine the mitigation and adaptation potential of different agroforestry systems as well as their significance for income generation for rural populations. New areas of research are proposed and a better use of existing agricultural management knowledge is called for.

Introduction

Climate change will affect developing countries more severely because of their low capacity for adaptation (IPCC 2001). Within these countries, the agricultural sector is particularly vulnerable, putting rural populations at risk. Furthermore, climate change is an additional threat that might affect a country's ability to meet urgent rural development demands including the improvement of food security, poverty reduction, and provision of an adequate standard of living for growing populations. There is a real risk of losing the gains of the Green Revolution, which has largely eliminated the danger of famines such as those seen in the 1950s and 1960s. Several modelling studies carried out in South Asia to assess the impact of climate change (Aggarwal and Mall 2002; Aggarwal and Sinha 1993; Berge et al. 1997; Kropff et al. 1996; Rao and Sinha 1994; Saseendran et al. 2000) have shown that increases in temperature lead to a decrease in the length of the growing season and the yield of most crops. Maize production in the tropics is predicted to decline by 10 percent (Jones and Thornton 2003), with regions such as the Sahel and southern Africa suffering disproportionately.

Within the United Nations Framework Convention on Climate Change (UNFCCC) negotiation process, mitigation and adaptation activities have been largely dealt with as separate matters. Carbon sequestration through land use, land-use change and forestry (LULUCF) as a measure for mitigating climate change has been a very contentious issue during recent negotiations. However, agreements have been made on the modalities and procedures for LULUCF projects, which offer, inter alia, opportunities for agroforestry activities under the Clean Development Mechanism (CDM). Adaptation, on the other hand, was only recently recognized as an important and separate topic as expressed, for example, in the Delhi Declaration of the UNFCCC eighth session of the Conference of the Parties (COP 8) in 2002.

The discussion on the potential synergies between adaptation and mitigation measures is just starting and is all too often reduced to a discussion of the costs of global adaptation vs. global mitigation. A practical understanding of the link between adaptation and mitigation measures, particularly with respect to land use and land management, does not yet exist. Yet agricultural research in the last few decades has been addressing the need to cope with adverse and irregular climatic conditions including rainfall variability or shifting weather patterns. Similarly, there has been a major emphasis on improving the productivity of agricultural systems, leading to the understanding that increasing soil carbon stocks in degraded lands is essential for enhanced productivity. Agroforestry provides a unique opportunity to reconcile the objectives of mitigation of, and adaptation to, climate change.

Agroforestry and climate change mitigation

A wide range of studies (Albrecht and Kandji 2003; IPCC 2000; Palm et al. 2005) have substantiated the fact that agroforestry systems, even if they are not primarily designed for carbon sequestration, present a unique opportunity to increase carbon stocks in the terrestrial biosphere (Table 1). Worldwide it is estimated that 630 x 10^6 ha are suitable for agroforestry. Carbon is particularly useful in agricultural systems (Figure 1), making agroforestry a quantitatively important carbon sink.

Agroforestry systems in the humid tropics are part of a continuum of landscapes ranging from primary forests and managed forests to row crops or grasslands. They are mostly perennial systems such as homegardens and agroforests in which the tree component can stay in the field for more than 20 years. Agroforestry trees play important roles including shading tree crops such as cocoa, nutrient cycling and improving the microclimate. Since trees and crops grow at the same time, these systems are referred to as simultaneous systems. Figure 2 shows that converting primary tropical forests to agriculture or grassland results in a massive loss of carbon storage capacity. While agroforestry systems contain less carbon than primary or managed forests, the fact that they contain significantly higher carbon stocks than row crops or pastures suggests that the introduction and proper management of trees in crop lands has a great potential for carbon sequestration, in addition to rehabilitating degraded land.

Unlike simultaneous systems, improved fallows are tree–crop rotation systems whereby fast-growing, often leguminous, trees are cultivated for a period of 8 months to 3 years to enhance nutrient-depleted soils and degraded lands in the sub-humid tropics. Even in drier areas such as the Sudan–Sahel zone of West Africa, recent field experiments have shown that this technology could significantly contribute to curbing land degradation and improving farm productivity. Typically, improved fallows are short-term rotation systems and as such sequester much less carbon above ground than perennial systems. However, several studies on soil carbon dynamics have indicated that soil organic matter increases after a few seasons of tree planting on degraded soils. On-farm trials in the

Table 1. *Potential carbon (C) storage[1] for agroforestry systems in different ecoregions of the world.*

	Ecoregion	System	Mg C ha^{-1}
Africa	humid tropical high	agrosilvicutural	29–53
South America	humid tropical low dry lowlands	agrosilvicutural	39–102 39–195
Southeast Asia	humid tropical dry lowlands	agrosilvicutural	12–228 68–81
Australia	humid tropical low	silvopastoral	28–51
North America	humid tropical high humid tropical low dry lowlands	silvopastoral silvopastoral silvopastoral	133–154 104–198 90–175
Northern Asia	humid tropical low	silvopastoral	15–18

[1] Carbon storage values were standardized to a 50-year rotation.
Sources: Dixon et al. 1993; Krankina and Dixon 1994; Schroeder 1993; Winjum et al.1992).

sub-humid tropics of Togo and Kenya have shown various degrees of success depending on location (rainfall and soil type), fallow species, duration of the fallow phase and sampling depth; soil organic carbon accretions through employing improved fallow were estimated to be between 1.69 and 12.46 Mg ha^{-1} (Table 2).

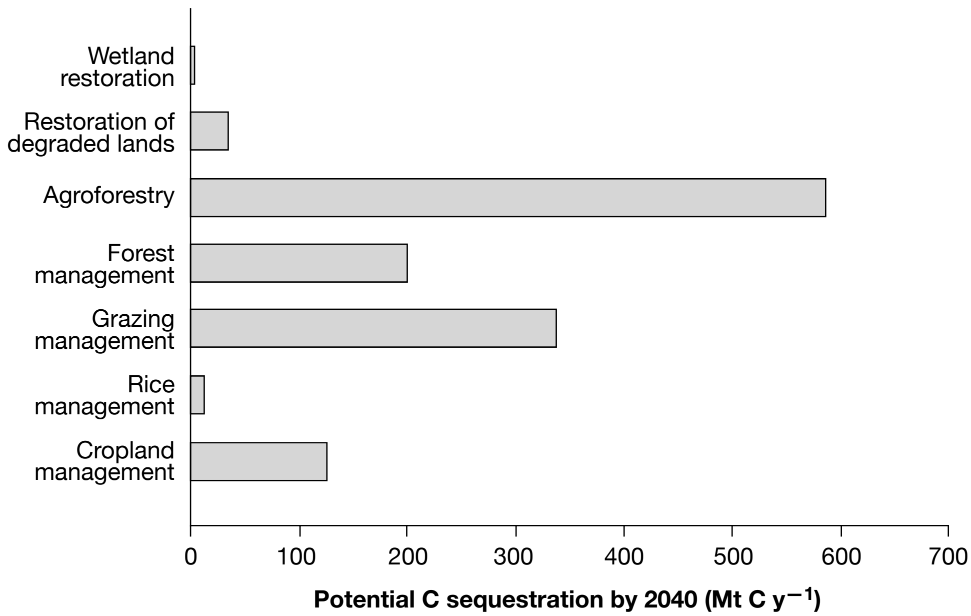

Figure 1. *Carbon (C) sequestration potential (in millions of tonnes per year) of different land use and management options.*
Source: IPCC (2000).

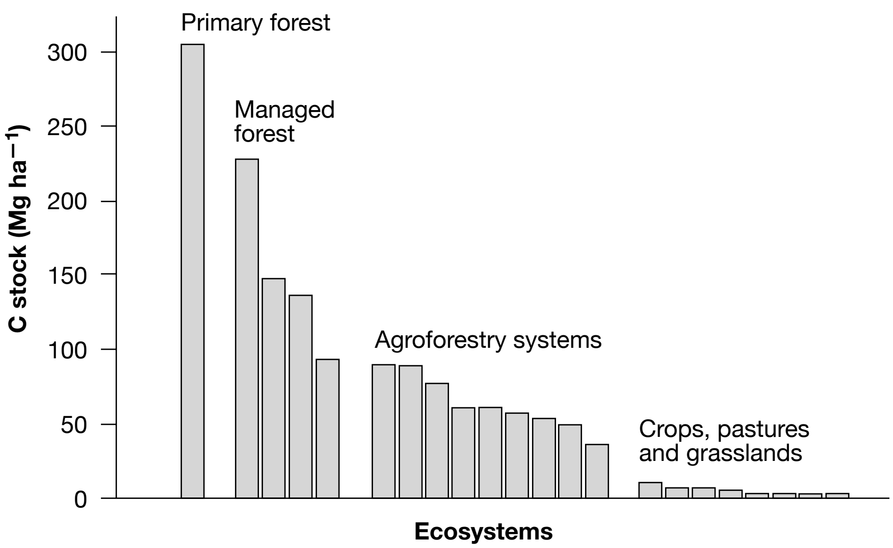

Figure 2. *Summary of carbon (C) stocks in different ecosystems of the humid tropics. Data are from the benchmark sites of the Alternatives to Slash and Burn (ASB) Programme of the Consultative Group on International Agricultural Research (CGIAR).*

Although carbon fluxes in agroforestry systems are well documented, we have a much poorer understanding of the effects of these practices on non-carbon dioxide (CO_2) greenhouse gases. In the case of nitrous oxide (N_2O) emissions, much depends on the presence or absence of legumes in the system. In general, agroforestry systems, which promote the use of legumes as fertilizer or shade trees, may increase N_2O emissions compared to unfertilized systems. Similarly, tree-based systems that encourage the introduction and development of livestock farming may contribute to increasing methane (CH_4) emissions. While efforts should be made to minimize the emission of these trace gases, what ultimately matters in terms of climate change mitigation is how these emissions compare to the amount of carbon sequestered in agroforestry systems. For example, in an improved fallow–maize rotation system in Zimbabwe, N_2O emissions were found to be almost 10 times those of continuous unfertilized maize (Chikowo et al. 2003), but these levels were still extremely low when compared to the increase in the amount of carbon stored.

Enhancing farmer adaptive capacity through agroforestry

As adaptation emerges as a science, the role of agroforestry in reducing the vulnerability of agricultural systems (and the rural communities that depend on them for their livelihood) to climate change or climate variability needs to be assessed more effectively. Rainfall variability is a major constraint in the semi-arid regions and to the upland farms in Southeast Asia that do not have access to irrigation. However, the effects of variable rainfall are often exacerbated by local environmental degradation. Therefore, curbing land degradation can play an important role in mitigating the negative impacts of climate change and

Table 2. *Soil organic carbon (SOC) increase over the duration of the fallow phase in a few tropical soils with different tree species in the sub-humid tropics.*

Country	Fallow duration (years)	Soil type	Fallow species	Sampling depth (cm)	SOC increase Total (Mg ha^{-1})	SOC increase Annual (Mg ha^{-1} yr^{-1})
Togo	5	Ferric Acrisol (sandy)	*Acacia auriculiformis* *Albizzia lebbeck* *Azadirachta indica* *Cassia siamea*	0–10	3.41–12.46	0.68–2.49
Kenya	1.5	Arenosol (sandy)	*Crotalaria grahamiana* *C. paulina*	0–20	1.69–2.15	1.13–1.43
Kenya	1.5	Ferralsol (clayey)	*Crotalaria grahamiana* *C. paulina* *Tephrosia vogelii*	0–20	2.58–3.74	1.72–2.49

Source: Albrecht and Kandji (2003).

variability, and that is where agroforestry can be a relevant practice.

Successful and well-managed integration of trees on farms and in agricultural landscapes often results in diversified and sustainable crop production, in addition to providing a wide range of environmental benefits such as erosion control and watershed services. In western Kenya, the World Agroforestry Centre, together with various partners, has tested the potential of improved fallow systems for controlling soil erosion, using fast-growing shrubs such as *Crotalaria* spp. and *Tephrosia* spp. These species showed great promise in reducing soil losses (Boye and Albrecht 2005). At the same time a significant improvement in soil water storage has been observed in the improved fallow systems (Figure 3). We now understand that climate change may translate into reduced total rainfall or increased occurrence of dry spells during rainy seasons in many semi-arid regions. Therefore, optimizing the use of increasingly scarce rainwater through agroforestry practices such as improved fallow could be one way of effectively improving the capacity of farmers to adapt to drier and more variable conditions.

Under many of the different farmer practices in Africa, crops will still fail completely or yield very little in drought years. Results from improved fallow trials were used to model these various systems. The model suggested that it would be possible to produce an acceptable amount of food in low rainfall years if practices such as improved fallows were pursued (Table 3). As expected, maize production was higher after improved fallow than in a continuous cropping system in good rainfall years (typically 962–1017 mm of rain). A similar trend was observed in low rainfall years (< 600 mm). Most interestingly, the model predicted that maize yield in a low rainfall year after a *Sesbania* spp. fallow period was even higher than maize yield in the continuous cropping system in a good rainfall year. If we define rainfall use efficiency (RUE) as the amount of maize (in kg) produced with each mm of rainwater, then, apparently, the maize crop after improved fallow made better use of the available water than the continuous crop, especially when rainfall was low (Table 3). In low-rainfall years, water availability to crops is paramount and seems to be the dividing factor between absolute crop failure and reasonable food production. Buffering agricultural crops against water deficiencies is, therefore, an important function agroforestry would have to play in the adaptation battle.

There are other mechanisms such as improved microclimate and reduced evapotranspiration through which agroforestry practices may improve the adaptive capacity of farmers. In the African drylands, where climate variability is commonplace, farmers have learned to appreciate the role of trees in buffering against production

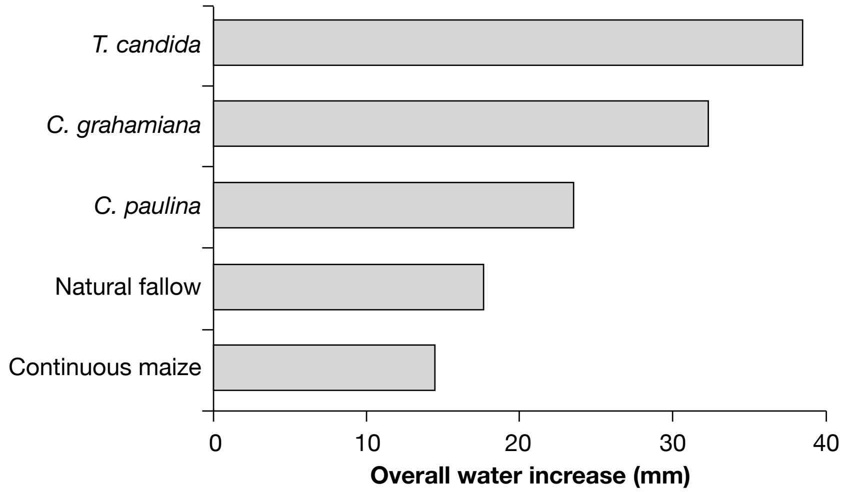

Figure 3. *Change in soil water stocks (0–60 cm depth) in a western Kenyan soil under continuous maize, natural fallow and improved fallow systems using either* Tephrosia candida*,* Crotalaria grahamiana *or* Crotalaria paulina.

Source: Orindi (2002).

risk (Ong and Leakey 1999). The parkland farming system, in which trees are encouraged to grow in a scattered distribution on agricultural land, is one example. One of the most valued (and probably most intriguing) trees in the Sahel is *Faidherbia albida*. Thanks to its reversed phenology (the tree sheds its leaves during the rainy season), *F. albida* significantly contributes to maintaining crop yield through biological nitrogen fixation and provision of a favourable microclimate while minimizing tree–crop competition. A study on an *F. albida*–millet parkland system in Niger demonstrated that shade-induced reduction of soil temperatures, particularly at the time of crop establishment, is critical for good millet growth (Vandenbeldt and Williams 1992).

This type of reversed phenology is not observed in other parkland trees such as the shea butter tree (*Vitellaria paradoxa*) and néré (*Parkia biglobosa*), which have a negative shading effect that may reduce millet yield under the tree by 50 to 80 percent in some cases (Kater et al. 1992). Farmers are well aware of this loss in yield, but do not mind it since the economic benefits from harvesting marketable tree products largely compensate for the loss of crop yield. However, in extremely hot conditions (which we may have to face in the future), the shading effect of these evergreen trees could compensate for the yield losses due to excess heat in the open areas of the field. Such a hypothesis has been validated by the work of Jonsson et al. (1999), who measured variables including temperature, photosynthetically active radiation (PAR is the light in the 400–700 nm waveband of the electromagnetic spectrum that is useful for photosynthesis) and millet biomass under and away from tree canopies in a parkland system (Table 4). The results showed that despite the heavy shading, similar amounts of millet biomass were obtained from the areas under these trees and in the open. This absence of yield penalty under trees was, to a great extent, explained by the fact that millet seedlings under tree canopies experienced only 1–9 hours per week of supra-optimal temperatures (> 40°C) compared with 27 hours per week in the open. In other words, the shorter exposure to extreme temperatures compensated for the millet biomass loss that would otherwise have occurred as a result of shading. This underscores the important role trees could

Table 3. *Grain yield (kg ha^{-1}) and rainfall use efficiency (RUE, kg mm^{-1}) of maize in continuous maize and improved fallow (IF;* Sesbania sesban*) systems across five seasons in Makoka, Zambia.*

	Season 1 (rainfall = 1001 mm)		**Season 2** (1017 mm)		**Season 3** (551 mm)		**Season 4** (962 mm)		**Season 5** (522 mm)	
	Maize	IF	Maize	IF	Maize	IF	Maize	IF	Maize	IF
Grain yield	990	1100	1300	2400	600	1850	1100	2300	500	1180
RUE	0.99	1.10	1.28	2.36	1.09	3.36	1.14	2.39	0.96	2.26

Table 4. *Mean temperature (T), duration when temperature exceeds 40°C (H40), photosynthetically active radiation (PAR) and millet biomass harvested under and away from the tree canopies. (Standard errors in parentheses).*

Treatment	T (°C)	H40 (h week^{-1})	PAR (µE m^{-2} s^{-1})	Millet biomass (g dry weight plant^{-1})
V. paradoxa (large)	–	–	429 (57)	46.2 (16.5)
V. paradoxa (small)	29.10 (0.3)	1	541 (64)	43.3 (17.5)
P. biglobosa (large)	28.30 (0.5)	9	451 (57)	56.2 (14.6)
P. biglobosa (small)	27.00 (0.3)	5	660 (45)	36.8 (14.3)
Control[1]	29.98 (0.4)	27	2158 (40)	39.8 (15.2)

[1] Control plots away from tree canopies.
Source: Jonsson et al. (1999).

play in mitigating the negative effects of extreme temperatures on crops, especially in semi-arid regions.

Pests, diseases and weeds already stand as major obstacles to crop production in many tropical agroecosystems and there are strong reasons to believe that their prevalence and deleterious effects on crops may increase with a warmer climate (Beresford and Fullerton 1989; Hill and Dymock 1989; Rosenzweig et al. 2000). It is strongly believed (Altieri and Letourneau 1982; Speight 1983), yet not sufficiently tested, that enhancing plant biodiversity and mixing tree and herbaceous species in agricultural landscapes can produce positive interactions that could contribute towards controlling pest and disease outbreaks. The potential of agroforestry to control both ordinary weeds (Gallagher et al. 1999; Impala 2001) and parasitic weeds such as *Striga hermonthica* (Rao and Gacheru 1998) has also been demonstrated.

Income generation through tree products

Besides the biophysical resilience, which allows the various components of the agroforestry systems to withstand shocks related to climate variability, the presence of trees in agricultural croplands can provide farmers with alternative or additional sources of income, so strengthening the socioeconomic resilience of rural populations. Tree products (including timber, fodder, resins and fruits) are normally of higher value than maize or hard grains such as millet and sorghum, and can buffer against income risks in cases of crop failure.

The Sahelian Eco-Farm (SEF) provides an eloquent example of how an agroforestry-based integrated natural resource management regime can help improve the livelihood of the rural poor in vulnerable regions such as the Sahel (Pasternak et al. 2005). The SEF is an integrated land-use system that incorporates high-value multipurpose trees/shrubs with soil and water conservation structures. The value produced is in the form of food, fuelwood and forage (which can all be converted into cash), plant nutrients, biomass for mulch (which contributes to increased infiltration of rainfall, and addition of organic matter to the soil), and protection from wind erosion. The first on-station test of the SEF took place at the Sahelian Center of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger during 2002. The estimated income from a 1-ha farm was US$600, some 12 times the value of a typical millet crop (Table 5). The estimated costs of establishing the SEF are not high; the plant material costs about US$60 per ha, and the one-time application of fertilizer about US$10. The labour requirements for land preparation and tree planting are met by farmers and their families.

In the semi-arid zone of Kenya, the parkland system is showing similar success. The fast-growing indigenous species *Melia volkensii* is highly compatible with crops and can provide high-value timber in 5–10 years (Stewart and Blomley 1994). A study by Ong et al. (2002) in the Kitui district of Kenya showed that in an 11-year rotation period, the accumulated income from tree products exceeds the accumulated value of crop yield lost through competition. This income difference is worth US$10 or 42 percent during average years, and US$22 or 180 percent if a 50 percent rate of crop failure owing to drought (reasonable for Kitui) is assumed. In such a hostile environment, where crops normally fail every other year, good and secure financial returns from *M. volkensii* even in drought years can provide significant relief for farmers. This will be all the more necessary as extreme climate events (droughts and floods) are likely to increase in frequency and in magnitude in the near future.

Conclusions

The impact of climate change will be felt on several levels in the agricultural sector. Most of the effects will hit the rural poor in developing countries, who are the most vulnerable because of their poor ability to adapt. The adaptive capacity of farmers in developing countries is severely restricted

Table 5. *Value of Sahelian Eco-Farm (SEF) products from SEF–ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Sadoré station during 2002.*

Species	Quantity per unit area	Yield per unit	Unit value (US$)	Total revenue (US$ ha^{-1})
Acacia colei	320 trees ha^{-1}	2 kg seeds tree	0.14 kg^{-1}	90
Zizyphus mauritiana	63 trees ha^{-1}	30 kg fresh fruit $tree^{-1}$	0.12 kg^{-1}	225
Andropogon gayanus	567 metres ha^{-1}	1 bundle 10m	0.8 $bundle^{-1}$	45
Millet	1/3 ha	1500 kg ha^{-1}	0.1 kg^{-1}	50
Cowpea	1/3 ha	1260 kg ha^{-1}	0.2 kg^{-1}	84
Roselle	1/3 ha	400 kg ha^{-1}	0.8 kg^{-1}	106
Total	1 ha			600

Source: Pasternak et al. (2005).

by their heavy reliance on natural factors and a lack of complementary inputs and institutional support systems.

The concepts of resilience and sustainable productivity are well established in agriculture and can be linked directly to the discussions about adaptation to and mitigation of climate change. Thus, policy makers can draw upon a substantial body of knowledge in this respect. However, the adaptation and mitigation synergies of agroforestry management systems warrant further investigation.

Within international fora, there is much talk about bringing adaptation into the mainstream of planning processes. We have shown above, through the specific case of agroforestry, that some mitigation measures simultaneously provide opportunities to increase the resilience of agricultural systems. It is suggested that such synergies ought to be promoted more intensively through the channels of the UNFCCC such as the CDM. However, if agroforestry is to be used in carbon sequestration schemes including the CDM, several areas need to improve, for example, we need better methods of assessing carbon stocks and non-CO_2 emissions. Furthermore, the debate on durable wood products is ongoing, but what is known is that farmers will need provisions to allow them to market wood products from their agroforestry systems, and we should develop methods to account for the lifetime of the carbon sequestered in agroforestry products. As small-scale farmers are enrolled in carbon-offset projects, we will need to develop a better understanding of the implications of these for carbon sequestration by agroforestry and what it means to livelihoods. Finally, the CDM has very stringent rules for participation that may be beyond the reach of small-scale farmers to understand or to provide evidence of compliance. There is a need for institutional support by national, regional and international centres of excellence to facilitate effective participation of small-scale farmers in the CDM.

In their attempts to develop adaptation strategies for the agricultural sector, scientists and policy makers must consider the complex interactions of constraints created by changing climates in the light of other stress factors. Government and international support in terms of research, education, and extension will be required to help farmers in developing countries cope with the additional stresses created by climate change and increased climate variability. Agroforestry can very likely contribute to increasing the resilience of tropical farming systems. However, our understanding of the potential of agroforestry to contribute to adaptation to climate change is rudimentary at best. Better information is required on the role of agroforestry in buffering against floods and droughts from both the biophysical (e.g. hydraulic lift or soil fertility) and financial (e.g. diversification and income risk) points of view.

Agroforestry promises to create synergies between efforts to mitigate climate change and efforts to help vulnerable populations adapt to the negative consequences of climate change. The research agenda in this area is fairly well defined; much is already known and putting these ideas into practice on the ground with small-scale farmers will allow us to learn important lessons.

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Chapter 14

Environmental Services: Working Group Report

Introduction

Working groups were designated around the four focal areas of the environmental services theme: watershed management, biodiversity, climate change and environmental policy. The groups considered three tasks:

- Identify problems and challenges for environmental services and pro-poor agroforestry.
- Identify significant roles that the Centre can undertake to address these challenges.
- Identify targets for the Centre to achieve over the next 10 years.

The following conclusions were reached.

Watershed management: pro-poor strategies to enhance watershed functions

Problems and challenges of watershed management and pro-poor agroforestry

The last 20 years have seen a wide variety of approaches to watershed management across the developing world. There has been some synthesis of this experience during the last few years and four major conclusions stand out. First, watershed management programmes need to be redesigned to better involve multiple stakeholders and link upstream resource use with downstream impacts. Second, there are vital gaps in local and global knowledge about land–water and land use interactions that inhibit appropriate action for improved watershed management, particularly over large land areas. Third, there is a need for better networking among people involved in research, development and policy for watershed management. And fourth, there is increased realization that the main output of watershed management is water.

Forest management has traditionally been tightly associated with good watershed management. However, with increased pressure on available water and state forest resources, there is a need to reassess the relationships between trees, water and soils in watersheds. Improved understanding of the effects of trees on different watershed functions – water quality, flood risk, landslide risk, dry-season flow – can help to target forest conservation, afforestation and agroforestry interventions.

The United Nations Convention to Combat Desertification (UNCCD), the UN Convention on Biological Diversity (UNCBD) and the UN Framework Convention on Climate Change (UNFCCC) are creating new situations in which public and private agencies are planting trees for the sake of improved environmental management. Without due care, this might put unacceptable new pressures on available water resources. There is a need to assess these risks and tradeoffs.

Roles for ICRAF in pro-poor watershed management

Three main questions motivate the Centre's work on pro-poor watershed management. First, what is the potential for agroforestry systems to conserve or restore watershed functions in multiple-function watersheds? Second, how can agroforestry systems be designed and adapted to have the greatest beneficial impact on water quality, flood risk, landslide risk and dry-season flow in the wide range of environments found in watersheds across the less-developed countries of the world? Third, how can poor farmers benefit from the watershed benefits produced by their agroforestry systems?

During the past 5–10 years, the Centre has engaged in watershed management research programmes in a number of sites in Southeast Asia and East Africa. It is essential that the Centre continue to engage with local stakeholders in a range of conditions. Ground-level work is particularly important for evaluating tree–water–land interactions and for assessing negotiation support and environmental service mechanisms that can link different stakeholders. Outputs should be synthesized across sites and implications for larger areas can be drawn. There is an increasing role for ICRAF in policy development and advocacy, connecting and linking tree farmers (small- and large-scale), non-governmental organizations (NGOs) and government agencies to develop improved schemes for reforestation. The Centre can also help in forging links between different line agencies.

Furthermore, ICRAF can play a part in networking at the regional and global levels. It has begun to do this through co-hosting the African regional workshop for the next generation of watershed management programmes.

ICRAF priority outputs in pro-poor watershed management for next 10 years:

- Develop guidelines and manuals for agroforestry and negotiation support in watersheds. This should include information on how to deal with new species and potentially invasive species.
- Help to develop reward mechanisms and joint systems for watershed management. ICRAF will need to develop different models for different water uses and water management objectives (total water yield, water quality, reduced sedimentation, and so on).
- Develop and test alternative financial and reward mechanisms for linking upstream and downstream watershed management (e.g. the polluter [and water user] pays principle).
- Consider where and how protection and natural regeneration of vegetation may be preferable to new tree planting.

Biodiversity: use and conservation of biological diversity in working landscapes

Problems and challenges of biodiversity in working landscapes

Scientists are increasingly recognizing that much of the world's valuable biodiversity exists outside of protected areas, and that it is strongly influenced and shaped by human activity. Recent reviews show that changes in agroforestry practices can affect wild biodiversity in both positive and negative ways (see Chapter 11, this volume). A positive contribution results from the provision of habitat areas and corridors for wildlife and plant geneflow in multi-use landscape mosaics. Generally, the impact of alien invasive species on indigenous biodiversity is potentially negative. In the conservation community, there is increasing awareness of the need for ecosystem and landscape approaches to conservation planning, including agroforestry and community forestry. For example, the UNCBD recognized the value of the ecosystem approach in 2000, while the World Conservation Union (IUCN) has now embraced ecosystem management as one of its major themes (www.iucn.themes/cem). There is currently a need to identify models that should be scaled up, and to identify policies that shape land use in conservation landscapes.

For landscape approaches to biodiversity conservation to be convincing to local and national policy makers, however, good quantitative analysis of the contributions of biodiversity to rural livelihood improvement is needed. There are both direct contributions – through agroforestry and non-timber forest products – and indirect contributions, through the ecosystem services affected by biodiversity (e.g. nutrient cycling and water balances). It is important to go beyond simply measuring the composition of biodiversity in order to gain an improved understanding of its impact on ecosystem structure and function. For example, there are possible trade-offs between the genetic diversity within one species and across many species. We also need to know more about the contribution of tree domestication to the livelihoods of local people.

Information on the trade-offs associated with different landscape configurations needs to be developed and shared with the range of stakeholders who have interests in conservation areas and the surrounding landscapes. Negotiated agreements on the conservation, use and shared benefits of biodiversity require those various stakeholders to have a shared understanding. Furthermore, there is a need to create greater awareness of the ways in which agroforestry can contribute to achieving the social goals related to biodiversity. The messages need to be simple enough to shape policy and programme design, but should not oversimplify complex processes.

The main roles for ICRAF in biodiversity

ICRAF has a comparative advantage in research on agro-ecosystem biodiversity relative to most other organizations concerned with biodiversity. That is, agroforestry links plot to landscape scales, agrobiodiversity to wild biodiversity, biodiversity to ecosystem function and livelihoods, and links national systems, development agencies and international conservation organizations. Specifically, research should identify: i) the role of biodiversity conservation in risk management, system resilience and livelihoods; and ii) native tree species that are valuable but under threat, as priorities for domestication. Location-specific research should be done in a way that contributes to the identification and negotiation of local solutions. The research programme should cut across and integrate the four themes of ICRAF:

- Land and People – concerned with below-ground biodiversity and the ecosystem services of biodiversity;
- Trees and Markets – concerned with on-farm biodiversity and tree domestication;
- Strengthening Institutions – concerned with building capacity in biodiversity assessment and domestication; and
- Environmental Services – concerned with landscape-scale biodiversity.

ICRAF should also be an information clearinghouse, providing storage, organization and management for enhancing user access.

The Centre should promote and convene non-conventional partnerships:

- be an active participant in research as well as a convenor and catalyst of priority research;
- catalyse a Working Group on Biodiversity that draws together diverse scientific perspectives (agriculture, conservation, development and social science) within CGIAR and the international conventions; and
- continue to be an active member in Ecoagriculture Partners.

ICRAF should play a vital role in raising awareness and education, by:

- catalysing development of educational materials;
- raising community-level awareness to strengthen local processes; and
- participating in sensitizing donors.

Major ICRAF outputs for the next 10 years in biodiversity:

- Conduct a review and develop an action plan for a strategic research programme that moves the agricultural biodiversity debate beyond landraces to ecosystem structure and function at the landscape level.
- Support the development of national policies that take account of the potential contributions of agroforestry to biodiversity.
- Support landscape initiatives in high-priority locations with respect to both biodiversity and agroforestry.

Climate change: climate change mitigation and adaptation for rural development

Problems and challenges related to climate change

Climate change will have consequences for farmers all over the developing world. These effects will play out over long periods of time, while farmers and policy makers tend to have relatively short planning horizons.

There is increasing interest in the idea that agroforestry can contribute to the mitigation of net greenhouse gas emissions. This approach uses mechanisms that offset continued carbon emission in more-developed countries with carbon sequestration in developing countries. The Clean Development Mechanism (CDM) of the Kyoto Protocol on Climate Change is one such agreement that most countries around the world have already signed. In addition, there has been a mushrooming of similar voluntary mechanisms outside the CDM.

An initial assessment of the potential for agroforestry to contribute to greenhouse gas mitigation was included in a crucial report of the Intergovernmental Panel on Climate Change. However, that assessment was based on a very thin set of biophysical data. Thus the effects of agroforestry on the emission of all relevant greenhouse gases needs to be investigated thoroughly, including the gathering of multiyear, multisite evidence.

To date, the various discussions about the potential of agroforestry to contribute to carbon sequestration have been kept separate from discussions of the environmental consequences of tree planting and its effect on the livelihoods of the poor.

Roles for ICRAF in climate change:

- Create a regional project to network national agriculture research systems, environmental research institutes and centres of the CGIAR to assess the strategies that farmers and communities use to cope with multiple stresses.
- Use hotspots of agroforestry adoption as learning sites for environmental service assessment.
- Link crop models to climate-change models.

ICRAF outputs for the next 10 years in climate change:

- Act as a broker, provider and facilitator on information on climate change to enable debates at various levels (for example, by supporting farmers to attend international global forums).

- Conduct measurements in different agro-ecological zones and establish the role of agroforestry in mitigation and adaptation.

Environmental governance: policies to harmonize environmental stewardship and rural development

Problems and challenges in environmental governance

Agroforestry is a cross-cutting and integrative land use. This means that it is affected by a wide variety of sectoral policies, especially those regarding forestry, land, water, agriculture and environment. It also means that it can be challenging to link agroforestry with processes for planning and financing of rural development and poverty alleviation.

Better analytical tools are needed for environmental governance. This includes tools that assist with understanding and strengthening collective action and property systems at multiple scales. It also includes tools that clarify the links between environmental services, governance and service reward themes.

It is important to recognize that environmental governance incorporates formal government structures as well as locally based and community-based natural resource management systems.

Major roles for ICRAF in environmental governance

ICRAF must play a leading role in showing how agroforestry is affected by sectoral policies and regulatory frameworks. The Centre can take the lead in promoting integrative approaches, for example in the way that we engage with investors in agroforestry. Furthermore, it can help governments to cut through the complexity of environmental governance by fostering principle-based and evidence-based environmental management at multiple scales.

ICRAF should continue to catalyse important partnerships that create links across agriculture, the environment, forestry and governance [for example, by linking with the environmental service and governance programmes of the Center for International Forestry Research (CIFOR)].

Priority outputs for ICRAF for the next 10 years in environmental governance:

- Gather a critical mass of national and regional expertise in effective methods for multistakeholder assessment and negotiation support.
- Empower vulnerable groups of indigenous people who rely on agroforestry by giving them more secure property rights.
- Develop, test and disseminate policy and institutional options for promoting the role of agroforestry in enhancing the livelihoods of smallholder farmers, while at the same time meeting environmental objectives.
- Encourage governments in priority countries to enact changes in environmental governance that recognize the multifunctional nature of landscapes.
- Contribute to the modification of international and regional conventions, agreements and action plans to help smallholder farmers practise agroforestry.

Strengthening Institutions

"Agroforestry can and does play a major role in halting and even reversing the decline in agricultural production. It can also help to increase food security, reduce poverty and malnutrition, improve health and reduce land degradation. Agroforestry education therefore represents a direct pathway to reducing Africa's poverty and increasing fertility and agricultural production."

Chivinge

Keywords:
Sustainability, core values, integrated, commitment, youth, practical

Chapter 15

Sustainable agriculture and rural development – a response to the realities of rural Africa

Tony Dolan, *Baraka Agricultural College, Kenya*

Abstract

One of the main challenges for African agricultural education, training and extension is to devise systems that will give smallholders and pastoralists the hope, self-confidence, knowledge and skills they need to play a central role in the development process. In most African countries, agriculture is the major source of livelihoods, and current standards of agricultural training must be improved if we are to achieve the goal of sustainable development. Many systems have been tried, from the 'bwana shamba' (government extension agent) in each village, to the World Bank's 'training and visit' system. All have met with only limited success. Baraka Agricultural College is a small private institution, owned by the Catholic Diocese of Nakuru. Our mission is to promote sustainable agriculture and rural development (SARD) in eastern Africa through dialogue, participatory education, training, research and extension. Agroforestry is one of the non-negotiable programmes for sustainable agriculture and Baraka is an ardent promoter of the practice. Bottom-up development is the approach, and the aim is to promote development through participatory action research. Collaboration and partnership are the two fundamental values underpinning the work of the College. Baraka's experience has shown that the SARD strategy works. We believe that it should be adopted as a tool for rural development throughout Africa.

Introduction

Baraka Agricultural College is a small private institution situated in the highlands of Kenya, 7 km from Molo town. Owned by the Catholic Diocese of Nakuru, the College is managed by Franciscan Brothers. The college was established in 1974 to respond to the education and training needs of the newly settled farmers of Rift Valley Province. Initially, these needs were met by providing short courses in close collaboration with the Ministries of Agriculture and Livestock. However, the problems of running an institution on short courses alone soon became apparent. It proved difficult to create a learning atmosphere and maintain staff motivation because of a lack of continuity in attendance of course participants. To solve this problem, we introduced a 1-year course in general agriculture aimed at school leavers entering farming. The curriculum for the new course was derived mainly from European agricultural colleges, with the emphasis being on high external input/high output agriculture.

By the mid-1980s, it had become clear that the college curriculum was not supporting the needs of increasing numbers of smallholder farmers. An international workshop on sustainable agriculture was held at the college in 1986, and this proved to be a turning point in the Baraka approach. After this, we focused on refining the concept of sustainable agriculture and developing curricula and technologies to promote it. The concept of rural development was added in the early 1990s, when it became apparent that efficient farming alone would not solve the economic and social problems of rural eastern Africa.

Conscious of the need to ensure that the focus of Baraka remained on primary producers in rural communities, a strategic planning process was started in early 2003. This involved intensive work by college management, staff and many partner organizations, including Kenya's Ministries of Agriculture and Education, Science and Technology. The resulting strategic plan charts a clear path for the future. Bakara College will continue its role of striving to empower rural communities through promoting the concept of sustainable agriculture and rural development (SARD).

This chapter is based on the practical experience of Baraka College over the past 29 years, hence we do not refer to the literature.

Dependency on agriculture

A cursory social analysis of the countries of eastern Africa gives a clear picture of the social, economic, environmental and political realities of the region. Seventy percent of the population lives in rural areas and 60 percent of rural inhabitants live in absolute poverty; the physical and social infrastructure is very poor; education levels are low; government development services are inadequate and not likely to improve; government decision making is influenced by a small percentage of the population; cultural values are strong, but cultural practices have not adapted to changed realities; the informal education system has been neglected; and there is over-emphasis on academic university education and a corresponding neglect of the middle-level education institutions. The hasty dismantling of State Marketing Boards and other essential rural development services has left smallholder farmers and pastoralists with little practical State support. The nurturing of dependency and the neglect of the informal education system has contributed to a lack of organization by rural people and they generally lack the confidence to contribute to or influence the national and international policies that affect them.

Box 1. Baraka Agricultural College

Our Vision: 'Rural communities where people live in dignity and harmony with their environment and God'.

Our Mission: 'To promote sustainable agriculture and rural development in eastern Africa through dialogue, participatory education, training, research and extension'.

Yet according to government planning, the smallholder–pastoralist sector will become more important in providing employment and creating wealth in the future. Table 1 clearly shows the scale of the challenge. By 2008, the small-scale agriculture sector is expected to directly absorb 10.09 million of an estimated 18.05 million labour force. By that time, the formal sector of the economy will employ a mere 1.83 million people. Baraka Agricultural College is convinced that SARD is the most appropriate response to the economic, social, environmental and political realities of eastern Africa.

Sustainable agriculture and rural development

SARD is a development concept that promotes efficient, environmentally friendly farming and integrated rural development. Sustainable agriculture is concerned with educating and training farmers, students and development workers to look on farming as an environmentally friendly business. The emphasis is on using locally available resources and technologies. Criteria in all decision-making processes include the economic, environmental, social and cultural impacts of such decisions. The concept includes activities outside the farmgate, including the need for cooperation with neighbours, for example, self-help groups, marketing associations, cooperative societies or other farmer-representative structures. From the farmer's perspective, for a farm to be sustainable, it must satisfy the food security, cash and energy needs of the family depending on it. Therefore, home management, social and cultural issues also need to be addressed.

Sustainable agriculture aims to promote efficient farming, but no matter how efficient, farming alone will not eradicate poverty. Rural development encourages the integrated development of rural areas through adding value to farm produce, improving the efficiency of the informal industrial sector and attracting local and foreign capital and expertise to invest in rural areas, so bringing jobs to the people. Rural development is also concerned with improving education and medical services, security and recreation facilities, and generally making rural areas more attractive to live in.

Baraka College takes community development as a prerequisite for the success of SARD. Youth development, gender, the environment and HIV/AIDS are some of the crosscutting issues that have to be addressed within the SARD concept. We emphasize the value of informal education and training systems and promote integral development of the individual and resources.

Table 1. Projected employment in Kenya.

Sector	Numbers employed (millions)	
	2000	2008 (projected)
Formal agriculture	0.34	0.35
Small-scale agriculture	8.41	10.09
Rural informal	1.58	2.07
Urban informal	2.85	3.71
Formal non-agriculture	1.45	1.83
Total labour force	14.63	18.05

Source: Republic of Kenya National Development Plan 2002–2008.

Principles of SARD

The fundamental principles underpinning our work are those of collaboration and partnership. As a private institution, Bakara believes that it should be innovative and prepared to takes risks in experimenting with new ideas, approaches and technologies. It is appreciated that the private sector has the responsibility to be at the cutting edge in order to be competitive. Partnership with the Kenya Ministry of Agriculture has been a major factor in the success of Baraka. We also collaborate closely with the Kenya Agricultural Research Institute (KARI), Egerton University, the African Network for Agroforestry Education (ANAFE) and many non-governmental organizations (NGOs) and churches. Partnership with external agencies is vital, as it brings a shared experience accumulated by partner agencies from other parts of the world (and crucial financial support). Baraka has worked in close partnership with agencies such as the German Catholic Bishop's Organization for Development Cooperation (MISEREOR), the Overseas Development Agency of the Catholic Church in Ireland (Trócaire), the Freedom from Hunger Council of Ireland (GORTA), Self Help Development International and the Government of Ireland's Agency for Personal Service Overseas (APSO). Advice and support from these agencies has made an important contribution to Bakara's success.

However, partnership and collaboration with local and external agencies is only of value when the rural community is put at the centre of the equation. As Baraka sees it, the challenge is to create a learning community. That is, to create 'mass action', so that development momentum is generated and the community – as a corporate entity – gains the capacity to continue developing when the project or programme is over. No single methodology will achieve this. In general, the Baraka approach is one of 'participatory action research'. This approach puts the needs of the community at the centre, and all development agencies working with the community are encouraged to respond to these needs in a spirit of collaboration. Rather than giving directives on what is right or wrong, communities use their own experience to develop solutions, with advice from the professionals. These are the principles followed by ANAFE, of which Baraka is a member. The establishment of ANAFE is having a very positive impact on the promotion of sustainable development in Africa through supporting third-level education and training institutions.

Box 2. The ANAFE approach – an illustration

When a Baraka extension worker was discussing the value of recycling organic matter on the farm with a group of farmers, one of the participants suggested that, from his experience, he got a much better crop of maize after burning the stalks of the previous year. Instead of saying 'you must be wrong!' the extension worker asked the individual and the group to reflect and encouraged them to research why this might be so. She used the opportunity to develop a better understanding of the many aspects of soil fertility.

The role and approach of the trainer, extension worker or researcher is vital. There is no room for the so-called 'expert' coming in with pre-packaged solutions. Technology alone will not solve development problems. There is a need for a holistic approach and direct involvement of the community – and the development of community leadership and self-confidence is central to the process. In our work we must realise that development is a slow process and that no two communities are the same.

Baraka programmes

Baraka College runs six programmes all of which aim to improve the development capacity of rural communities.

- Certificate in sustainable agriculture and rural development (CSARD)
- Diploma in sustainable agriculture and rural development (DSARD)
- Short courses
- Beekeeping development programme
- Area-based development programme
- Day-release courses.

The CSARD course is a 16-month programme and the college has the capacity to take 80 students each year. Participants come from Kenya, Sudan, Tanzania and Uganda. The curriculum has been developed over the years to meet the needs of participants and their communities. The course aims to empower communities from within, by encouraging them to nominate intelligent women and men who have demonstrated a commitment to community development. A scholarship scheme, sponsored by GORTA, allows students from some of the poorest regions to participate.

Starting in 2006 Baraka College will offer a diploma course in sustainable agriculture and rural development (DSARD). This will be a full-time residential eighteen-month programme offered at Baraka. The course is aimed at certificate in agriculture/rural development graduates who a have a minimum of two years experience working with rural communities.

Participants know that there will be very few opportunities for employment with NGOs, government or church organizations. However, Bakara realizes that graduates of this course will have problems satisfying their aspirations for a better quality of life in rural communities. Consequently, we have a support structure for past students, the Baraka Agricultural College Old Students Association (BACOSA), which gives practical support and includes a saving and credit scheme. In addition, the College has designed special short courses in 'starting your own business' and 'participatory project planning' for past students of the CSARD course. We believe this is a cost-effective and efficient way of improving the development capacity of rural communities.

On average, 500 farmers and development workers complete one-week courses at Baraka every year. The content of these courses ranges from organic farming to e-business. The emphasis in all short courses is on the participant acquiring practical skills that she/he can apply on their farm or in their community or small-scale business.

The beekeeping development unit provides training and extension services in all aspects of beekeeping, an enterprise that has good potential to create sustainable livelihoods, especially in arid and semi-arid areas.

The area-based development programme is concentrated in the Kamara and Lare divisions of Nakuru district. This programme applies the principles and methods of SARD used in all other Bakara programmes. It also demonstrates that the concept works and provides a practical training ground for course participants.

Day-release courses are aimed at teachers, school and college students and members of the general public. The objective is to promote the SARD concept among the general public.

Sustainability of Baraka College

Income generating units (IGUs) are an important part of our strategy to develop a sustainable college. Baraka has four such units: the farm, workshop, highlands honey and shop. Until 2002, these units were run directly under college management and were an overall financial liability to the college. In 2002, they were separated from direct college management and set up as an independent department. Efficiency has improved and the units are now contributing approximately 5 percent of the college budget. The aim is to increase this to 20 percent by 2007. It is clear that management of IGUs demands a very different management style from that required for social service provision!

However, no matter how successful local finance generation is, it is evident that finance from external sources will have to be provided if institutions such as Baraka are to fulfil their missions. In developing countries, in the absence of direct State financial support, this funding will have to come from external sources; hence the need for loyal long-term external partners.

Conclusion

There are several lessons learned from Baraka's experience that have broader application in the challenging work of bringing smallholders and pastoralists into the heart of the development process. From a global perspective, theorists and policy makers must respond to realities – and do so quickly. The symptoms are all there – international terrorism, ecological disasters, uncertainty over energy supplies, disease, urban violence, unhappiness in the developed world, especially among youth – and the paradigm that is responsible for these symptoms needs to be challenged and alternatives proposed.

In Baraka's view, SARD is a concept that has the potential to achieve the sustainable development of the African continent. Sustainable agriculture, properly understood and applied by State policy, will promote economically efficient, environmentally friendly farming. Rural development requires strong national and international policies and support and, in rural communities, work is needed to create the preconditions for take-off. However, with current developments in information and communication technology, there is no reason why environmentally friendly rural industrialization cannot be promoted.

The uptake of SARD in rural communities requires close collaboration between education, extension, training and research service providers. The objective of creating a learning community through participatory action research also requires the collaboration of line ministries, such as Health, Water, Community Services, etc. Too many government development programmes are donor-dictated and short-term. There is a temporal infatuation with the latest participatory approach and time is seldom allowed for any of these systems to make a lasting impact. Rural communities require committed, dedicated and available development workers who have vision and who see their profession as a vocation rather than just a way to make a living.

The experience of Baraka Agricultural College shows that, even in times of limited resources, there are innovative ways of providing rural communities with the education, training and extension services necessary to achieve sustainable development.

Keywords:
Educational impact, sustainability, rural development, farmers of the future, environmental policy, responsive entrepreneurship, integrated approaches

Chapter 16

Capacity building in agroforestry in Africa and Southeast Asia

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Abstract

Since its formation in 1978, the International Centre for Research in Agroforestry (now the World Agroforestry Centre) has generated a lot of general knowledge on agroforestry. The need to advance this knowledge for specific geographical locations led to the formation of the African Network for Agroforestry Education (ANAFE) in 1993 and the Southeast Asian Network for Agroforestry Education (SEANAFE) in 1999. Since then these networks have built condsiderable human capacity and developed region-specific material. Many lecturers in agriculture, natural resource management and forestry have been trained in aspects of agroforestry through short-term training programmes and workshops organized by ANAFE and SEANAFE. Capacity building has taken the form of training of trainers, curricula development, writing teaching materials, postgraduate scholarships for thesis research, staff and student exchange programmes, student attachment, establishment of demonstration plots, farmers of the future (FoF) programme (aimed at young school children), short courses and workshops for policy makers, farmers and education–research and extension links. As a result of these efforts, many universities and colleges are now teaching agroforestry either as part of a course or as a full course at diploma, undergraduate and postgraduate levels. However, there are still many challenges to capacity building and dissemination of technologies that need to be met in order to have adequate human resources to help reduce poverty and food insecurity, improve people's livelihoods and reduce malnutrition. These include more capacity building, continuous review of curricula, establishing agroforestry courses in all institutions offering agriculture and natural resource management, securing more financial resources, and linking education with research and development to continuously build capacity in agroforestry.

Introduction

Agroforestry can and does play a major role in halting and even reversing the decline in agricultural production. It can also help to increase food security, reduce poverty and malnutrition, improve health and reduce land degradation. Agroforestry education therefore represents a direct pathway to reducing Africa's poverty and increasing fertility and agricultural production (Kung'u and Temu 2004). In their 2002 paper, Chivinge et al. emphasized the need and role of agroforestry capacity building at the regional level, while the situation at continental level is given by Temu et al. (2003).

Since the formation of ICRAF in 1987, much useful and relevant knowledge and information on agroforestry has been developed. However, there were limitations to how this information could reach relevant stakeholders around the world. Hence in April 1993 the

African Network for Agroforestry Education (ANAFE) was established by African colleges and universities teaching agriculture and natural resource sciences, and in 1999 Southeast Asian colleges and institutions followed suit by establishing the Southeast Asian Network for Agroforestry Education (SEANAFE; Temu 2003). At that time, these institutions were not offering courses or programmes in agroforestry, and agroforestry was not part of the curriculum. However, they realized that agroforestry has a critical role to play in agriculture and natural resource management (NRM), and their leaders – including vice-chancellors, deans of faculties and chairpersons of departments – decided to revise curricula to include it.

ANAFE and SEANAFE's objectives include strengthening agroforestry and NRM education at African and Southeast Asian universities and colleges; linking education with research and extension; improving availability and access to multidisciplinary land-use education; creating awareness among policy makers of the role of agroforestry and NRM; enhancing the availability and quality of teaching, which includes human resources, teaching material and facilities; and linking institutional teaching and land-use education through networking. These organizations target higher educational institutions including universities, colleges and research institutions as well as secondary and primary schools, local farmers and farming communities, and policy makers.

Since their foundation, ANAFE and SEANAFE have become increasingly effective as agents for advancing integrated natural resource management (INRM) education in Africa and Southeast Asia, and are also strategic vehicles for sharing agroforestry and NRM knowledge. As one of its first tasks, ANAFE undertook a study of the current educational technologies offered by its members and came up with a strategy to improve teaching and learning, including application of modern information and communication technologies (ICTs). As a result, both ANAFE and SEANAFE have strengthened training of trainers, development of teaching materials and training facilities. Now, the academic weight of agroforestry ranges from merely featuring as a topic in a course to being a full programme at diploma, undergraduate and postgraduate levels. The sheer number of workshops and meetings held on the subject have led to policy issues on agroforestry being implemented in many institutions. All universities offering postgraduate programmes in agroforestry are being monitored, and the networks assist in programme and content design to ensure quality capacity building.

Why educate in agroforestry?

Agricultural production in some areas of Africa and Asia is in decline, leading to food insecurity, increased poverty, malnutrition and poor health. The Green Revolution emphasized monocropping and relied on the use of machinery and synthetic chemicals; completely neglecting the concept of smallholder farming. In many parts of the world, this led to natural resources being destroyed and land degraded, resulting in environmental problems and a decrease, rather than the intended increase, in crop yields and other agricultural activities. Soil fertility still declines in many countries therefore agroforestry is an important tool for rural farmers to use in successful agricultural production and land conservation. Prior to the formation of ANAFE and SEANAFE, it was clear that farmers were not maximizing the opportunities for agroforestry. INRM is critical for successful agricultural production. Furthermore, agroforestry products need to be marketed, and hence product processing and adding value are also critical steps in the process. It was therefore essential to include agroforestry education at certificate, diploma, undergraduate, masters and Ph.D. levels, and for farmers, extension/development workers and policy makers to be aware of it.

Achievements

Both ANAFE and SEANAFE are active in agroforestry capacity building in African and Southeast Asian educational institutions, and in raising awareness among policy makers, extension staff and farmers, and at community levels. The number of institutions teaching agroforestry at various levels is increasing. Currently 123 universities and colleges in 35 countries under ANAFE, and 76 institutions in five countries under SEANAFE are offering agroforestry courses (ICRAF 2003). ANAFE and SEANAFE have had many notable achievements, including training of trainers on how to develop extension materials, curricula development, preparation of agroforestry teaching materials for universities and colleges, establishment of demonstration plots at teaching institutions and on farms, agroforestry theses at the B.Sc. and postgraduate levels, and provision to the institutions of agroforestry publications. ANAFE and SEANAFE have both produced newsletters to share information on agroforestry education and networking.

Training of trainers

Various training-of-trainer courses and workshops have been conducted by ANAFE and SEANAFE in different countries and institutions, resulting in about 300 lecturers being trained or retooled in such aspects of agroforestry as curricula development and review, and writing agroforestry materials (Table 1).

Through fellowships provided by ANAFE 20 agroforestry monographs have been written by various teams, for the benefit of the region. To date 100 lecturers have attended curricula-development workshops under SEANAFE, where teachers were trained in agroforestry theory and practices and pedagogic skills and took courses on translating material into local languages. Furthermore 25 faculties from universities and colleges have attended training in participatory on-farm experimentation. Short-term courses have been conducted to enable lecturers to update the agroforestry curricula in both Africa and Southeast Asia. SEANAFE has held participatory curricula development courses with 20 lecturers in each of the countries it covers. Through scientific writing workshops, lecturers are being given the opportunity to develop their own writing skills. Some short-term courses for farmers/extension staff are being held in collaboration with ICRAF. Under ANAFE 152 farmers have received short-term training on various aspects of agroforestry in universities, colleges and vocational institutions.

Table 1. *The number of people who attended ANAFE curricula review 1993–2002.*

Discipline/Level	Certificate	Diploma	First degree	Postgraduate	Total
Agriculture	2	4	15	2	**23**
Forestry	7	8	6	2	**23**
Other (e.g. rural development)	1	2	3	0	**6**
New agroforestry programmes	0	4	5	6	**15**
Total	**10**	**18**	**29**	**10**	**67**

Table 2. *Number of trainers/lecturers trained between 1993 and 2002.*

Level/Discipline	Agriculture	Forestry	Other	Total
Universities	47	17	33	**97**
Colleges	26	18	10	**54**
Vocational institutes	2	0	0	**2**
Extension organizations	43	5	8	**56**
Total	**118**	**40**	**51**	**209**

Curricula development

Under SEANAFE and ANAFE, many universities and colleges have developed and updated agroforestry curricula at certificate, diploma, graduate and postgraduate levels. ANAFE has conducted many workshops for curricula reviews incorporating agroforestry and INRM, reaching a total of 154 people between 1993 and 2002 (Table 2). Currently, 31 colleges and universities in the Philippines offer B.Sc. degrees in agroforestry. In Africa, more than 30 universities offer agroforestry as a thesis research area, and 20 universities offer postgraduate programmes. One of the best new products on offer is the new agroforestry diploma from Nyabyeya Forestry College in Uganda, which many other institutions are now adopting in part or in full. In terms of M.Sc. availability, a regional agroforestry curriculum guide was produced and distributed to all member institutions under SEANAFE, which should lead to M.Sc. curricula being developed. SEANAFE, like ANAFE, has made relevant teaching material available to institutions. It has also produced teaching material and manuals in local languages, which are now available to most institutions. Both networks have produced teaching and field-based materials and manuals at various levels.

In both Africa and Southeast Asia, agroforestry has been incorporated in education and training programmes at unprecedented rates; many undergraduate and postgraduate programmes in agriculture, forestry and NRM now offer agroforestry as an area of specialization. In collaboration with ICRAF, many institutions are developing and implementing programmes on outreach activities, and there is also a focus on interdisciplinary approaches in agriculture and

NRM. New topics are being added to the agroforestry curricula that place emphasis on indigenous trees and crops, value addition, processing and marketing that are critical areas for rural communities.

Teaching material development

To date, ANAFE has distributed many publications to its member institutions, including 23 book titles, various course and workshop handouts, and other materials, mostly used by ICRAF in training courses. Eight focal institutions have received multiple copies of publications, books and equipment to support training. Together with the Regional Land Management Unit (RELMA), the Centre for Agricultural and Biosciences International (CABI) and others, ANAFE has supplied books, manuals, CD-ROMs and other teaching material in many areas of agroforestry. In Asia, 46 publications from SEANAFE, ICRAF and the Food and Agriculture Organization of the United Nations (FAO) have been made available to all SEANAFE member institutions. SEANAFE has also developed an activities handbook, agroforestry teaching materials for different levels, and short-term teaching materials and brochures, all of which have been distributed to relevant member institutions.

Demonstration plots

In order to capture farmers' indigenous practices for part of the curriculum, ANAFE and SEANAFE have funded demonstration plots at institutions and on farms around the region, providing various technologies to strengthen teaching and income generation. ANAFE has also held agroforestry farmers' field days at colleges, universities and on farms. Sixteen institutions in Africa and Southeast Asia have developed agroforestry demonstration plots, related to their curricula and specific to local problems. These plots have been set up specifically to help students, extension staff and farmers.

On-farm demonstration plots can be used for both teaching and capacity building for extension services, while Kenyan on-farm agroforestry trials in fertility have been established to benefit farmers (Ngumi et al. 2004). Through such field days, farmers have been exposed to and learned much about available agroforestry technologies that can result in improved and sustainable crop production. More farmers are now employing the technologies they find appropriate for their communities and socio-economic circumstances. Seventy four percent of the farmers who visited field days are now using the technologies. This has resulted in maize grain yields of 1.7–4.8 t ha^{-1}, compared to 1.5 t ha^{-1} where no agroforestry technologies are applied (Ngumi et al. 2004).

Institutions use demonstration plots for practical aspects of their courses and to fulfil their mission – to build human capacity in research for sustainable economic development, poverty reduction and improved food security. Some also use them for in-service training and research; conservation and domestication of high-value trees and shrubs; and for growing herbs as medicinal plants.

Postgraduate fellowships

As part of capacity building, many postgraduate fellowships have been offered to various institutions in member countries. Since the formation of ANAFE 160 postgraduate fellowships covering educators, researchers and development workers have been awarded: 136 provided by ANAFE (103 males and 33 females). In Southeast Asia, in many activities, there is equal representation of men and women. While there are teaching staff at various levels in agroforestry, there are not yet sufficient numbers to teach the large number of students, although scientists and development specialists are now available.

Agroforestry graduates work with various organizations including educational institutions, governments, international organizations and developmental organizations promoting agroforestry. Their theses have contributed significantly to agroforestry science, knowledge and capacity building at various levels, and have contributed to African and Southeast Asian farmers' improved agricultural production.

Student and staff exchange

ANAFE has funded staff and student exchange programmes with many institutions and ICRAF research institutes. Through these human resource exchange programmes, the network has been able to make capacity available that can be deployed where the greatest needs are found (Zoungrana et al. 2004). As a result of the increase in human resource capacity, many institutions have developed a critical mass capable of delivering agroforestry courses. SEANAFE and ANAFE sponsorship has enabled many students to do M.Sc. or B.Sc. theses in agroforestry. Staff exchanges also allow the networks to share knowledge and skills in curriculum development, training of teachers and development of agroforestry teaching materials.

Education research extension links

Through the Regional Agroforestry Training Team (RAFTT) meetings, workshops and field days for farmers at universities, colleges and farms, considerable capacity has been built at farmer and extension levels. Some institutions have developed brochures for use by extension staff and farmers. In both ANAFE and SEANAFE, some training materials have been developed in local languages, thereby helping many farmers. Programmes developed by colleges and universities have resulted in farmers and extension staff being trained in various aspects of agroforestry as well as the development of training materials and guidance on methodology in adult learning (andragogy) as short-term courses. Extension staff have been taught to teach in colleges.

Farmers of the future

The FoF programme, established by ANAFE, aims to teach those school pupils who will become farmers without a university or college education. The aim of the FoF programme is to build capacity with policy makers and educators to implement agroforestry in primary and secondary schools. Teachers are being taught how to develop teaching materials. This initiative is very important as it connects the agroforestry education continuum from primary school to university level.

Challenges

Despite the successful capacity building to date, there are still many challenges related to agroforestry education. Changes in educational programmes take a long time to produce visible results, and it is important to continue to address critical NRM and environmental issues through capacity building in agroforestry.

Although agroforestry is now accepted as discipline in many institutions of higher learning, transferring technology to farmers and stakeholders is still challenging. Some lecturers lack the skills to develop teaching material in a pedagogically acceptable manner. Others lack the ability to merge theory and practices – an essential element in agroforestry. Capacity at the local and institutional levels needs to be built in order that more sustainable and profitable livelihood options are created. High-quality research, education and extension advisory services are therefore key elements in building up capacities of farmers and communities in adopting agroforestry technologies. Capacity building in agroforestry is a viable pathway to integrate rural development and hence should be given priority.

One of the current limitations in agroforestry research and development is the small number of scientists and professionals who are planning to undertake research in multidisciplinary land-use programmes. The challenge facing African institutions of higher learning is to build agroforestry programmes that are adequately integrative. Furthermore, many of the scientific theories and practices generated through student theses need to be transformed into appropriate educational materials. There is a shortage of curricula and teaching material in institutions in some regions, such as West Africa, yet many lecturers lack the skills to write appropriate educational material. Existing materials in English should be translated into Portuguese and French. All of these activities require funds for capacity building, especially for student agroforestry research theses.

The future

Good agroforestry education must involve people from environmental science, forestry, agriculture, rural development, social sciences, and veterinary science. It is important to ensure that all relevant stakeholders have access to agroforestry technologies, and that agroforestry material development takes account of the differences in each region. Adequate training modules for extension staff/developmental workers should be made available, and there should be incentives to keep the capacity developed within each region. It is essential that appropriate agroforestry technologies be fully utilized by the relevant stakeholders.

Training on later stage processes, such as food processing and marketing of agroforestry products should be implemented in the curricula. The role of agroforestry in alleviating the effects of HIV/AIDS should be emphasized, and ways should be found to reduce the human capacity lost through these diseases.

In education, institutions not teaching agroforestry should be encouraged to do so. There is also a need to build capacity at local/community levels on technical aspects of agroforestry scaling up. For the young, the FoF programme is going to be increasingly important, as children will be the ones to promote agroforestry techniques and knowledge in rural communities in the future.

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Keywords:
Networking, research–extension–education links, agroforestry landscapes, training needs assessment, educational change

Chapter 17

Institutional collaboration in agroforestry: Networking and knowledge management

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Abstract

As the focus of rural development has shifted from sector-based to integrated approaches, agroforestry has emerged as a key element of integrated natural resources management (INRM). Integrated approaches require effective links across the research, education and extension continuum. This chapter discusses weaknesses in this continuum that lead to the unsatisfactory impact of investment in agroforestry development, with emphasis on the education system. We describe the change from opportunistic agroforestry teaching – often initiated by alumni of the World Agroforestry Centre's training courses – towards regional agroforestry education networks. The African Network for Agroforestry Education (ANAFE) was formed in 1993 and the Southeast Asian Network for Agroforestry Education (SEANAFE) in 1999 to improve the access to and quality of agroforestry education. Activities include curriculum development and review using participatory approaches, training of trainers, teaching materials support, graduate thesis research, information and policy advocacy.

Introduction

A widespread traditional practice among farmers, agroforestry has emerged as a science only during the past 25 years. The education system has taken note and agroforestry courses are now offered widely in universities and technical colleges in Africa and Southeast Asia, as well as in Latin America and South Asia. Many universities in developed countries also teach the subject.

Agroforestry science initially focused on classification of agroforestry systems, intercropping research and the development of agroforestry technologies – approaches that were embraced by extension and education systems. But efforts to disseminate agroforestry as a technical package to increase food security and income and to protect the environment showed mixed results. Meanwhile, many traditional agroforestry practices were overlooked. Today, agroforestry science has broadened its scope and now includes multidisciplinary research on landscape functions and the livelihoods of people. One obstacle to developing agroforestry in an integrated, participatory and innovative manner has been a lack of adequately trained agroforestry researchers, extension specialists and teachers.

Integrated natural resource management (INRM) is a new approach to agricultural research and development that has emerged to address these complex interactions. The INRM paradigm differs notably from the traditional crop improvement paradigm that was successful in bringing about the Green Revolution (Izac and Sanchez 2001). INRM reflects the broad interactions required to simultaneously reduce poverty, increase food security and achieve environmental protection. It also recognizes ecological, social and economic interactions at different scales in time and space (CGIAR 2000). These trends influence development strategies in Africa and Southeast Asia too, as they evolve from sector-oriented towards integrated rural development. Agroforestry practices play an important role in such integrated approaches to natural resource management.

Complex problems require new organizational forms for their solution. Interorganizational networks among public, private and grassroots organizations have emerged to meet this need (Boje and Wolfe 1989). In the 1990s, regional networks were formed in Africa and Southeast Asia to improve the access to and quality of higher education in agroforestry. The two networks of universities and technical colleges contribute to educational change and to building the capacity of present and future agroforestry and natural resource management professionals. This chapter shows how institutional collaboration, in the form of networking, can be a powerful tool for managing knowledge about agroforestry, thus underpinning the complex processes of rural development.

Missing links in the research–education–extension continuum

The starting point of our discussion is a model of the links between research, education and extension – a continuum that depends on, and interacts with, a range of other stakeholders and the policy framework (Figure 1). Rural development efforts have often had weak or missing links in this continuum, which led to unsatisfactory or sub-optimal impact of investments in agroforestry development. The situation that is yet to be fully corrected, was characterized by:

- poor adoption and slow scaling up of agroforestry innovations;
- technology oriented research and extension and local knowledge not sufficiently recognized by research and education institutions;
- research results not effectively reaching or entering education programmes;
- poor capacity among graduates to use participatory approaches in developing rural areas; and
- government research, education and extension departments being located in separate units, resulting in poor links and a fragmented approach.

Underlying causes

To understand the reasons for the missing links, we need to look at each of the three components in our model: education, research and extension.

Education was often not geared towards development – this was supposed to be taken care of by the extension system alone. Similarly, universities in Africa and Southeast Asia often have weak research programmes (due to, for example, low salaries and poor facilities). Thus, education programmes often have limited research or extension content (although there are exceptions). Theoretical bias is common: programmes are too academic and do not have practical learning methods, making it difficult for graduates to face reality when they enter the job market. At the same time, lecturers tend to lack field-level skills. Too many curricula have been developed in a top-down, programme-based manner, as opposed to participatory and needs-based approaches. Finally, there is a lack of integration between university and ministry structures (hampering interdisciplinary education), and between researchers and educators.

The **research system** generally shows weak links with education and extension. This is because: i) research and extension in most countries are handled by separate institutions; ii) the research agenda is too narrow (i.e. not systems-oriented) and farmers do not participate sufficiently in identification of research topics, the conduct of research or feedback on results;

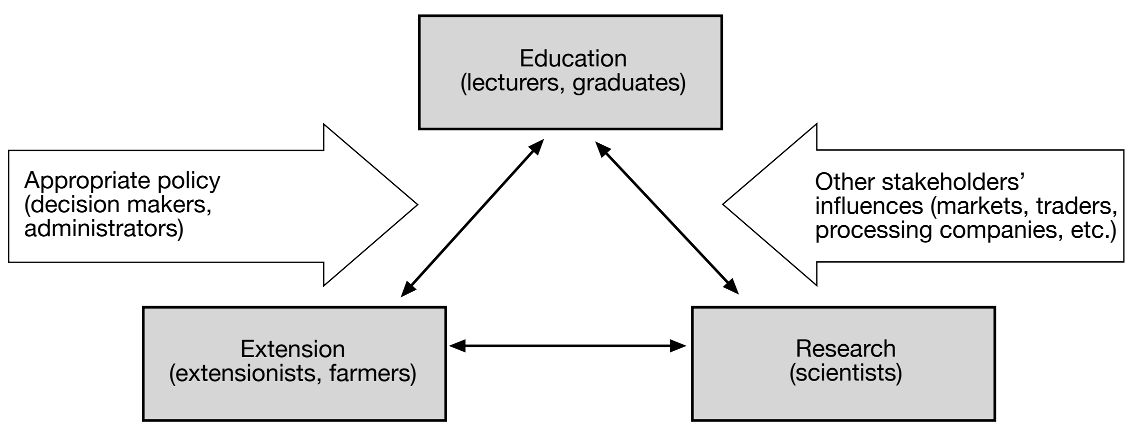

Figure 1. *The research–education–extension continuum.*

and iii) there is a lack of interdisciplinary team work, leading to sub-optimal use of existing human resources and a lack of synergy. Research results are therefore not disseminated effectively.

The **extension system** also has several bottlenecks that hamper the free flow of information with research and educational organizations. These include: i) a hierarchical extension approach, using one-way communication for spreading national policies and tending to overlook local knowledge and practices; ii) a focus on technologies that do not consider socio-economic or cultural aspects; iii) weak institutional support systems (e.g. resources, facilities, human resources, knowledge and skills) hamper the acquiring and sharing of knowledge; and iv) limited experience and lack of capacity in using participatory methods. In addition, cross-cutting policy and institutional factors influence the links between research, extension and education. Policy makers are often not sufficiently involved in the development process at a local level. Institutional structures do not help either; there are often several different ministries involved, which may or may not collaborate.

As a result of these bottlenecks and missing links, educational institutions face difficulties in teaching subjects that require interdisciplinary skills and a good grasp of current research and extension paradigms. Examples of such complex areas are the livelihoods in the ethnically diverse uplands of Southeast Asia, the links between local land use and environmental services, or farmers' postharvest processing and marketing.

Given the increasing interest in agroforestry education at tertiary level, how can individual institutions tackle the kind of issues discussed above? They cannot change such a complex situation alone. To have a strong voice, they need to unite. Networking among universities and colleges has been found to be an effective tool.

Development of regional networks

Several universities and colleges in Africa and Southeast Asia began to take an interest in agroforestry education during the mid-1970s. This was triggered by population increase, rapid changes in land use (including extensive deforestation) and issues raised by the global society about sustainable development and the environment, such as widespread soil erosion and land degradation. Educational institutions were also influenced by external factors, such as advances in international agroforestry research and development. The process of strengthening capacity for agroforestry education and training evolved through the following steps:

1. International training courses, such as the World Agroforestry Centre's 'Introduction to agroforestry research and development' in the 1970s and 1980s, exposed educators and researchers to agroforestry principles and practices.
2. Alumni tried to introduce agroforestry courses into their home institutions in Africa, Asia and Latin America, with varying degrees of success. This was done opportunistically.
3. A broader interest emerged in universities and colleges to incorporate agroforestry into education programmes, particularly in faculties of forestry.
4. Some institutions developed degree programmes (B.Sc. and M.Sc.) in agroforestry.
5. In time, many institutions began teaching agroforestry courses or programmes at technical, B.Sc. and M.Sc. levels, but there were few mechanisms for institutional collaboration nationally or regionally (compared to forestry and agriculture).
6. The need for joint curriculum standards and sharing of resources was recognized.
7. Regional workshops were held, culminating in decisions by educational institutions to establish regional networks. This process was jointly facilitated by the Centre's African and Southeast Asian offices and key universities in the two regions.

Status and needs assessments and institutional visits to universities and colleges (conducted in the early 1990s in Africa and in 1997/8 in Southeast Asia) revealed a series of constraints to agroforestry education (Hansson 1992; Temu and Zulberti 1994; Rudebjer and del Castillo 1999):

- agroforestry was not recognized as specialization or discipline;
- agroforestry curricula were inadequate: they were often incomplete and lacked a common standard;
- training materials were in short supply: they were to few, too specialized, or in the wrong language, and even when materials were available, the libraries could not afford them;
- there was limited research capacity among staff and graduates;
- lecturers needed training in all aspects of agroforestry because agroforestry science had developed so fast that there were few trained teachers; and
- there were inadequate links with field practices.

At the same time, opportunities for networking were appearing. Agroforestry programmes were offered within many educational institutions. Stronger institutions wanted to take the lead while the 'weaker' ones wanted to learn from others. There was recognition of the challenges related to land sub-division and intensification of land use. Agroforestry practices seemed to provide viable solutions. Governments, non-governmental organizations (NGOs) and multilateral organizations also took an increasing interest in agroforestry development. Support from the policy level increased, but human capacity was needed to implement such programmes. Partnerships with like-minded projects and organizations emerged, including links with social and community forestry efforts and sustainable agriculture.

Agroforestry network development took a major step forward when the Swedish Agency for International Development Cooperation (Sida) offered its support and, in 1993, the African Network for Agroforestry Education (ANAFE) was established. This network now has123 member colleges and universities in 34 African countries and is organized into four regional sub-networks, some of which include national sub-networks. The Southeast Asian Network for Agroforestry Education (SEANAFE) was established in 1999. There are 76 member colleges and universities in five national sub-networks (Indonesia, Lao People's Democratic Republic [PDR], the Philippines, Thailand and Vietnam).

Latin American countries are also following suit and a planning workshop for a Latin American agroforestry network was held in 2002.

Membership, management and activities

The networks link institutions rather than individuals. Membership is free. In Africa, any relevant institution may apply for membership. In Southeast Asia, given the potentially very large number of institutions in some countries, membership is based on invitation as advised by the National Agroforestry Education Committee in each country.

Ownership by the members is secured through elected network leadership at regional, sub-regional (Africa) and national (Southeast Asia) levels. The members show commitment through sharing the costs of network administration and meetings. The medium- to long-term direction and strategies are discussed at regular meetings. The network coordination/facilitation units are located at the Word Agroforestry Centre offices in Nairobi (Kenya) and Bogor (Indonesia), where they benefit from the latest advances in agroforestry research.

The networks conduct similar types of activities, with variations depending on national and sub-regional needs. The key activities are:

- curriculum review (using participatory approaches) and publication of guidelines for such reviews (e.g. Temu et al. 1995; Rudebjer et al. 2001);
- training-of-trainers in agroforestry theory and teaching methods;
- preparing, developing, translating and adapting teaching materials;
- supporting graduate thesis research in agroforestry;
- linking the networks to the regional agroforestry research agenda;
- pooling of resources and exchange of staff and experiences between institutions in the networks (where 'stronger' institutions assist 'weaker' ones);
- providing information on network outputs and activities through publications, newsletters and websites; and
- inviting policy makers to key events.

Achievements

SEANAFE and ANAFE have already become powerful mechanisms for managing knowledge and communicating and sharing experiences in agroforestry among educational institutions through their publications, newsletters, websites and databases. They are the largest working networks of educators in Africa and Southeast Asia and are recognized internationally – being regional hubs for the International Partnership on Forestry Education (IPFE), an initiative launched at the World Forestry Congress in 2003. IPFE, with initial support from the World Bank, aims to strengthen university-level education about forests and forestry worldwide, by facilitating and supporting collaboration.

The efficiency and relevance of the networks is enhanced by their regional and national sub-networks, which encourage local solutions to local problems. The networks form a platform for multidisciplinary dialogue among educators, researchers and development workers – effectively encouraging greater integration and synergy. Colleges and universities are realizing that, to be effective, they need to work more closely with farmers and to capture their experiences into teaching programmes. New and revised educational programmes emerge every year, all addressing various aspects of agroforestry and INRM. Due to changes in education policies, agroforestry and INRM are being accepted as important components of college and university education; institutions now consider agroforestry as a suitable platform for launching broader natural resource management programmes, such as watershed management or environmental conservation. At the national level, the networks have developed agroforestry teaching manuals for B.Sc. courses in local languages and institutions have established practical field sites for training, research and outreach activities. In addition, the Centre supports thesis research, staff exchange and attachments at their own research sites throughout the regions.

In conclusion, the institutional networks have proven valuable in terms of:

- changing attitudes among educators: there is now greater understanding of the need for local context in rural development;
- providing leadership for, and analysis of, agroforestry education within countries and regions;
- sharing experiences and enhancing programmes;
- bringing integrated approaches to natural resource management into education systems; and
- facilitating interaction between academics, researchers, policy makers, extension workers and farmers.

Challenges

Although member institutions of ANAFE and SEANAFE have responded strongly to the need for curricula reform, there is still much to do, since the science of agroforestry is developing rapidly. For example, the emerging broad landscape view of agroforestry is still not widely covered. There is still a need to incorporate such knowledge into education programmes and develop methods for field-based learning with farmers.

ANAFE and SEANAFE also need to address the challenge of growing demand for participation and membership in the networks. The establishment of new, more decentralized sub-networks brings issues of sustaining leadership and communication at the regional level. Regional meetings are expensive to organize and mobilizing resources to support the growing networks will not be easy. It is easier to find resources for specific activities, such as training and teaching material development, than for network management. Furthermore, as demand grows it will be difficult to develop and distribute sufficient academic materials to meet the growing need, particularly where countries use local languages of instruction (e.g. Lao PDR and Vietnam).

Finally, there is still a lack of policy-level recognition of agroforestry as a field of study and a career path. It is generally felt that there is need for agroforestry competence but a shortage of specific agroforestry jobs.

Future opportunities

The two networks are very well placed to address weakness in the education system for natural resources management and to capture opportunities for educational change. The networks have brought individuals and institutions into long-term partnerships. They have come to know each other, which also opens opportunities for partnerships beyond agroforestry.

Box 1. On-campus field laboratory in the Philippines

The Misamis Oriental State College of Agriculture and Technology (MOSCAT) in the Philippines began offering agroforestry education in 1995. Two programmes were offered: a diploma and a bachelor degree. Both required practical experience, but the lack of a convenient field site proved problematic. So, in 1998 25 hectares on campus were designated as an agroforestry field laboratory. The college itself had extremely limited financial resources, so the development of the field laboratory was based on forming partnerships with local agencies, international research centres, NGOs and the private sector. The bulk of the financial support was provided by SEANAFE.

Initially a simple banana and coffee plantation, the site now has a woodlot, windbreaks, a multistorey system with free-range chickens, silvipasture with free-range goats and sheep, alley cropping with improved natural vegetative strips, a nursery and a fishpond. Farm income (from production of maize, lanzones, rambutan, sweet potato, jackfruit, 'marang', chayote, cassava and chickens) increased from US$117 in 2000 to US$425 in 2003. The centre also has goats, sheep, and cattle. Networking with other stakeholders has promoted a multisectoral approach to agroforestry development at the local level.

Future plans include:

- domesticating indigenous tree species;
- producing seedlings through macro-propagation;
- collecting non-timber forest products;
- enhancing existing agroforestry systems for improved production;
- developing an agro/eco-tourism village; and
- strengthening links with national government agencies, NGOs and people's organizations through collaborative research and development.

The network approach can be applied in a broader context. For example, ANAFE is not strictly about agroforestry only. It is about natural resources management, integrated beyond forestry, beyond agriculture. There is a change of attitude among educators towards putting education into context in rural development. Experiential learning methods and tools are emerging and the teaching and learning environment is changing to include farmers' participation. Agroforestry programmes can thus serve as vehicles for broader rural development.

The networks also reach out to regions and countries outside their core area (e.g. Latin America and South Asia) to influence change. This role can be further strengthened, for example through IPFE.

Finally, while the networks in some cases are being institutionalized (i.e. their programmes are becoming part and parcel of the institutions' regular work), the implementation of many good ideas will depend on resource mobilization activities that attract donors. Better funding will ensure the networks can play an important role in reducing poverty and conserving the environment in Africa and Southeast Asia.

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Keywords:
Capacity building, agroforestry, postgraduate research, gender, partnerships

Chapter 18

Building capacity for research in agroforestry

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Abstract

This chapter discusses the key components of capacity building and the mechanisms that have been used to develop research capacity in agroforestry. These include building new expertise, developing institutions, forming networks, involving stakeholders and strengthening the links between institutions that have an interest in agroforestry research (including those in the North and the South, and those with national and international mandates). We discuss the efforts of the World Agroforestry Centre to build research capacity, including training at postgraduate level, postgraduate research, review of curricula to include agroforestry and networking between institutions. We also cover the recommendations of a 1982 conference on professional education in agroforestry and the extent to which these have been implemented, and present the results of the Centre's graduate training programme. Finally, we outline the challenges to building capacity for agroforestry research, along with some suggested strategies and new opportunities.

Introduction

Capacity building: definitions and components

Capacity building is the structured process by which individuals, groups, organizations, institutions and societies increase their abilities to perform core functions, solve problems and define and achieve objectives, in order to understand and deal with their development needs in a broad context and in a sustainable manner. Temu and Garrity (2003) suggest that institutions with the right capacity have a good policy environment, good strategies, control capital and financial resources and have the needed expertise to successfully mobilize their capacity.

Szaro et al. (1997) define capacity building as enabling the indigenous peoples of developing countries to carry out development processes successfully by empowering them through strengthening of domestic institutions, provision of domestic markets and improvement of local government efforts to sustain infrastructures, social institutions and commercial institutions.

An effective research capacity building strategy aims to build scientific, technological and managerial abilities and capacities at the individual, institutional and organizational levels. To be successful, it should emphasize mechanisms that bring about a qualitative improvement in the way research is planned and implemented, and in the way results are disseminated.

In order to facilitate the transfer and adoption of knowledge generated, it is essential that capacity building efforts involve all stakeholders in the research process (including identification of issues, prioritisation, definition of research themes, activity monitoring and evaluation) and integrate traditional knowledge (Olsson 1996; Thulstrup 1996). This contributes to building capacity for the application of research findings.

Capacity building has three major components:

- strengthening institutions (legal and policy framework, support mechanisms, conducive environment);
- creating individual competence and strengthening a critical mass of human resources that is capable of planning and implementing agroforestry research projects to address the national agenda; and
- developing infrastructure (research equipment, buildings, facilities).

Temu (2003 unpublished) gives a rich illustration of the key components of capacity building. These include enabling policies, credible strategies and programmes, physical infrastructure, human resource capacity, financial resources, institutional power and voice, and networks or links with peers, clients and stakeholders (Figure 1).

Mechanisms for capacity building

The pooling of resources through networking is an essential element of any research capacity building project (Owino 1994). Networking can reduce the feeling of isolation and build critical masses of scientists within specialty groups in a virtual environment. Networking can take

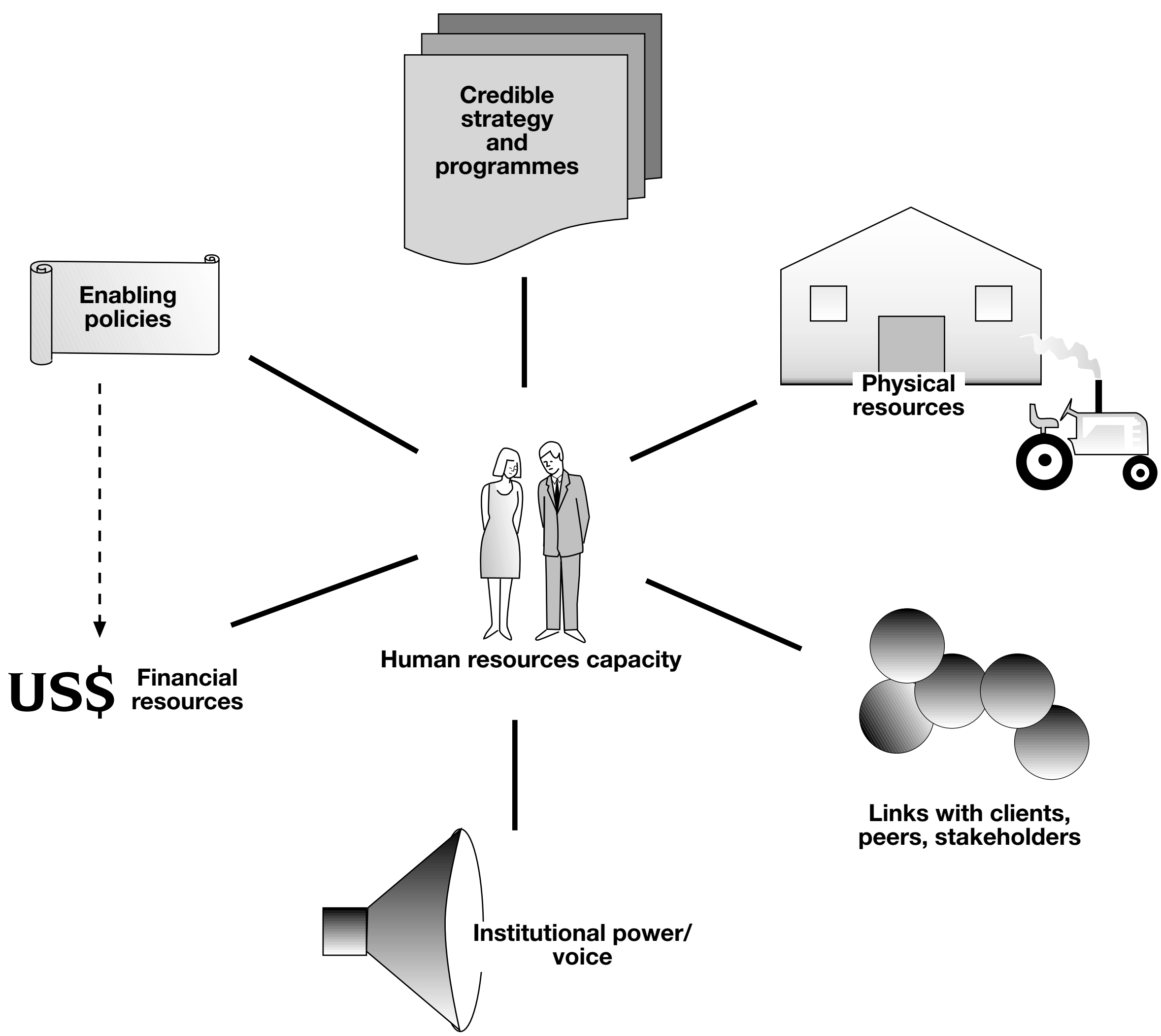


***Figure 1.** Key components of institutional capacity.*
Source: Temu (2003 unpublished).

many forms, including electronic, print or personal contact. All forms of networking should be encouraged, from local and national to regional and international. Networking ensures that neighbouring countries, and even institutions within the same country, share lessons and do not duplicate similar work. It must be pointed out, however, that networking has transaction costs such as communication and systems establishment. Well-developed scientific programmes are of little benefit if there is no participation from stakeholders and policy makers. Local input is essential to ensure the relevance of the work, and to create a sense of ownership once the science moves towards implementation in resource management and policy. Stakeholder engagement is a prerequisite for an effective capacity building strategy (Owino 1994).

The effectiveness of capacity building also depends on a step-by-step approach, beginning with existing capacity and activities. The goal is to make capacity building a unified process, within which particular activities can be organized and delivered in a logical order. Whatever the specific objectives of commitments or projects, capacity building is, above all, a long-term process that must emphasize the development of local structures and organizations.

In recent years, there has been increasing demand for research-trained manpower in key fields in many developing countries. There are several reasons for this, including global technology change towards more efficient research-based methods in both industry and agriculture, and increasing environmental concerns. The need for research-trained experts is often very specific for a given country and locality, and requires continuous production of research-trained human resources in the field (Thulstrup 1993).

One primary focus of research capacity building should be to engender and encourage relationships between institutions. These should focus on the links between developed and developing-country institutions, and between institutions within developing countries. Institutions may ask themselves several questions before deciding with which institutions to collaborate; for example, which organizational structures are to be involved? What institutional relationships need to be established between them? How are these relationships to be established? Which are the most crucial institutions with which to collaborate: those with similar interests, those with complimentary interests or those with completely different interests? (Szaro et al. 1997).

Another focus for capacity building is the strengthening of institutions, not only in terms of human capacity but also in terms of research strategies, policy and legal frameworks, communication capacity and research management capacity.

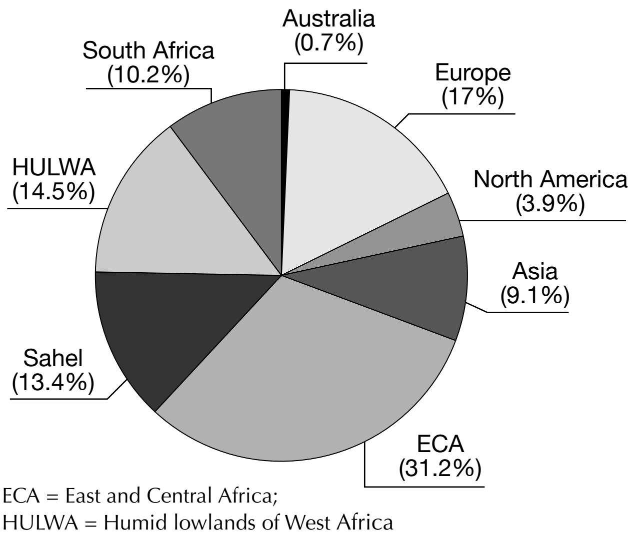
The World Agroforestry Centre's efforts to build research capacity

Since its inception in 1978, the Centre has built capacity in agroforestry in various ways. In the early days, capacity building took the form of preparing training materials, guiding in-house trainees, giving agroforestry lectures and contributing to seminars and world literature on agroforestry and its place in education. In 1982, the Centre held a major conference to discuss professional education in agroforestry (Zulberti 1987). The main recommendations were to: a) develop agroforestry into an experimental science that can be taught within the context of existing professional links; b) integrate agroforestry into existing courses, such as land use; c) incorporate agroforestry programmes at postgraduate level where appropriate; d) encourage short courses in agroforestry within institutions; e) develop agroforestry training materials that will be regularly updated; and f) encourage South–South and North–South collaboration between institutions. The Centre was seen as a major player in terms of supporting institutions to incorporate agroforestry and in providing material for agroforestry training.

Building expertise in agroforestry through graduate fellows

One of the main recommendations from the 1982 conference was to support postgraduate training in agroforestry through field research. This is producing new scientific knowledge about agroforestry systems in the context of agriculture, forestry and integrated management of natural resources. The knowledge is being absorbed and disseminated by teaching, learning and extension systems. It is also producing policy and technological innovations that encourage farming communities to adopt agroforestry. Collaboration between researchers, educators, development workers and farmers, and building on existing farmer knowledge/traditions is crucial in this process.

The World Agroforestry Centre has been helping to build the competence of individuals and the capacity of institutions through giving both financial and technical support. The technical support includes attaching students to Centre scientists and carrying out thesis research in Centre field sites. In the last 10 years, the Centre has supported 276 graduates at M.Sc. and Ph.D. level (the majority from Africa) to carry out field research in agroforestry (Figure 2). The highest percentage of trainees came from East and Central Africa (ECA). This is because the Centre has been



ECA = East and Central Africa;
HULWA = Humid lowlands of West Africa

Figure 2. *Geographical distribution of World Agroforestry Centre graduate trainees (1993–2003).*

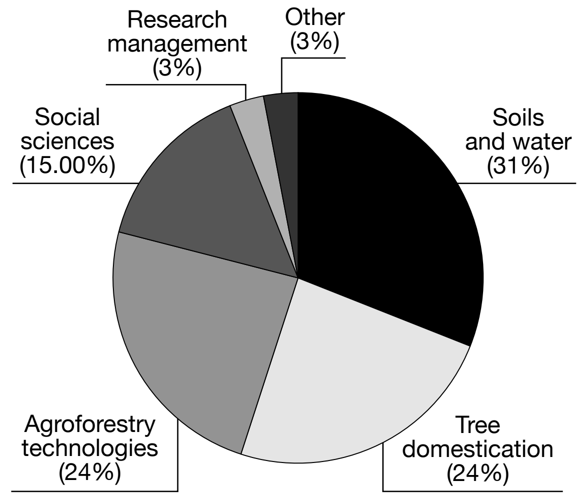


Figure 3. *Thematic areas pursued by World Agroforestry Centre degree fellows (1993–2003).*

very active in ECA and has many scientists based there. There are also more institutions teaching agroforestry at postgraduate level in ECA than in other regions.

The Centre has also trained many students from Europe, Asia and Latin America. Most of these are sent by major donors and are funded by their respective projects. Out of the 276 fellows 214 have pursued Masters programmes and 62 have pursued Ph.D. programmes. It must be noted, however, that the Centre has provided financial support (especially through the regional networks) to more than the 276 fellows reported here.

The thematic areas studied in postgraduate research are very varied and include soils and water, agroforestry technologies, tree domestication, social sciences and research management (Figure 3). Research under the social sciences has focused on issues such as marketing, extension, the role of agroforestry in poverty alleviation, adoption studies and studies on indigenous agroforestry knowledge. At the 1982 workshop, it was noted that agroforestry knowledge within the social sciences was very poor. However, Figure 3 shows that we have made positive developments in this area, with 15 percent of the fellows carrying out research in the social sciences between 1993 and 2003. Research management, although important, has only been studied by nine of the 276 fellows and has focused on geographical information systems (GIS), computer modelling and the effectiveness of agroforestry research with respect to funding levels.

Gender representation, although not equal, has been very encouraging (Figure 4). Around 32 percent of M.Sc. students and 37 percent of Ph.D. students were female. This is high compared to the general percentage of women working in agricultural sciences (12–15 percent).

One of the major achievements of the graduate programme is that it has built a critical mass of agroforestry experts in national agricultural and forestry services, especially in Africa. Although we have not formally followed up on individual trainees, we believe that many of them are working in forestry and agricultural departments of research institutions or universities.

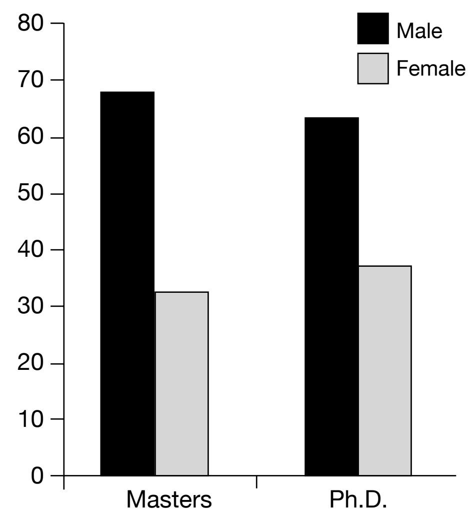


Figure 4. *Gender balance of World Agroforestry Centre degree fellows (1993–2003).*

Postgraduate programmes in institutions of higher learning

At the time of the 1982 agroforestry conference, there were hardly any postgraduate courses in agroforestry being offered by higher learning institutions, although a few provided courses on land use. By 2003, Africa alone had 31 institutions offering agroforestry as a postgraduate course (Table 1). Many others are now teaching agroforestry as a subject within other disciplines, such as forestry, agriculture and environmental sciences. In addition, several institutions have modified their curricula to include agroforestry (Table 2). The review and incorporation of agroforesty within the curricula of national universities ensures the sustainability of these programmes and facilitates interdisciplinary interactions.

Table 1. *Postgraduate education in agroforestry.*

Region	Number of universities
Africa	31
Australasia	4
Central and South America	3[1]
Eastern Europe and China	?[1]
North America	20
Western Europe	41
Southeast Asia	15
South Asia	?[1]

[1] Information not complete
Source: Temu (2003, unpublished).

Agroforestry research and education networks

Agroforestry research networks were started in Africa in the late 1980s and form an important component of the Centre's capacity building strategy. The networks have experimental sites in different countries in Africa, which provide excellent experiential learning for scientists from national research institutions and from the World Agroforestry Centre itself. Most of the research by the Centre's graduate fellows (as described above) is carried out at research sites managed by the networks.

There are now three main agroforestry education networks: the African Network for Agroforestry Education (ANAFE), the Southeast Asian Network for Agroforestry Education (SEANAFE) and the Latin American Agroforestry Network (LANAFE). These are described by Rudebjer et al. in Chapter 17 of this volume. In addition to these regional networks, many countries have also formed national agroforestry networks.

Issues and challenges in building capacity for agroforestry research

Agroforestry has come a long way since it was originally recognized as a simple extension of forestry. It was categorized in this way because the idea of planting trees appeared to fit best with the forestry profession, and foresters saw agroforestry as a way of helping farmers to produce their own tree products and reduce their dependency on natural forests. By and large, the early proponents of agroforestry were foresters (Temu, unpublished).

Agroforestry is now seen as a science that is of increasing interest to a wide variety of disciplines. Perspectives are changing and many new agroforestry programmes are being developed within agriculture, forestry, environmental education and other land-use programmes. Agroforestry is currently considered as an important entry point for holistic natural resources management studies within educational institutions. Temu and Garrity (2003) observe that agroforestry also provides an entry point for biodiversity education. Despite viewing agroforestry as a broad-based discipline touching on various sectors, most national agricultural institutes and university faculties still remain very sector-based with separate institutions for agriculture, forestry, wildlife, livestock, etc. Integrating the agroforestry agenda therefore represents a significant challenge, especially in cases where there is no institutional collabora-

Table 2. *Number of curricula reviewed to incorporate agroforestry in Africa (1993–2002).*

Discipline/level	Certificate	Diploma	First degree	Postgraduate	Total
Agriculture	2	4	15	2	**23**
Forestry	7	8	6	2	**23**
Other (e.g. rural development, horticulture)	1	2	3	0	**6**
New agroforestry programmes	0	4	5	6	**15**
Total	**10**	**18**	**29**	**10**	**67**

Source: Temu (2003, unpublished).

tion between sector-based institutions, ministries or faculties.

The sectoral nature of institutions, ministries and faculties brings new challenges within national programmes in terms of coordinating agroforestry activities. Despite recommendations at the conference in 1982 for more integration, this has not happened in most countries. In institutions of higher learning that do not offer postgraduate courses in agroforestry, students wishing to carry out their research in agroforestry have to find their own points of integration.

Funding constraints often prevent national agricultural research organizations (NAROs) and public universities retaining well-trained agroforestry staff. Once they become skilled, staff may move to the private sector, international research organizations or non-governmental organizations (NGOs), or go out of the region on teaching or research assignments. Although they may contribute in one way or another to research efforts in their home countries or regions, the high turnover presents a challenge for the national programmes. This problem is not specific to agroforestry and is linked to the more general 'brain drain' of expertise from the South to the North and, within countries, from the public to the private sector. For those that remain in the national programmes, regular salaries tend to be insufficient for sustaining an acceptable standard of living and a second income is often a necessity. Only rarely are second jobs conducive to research activities; usually they will take time away from research and (graduate) education. Lack of time and incentive for research therefore presents a serious problem for many developing-country research programmes.

Mainstreaming agroforestry into national programmes has been successful to a certain extent. In institutions of higher learning, agroforestry has become an area of study, even at graduate level, implying major policy changes in the recognition of agroforestry by universities. However, most of the agroforestry activities conducted in NAROs are donor funded and agroforestry has not become part and parcel of their core programmes and priorities. This is due mainly to persisting sectoral orientation.

Effective communication and sharing of information across sectoral barriers remains a daunting challenge at both local and national level. However, these problems are only part of the broader global capacity building challenge to promote, legitimize and institutionalize effective sharing of ideas and information across sectoral, national, cultural, linguistic and socioeconomic barriers. The increasing importance of electronic communication has often made matters worse for developing-country researchers, since the required facilities may not be available. In the long term, however, electronic communication is likely to become a valuable tool, helping developing-country researchers to overcome the long distances between them and other researchers in their fields.

Measuring the impact of capacity building efforts presents another challenge. There are various ways to do it, but each method has its own shortcomings. As with any impact assessment, issues of cause and effect will arise. A 'with and without' analysis suffers from bias, since the very effort that went into identifying target institutions would make any comparison suspect. A 'before and after' comparison assumes that over that same time period, there were no activities or initiatives affecting the institution other than the particular research capacity building efforts for which impact is being measured. Individual institutions therefore need to develop a combination of measures that will give the best results based on the objectives of their capacity building efforts. Examples of aspects that can be measured include:

- The number of people that have been trained (critical mass of expertise within organizations). This is really a measure of building research competence rather than research capacity.
- The number of publications produced by trainees. This approach has distinct limitations in that not all the good research is published, and there may be good reasons why some people do not or cannot publish their research results. Some work may be more effectively disseminated by means other than publishing in peer-reviewed journals. In many cases, there is a considerable time lag between the research results and publication.
- The funding attracted by researchers who have benefited from the capacity building effort. This has limitations, however, as comparisons may not be valid. Different institutions, especially in different countries, may attract different levels of funding based on their relations with donors. And this only measures researchers' ability to attract funding, not the impact of their research on the end user, i.e. farmers and the poor.
- The networks built by the institution. This measures the extent to which increasing the capacity of an institution increases its ability to establish partnerships with other international, regional and national organizations. While this is a good measure of the institutional growth as a result of the built capacity, it does not address issues of impact on the other institutions nor on the end users of the institutions' research products.
- Inclusion of agroforestry in national programmes is another measure of

impact that evaluates the extent of institutionalization of agroforestry within an institution's or a country's programmes. This can be measured in various ways including the evaluation of policy documents to assess whether and how agroforestry is articulated in these policy documents, the perceptions of key policy makers on the role of agroforestry, changes in practice, etc.

This kind of impact assessment and evaluation may be internal or external or a combination of both. There are advantages and disadvantages in internal and external evaluations and the two should be combined in order to reap maximum benefit from their advantages. While an internal evaluation allows and encourages learning, corrective measures and improvements, it may be subjective, since actors may fail to highlight weaknesses and concentrate on positive aspects. Building capacity in evaluation for learning and change can, however, reduce this risk. External evaluations may provide a more objective view of the strengths and weakness of an institution and the recommendations should be used to make improvements.

Conclusions and recommendations

Capacity building in agroforestry has come a long way since the 1982 agroforestry education conference. Most of the major recommendations from that conference have been implemented and the World Agroforestry Centre has played a leading role. However, significant challenges remain. The sectoral nature of research, education and administration has affected the institutionalization of agroforestry. Lack of funding and loss of staff to better-paying jobs also limits the effectiveness of capacity building efforts. In the institutions of higher learning that do not offer agroforestry as a full postgraduate course, it is still left to students of agriculture and forestry to integrate the two if they want to pursue research in agroforestry. Measuring the impact of capacity building efforts also presents a challenge.

New opportunities for capacity building in agroforestry are presented by forming links with sub-regional and regional organizations, such as the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) and the Forum for Agricultural Research in Africa (FARA). The World Agroforestry Centre forms a central point for linking educational institutions, NAROs, NGOs, donors and regional organizations (Figure 5). In the past, links between educational institutions and research institutions have been weak and have failed to address issues of strategy, such as joint research and education programmes involving different types of institutions. While links between research and extension have improved, there is still a gap between research and education. In most cases, the only points of contact are university students, who attend research institutions for experiential learning and to carry out their thesis research, and research staff, who attend university courses. These links need to be strengthened to promote sharing of information and development of coordinated agroforestry programmes.

A good model for improving the coordination of agroforestry education is the formation of a national agroforestry coordination committee. This would include representatives from different ministries or departments, universities, national agricultural and forestry research institutions, NGOs, the private sector and international agricultural research centres that are engaged in or have an interest in agroforestry. The World Agroforestry Centre is well placed to support the development of such committees.

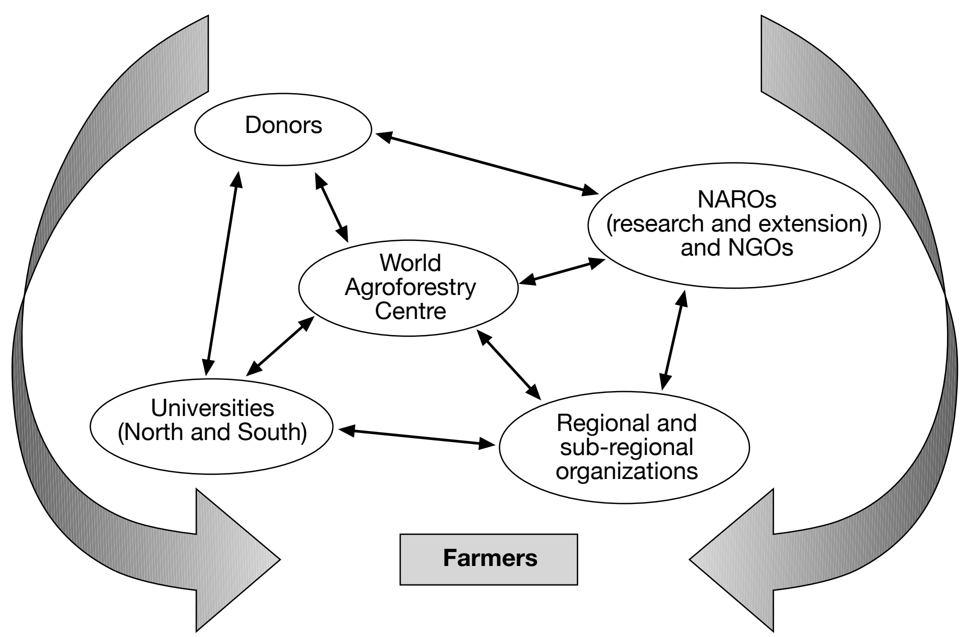


Figure 5. *Institutional links in agroforestry.*

The Centre has already been successful in creating national and regional partnerships and networks in developing countries. The next step will be to strengthen the links between them and agroforestry institutions in the North. The issues to consider when forming new types of partnerships are: a) the organizational structures that need to be involved; b) the institutional relationships that need to be established; c) the comparative advantage that each institution brings; and d) how to establish the relationships, including the sharing of credit/authorships and issues of intellectual property rights.

Relationships with institutions in the North would provide several benefits, including opportunities for overseas studies, joint review of agroforestry curricula, scientist exchange programmes, information sharing and improved communication technology, joint research and publications and access /training in new research methods and tools.

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Keywords:
E-learning, agricultural education,
Africa, Southeast Asia

Chapter 19

Can e-learning support agricultural development in developing countries?

Albert Dean Atkinson, *International Rice Research Institute*; Jan Beniest, *World Agroforestry Centre* and Sheila Rao, *World Agroforestry Centre* and *The Commonwealth of Learning*

Abstract

Advances in information and communication technology are opening up new opportunities for distance learning. Various centres within the Consultative Group for International Agricultural Research (CGIAR) have been developing electronic learning materials for use on the Internet, such as on-line short courses, CD-ROMs, on-line communities and collaborative sites. The centres have also developed virtual university courses for longer-term training. The CGIAR centres collaborate with national and regional partners in developing and using these e-learning materials. The centres are also creating a joint Learning Resources Centre. This will gather and coordinate learning materials based on ongoing research from contributing CGIAR centres, especially material with cross-disciplinary applicability, such as statistical analyses or scientific writing. These materials will be adapted for a broad range of applications, and will be presented in different media and levels of interaction, depending on local circumstances and the context of learning goals.

Introduction

Agricultural research and development (R&D) institutions in developing countries often have problems keeping up-to-date with advances in international science and technology. Members of the Consultative Group on International Agricultural Research (CGIAR) are working with many national institutions to help them improve in this area. For countries with few scientists and weak institutions, the CGIAR may help directly by organizing training programmes or providing materials and resources; while in countries with many competent scientists and well-functioning institutions, they adopt a collaborative and partnership approach through networking and sharing knowledge.

The training and education materials developed by the CGIAR are in great demand and are reaching audiences far beyond the participants of in-house training events. The materials can be translated and adapted to meet the needs of specific audiences in regional settings, but they need to be produced in partnership with national institutions to ensure ownership.

Face-to-face-based learning tends to be costly, particularly because of travel and accommodation expenses. Advances in information and communication technology (ICT) mean widely scattered audiences can now find out about recent developments in agricultural R&D and natural resource management. Although the innovations are proving successful in developed countries, problems with communications infrastructure and access to computer facilities have made this approach more difficult in developing countries. This chapter highlights some of the difficulties and takes a critical look at the new CGIAR approaches towards building capacity and strengthening institutions using electronic-based ICT.

ICT in training and education

When considering ICT, experienced educators know that the characteristics of the audience for whom the training is targeted and the content of the training, (for instance, will it close the knowledge gap?) are more important than the technology that delivers the training. For over 50 years, training professionals have relied on the instruction systems process as a guiding method for designing training (see Figure 3).

Information and communication technology is not new, nor is it limited to transferring large amounts of information at the speed of light across the Internet. Essentially, ICT is any technology that transmits information – whether it is cave paintings, smoke signals, kites, books, CD-ROMs, television, radio, or computers and the Internet. "It is an expanding assembly of technologies that can be used to collect, store and share information between people using multiple devices and multiple media" (Chapman and Slaymaker 2002). Despite the broad definition of ICT, we focus on advances in electronic and computer-based ICT here.

Development organizations working to improve access to information and education seem to be intrigued by the possibilities of ICT and there are good levels of funding for ICT-driven capacity-building projects. It is interesting to note that the pattern of interest in e-learning from development organizations resembles that of corporations in 2000/01. John Chambers, President of Cisco Systems Inc. claimed in 1999 that "the next big killer application for the Internet is going to be education. Education over the Internet is going to be so big it is going to make e-mail usage look like a 'rounding error' in terms of the Internet capacity it will consume" (Chambers 1999). So what happened? Figure 1 highlights the corporate e-learning experience from 1996 to 2003.

When the 'dot com' bust occurred in 2001, corporations began to realize that their corporate university investments were not providing a good return and they started to dissolve the mechanisms. Within six months, Electronic Data Systems, one of the world's largest ICT service providers, cut their corporate university from 245 staff to 25.

Kruse (2003) states: "Then 2001 brought the harsh, steep slope of unfulfilled promises. Several high-profile providers shut their doors while many more announced large-scale layoffs in the face of missed revenue targets and crashing stock prices. E-learning advocates retreated to the more defensible ground of 'blended learning.'"

The World Bank's 1999 World Development Report suggested that advances in electronic and computer-based ICT would allow 'unprecedented opportunities' for the world's poor. "Advances in communications have transformed society before: movable type, photography and telegraphy, the telephone, television, and the fax machine have all pushed outward the limits of our ability to store and transmit knowledge. Now the converging of computing and telecommunications appears ready to shatter those limits,

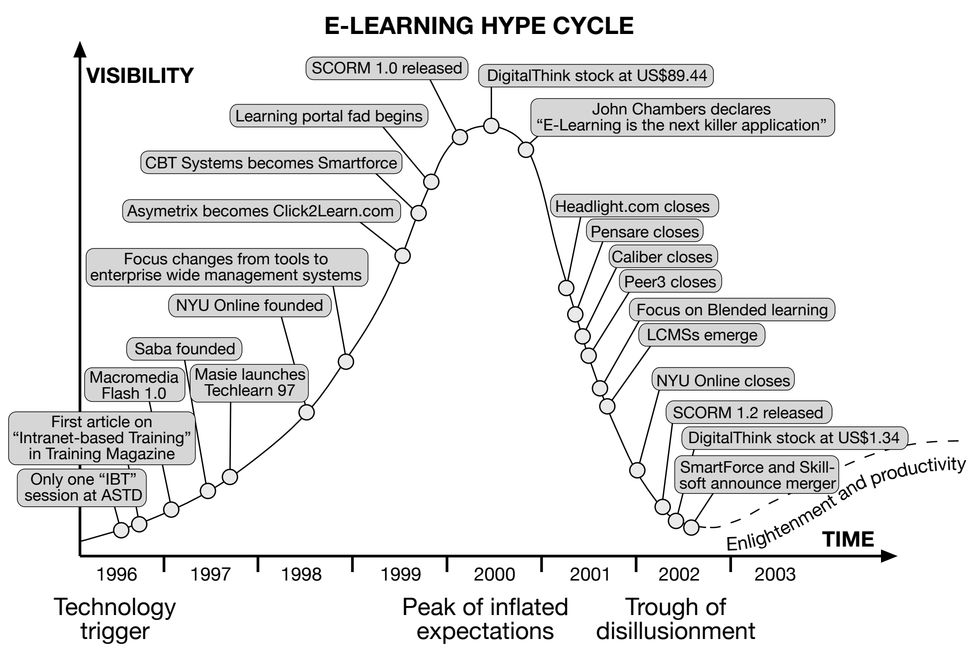

Figure 1. *E-learning hype cycle.*

Note: Figure illustrates the wave of interest and investment in e-learning. The acronyms are not relevant in this context.

Source: www.e-learningguru.com/articles/hype1_1.htm making it possible to send vast amounts of information anywhere in the world in seconds – at an ever-decreasing cost. This new technology greatly facilitates the acquisition and absorption of knowledge, offering developing countries unprecedented opportunities to enhance educational systems, improve policy formation and execution, and widen the range of opportunities for business and the poor.” (World Bank 1999).

While encouraging, the World Bank statement places a tremendous responsibility on educators and trainers. But while the technology will greatly facilitate information acquisition, it will do nothing for the ‘absorption of knowledge’ if the content is not structured and organized in a meaningful way. In other words, technology alone does not ‘create’ knowledge; it is the quality and design of the content that matters. Poorly designed and structured material delivered by distance learning is just as ineffective as when it is delivered face-to-face.

Computer and Internet availability, policies and training vary widely throughout Africa. For example, in 2001 in Kenya 1.6 per cent of the total population were Internet users. In Zambia, the figure was less than one percent (World Bank 2002). These figures are increasing rapidly as people realize the benefits of ICT. Professor Abdulrazak, Deputy Vice Chancellor of Research and Extension at Egerton University in Kenya believes that “investing in computer-based distance learning allows greater opportunities for future generations of students and faculty to access and to fully take part in the global information society” (Abdulrazak 2004). However, Internet access is limited, at present, to well-resourced, well-funded institutions and regions.

Table 1 shows that most Internet users are in North America, Europe and, to a lesser extent, Asia and the Pacific Rim. Africa has the lowest user numbers, next to Latin America. It also illustrates the large gap between usage, indicating the difficulties associated with developing e-learning. However, the number of users is rising everywhere.

Limited Internet connectivity and bandwidth availability is a major obstacle to increasing Internet use and e-learning in Africa. Figure 2 shows the connectivity in Africa through bits per capita (BPC). This takes into consideration the wide range of Internet applications available, from personal use to cybercafes and business transactions. The map shows the International level (bpc) bandwidth available in each African country with the darker shaded countries having the most accessablity and the lighter shaded countries with the least. The high percentage of outsourcing Internet and satellite coverage outside of Africa makes bandwidth availability expensive because of the telecommunication and administrative upkeep of such a system, and limits the amount of Internet use in educational settings. The average cost of using a local dial-up Internet account for 20 hours a month in Africa is about US$60 (Etta and Parvyn Wamahiu 2003).

Despite the technical barriers to computer-based ICT development in Africa (and to a lesser extent in other regions), e-learning is developing in response to the growing need for access to education. Even where reliable Internet connection is not yet possible, e-learning is being developed, based on the assumption that ICT infrastructure will continue to grow in the coming years. Therefore, establishing the theoretical and pedagogical background in e-learning will ensure valuable benefits in the future.

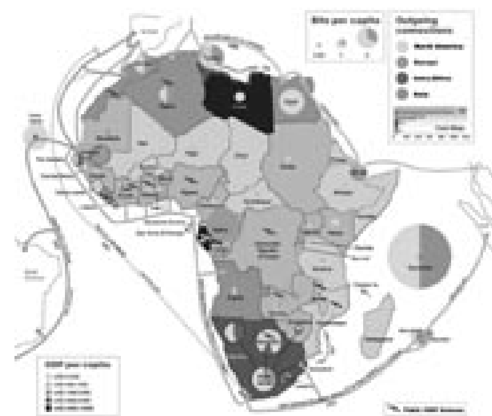

Figure 2. *Internet connectivity in Africa.* Source: IDRC 2003. For the full colour version of this map see http://web.idrc.ca/en/ev-6568-201-1-DO_TOPIC.html.

Table 1. *Active adult Internet users aged 14 and over, worldwide (in millions).*

	2000	2001	2002	2003	2004
North America	97.6	114.4	130.8	147.7	160.6
Europe	70.1	107.8	152.7	206.5	254.9
Asia and the Pacific Rim	48.7	63.8	85.4	118.8	173.0
Latin America	9.9	15.3	22.1	31.0	40.8
Africa and the Middle East	3.5	5.3	7.2	9.0	10.9
Worldwide total	229.8	306.6	398.2	513.0	640.2

Source: Dennis (2000).

Learning in e-learning

It is important to recognize that human learning is a complex psychological process. It can be structured or unstructured, formal or informal, supervized or unsupervized and carried out with or without the assistance of a teacher. 'Distance' or 'e-learning' is also referred to as correspondence education, distance education or training, distributed learning, on-line learning, open learning and web-based learning. For the sake of clarity, we consider the term 'e-learning' to be a catch-all phrase that suggests learning at a different time and in a different place (asynchronous learning), aided by a computer connected to the Internet.

A literature review of e-learning finds recurring references to its advantages over face-to-face learning. But, just as e-learning is neither inherently cost-efficient nor cost-effective, its advantages cannot always be assumed. For example, e-learning instructors need the same amount of time to facilitate a course as a face-to-face instructor. The student–instructor interaction still exists, but through the telephone or e-mail. E-learning allows students to maintain flexible hours and reduces travel and relocation costs. However, this is based on the assumption that the learner has continuous access to a computer and/or the Internet at any given time. In some regions, e-learning takes place in cyber cafes where accessibility is limited.

Many of the often-claimed advantages of e-learning will be realized only if the instruction is properly designed. So how can this be assured? The answer lies in the mechanics of the instructional systems design (ISD) process model (Figure 3).

The ISD process begins by analysing an audience's current state, comparing it with a desired state, then examining the gap between the two to see how it can be bridged. The point is to design content in a way that brings users closer to the desired state. The content is then developed and delivered. An evaluation closes the loop to check whether the design of the instruction was effective. The ISD model ensures the learning materials are of good quality and that the learning process, the instructional design of the materials and the learning outcome is not compromised as a result of the technological tools used.

Training and education and computer-based ICT

"ICTs, as any tools, must be considered as such and be used and adapted to serve educational goals. It is educational needs and goals, not materials or technology that must drive educational change. Many ethical and legal issues concerning widespread use of ICTs in education are yet to be solved" (UNESCO 2004).

Terry Hilberg, Chief Executive Officer of NextEd suggests, "In Asia, people like to sit in classrooms with a professor at the front of the class, handing out pearls of wisdom to a silent student body" (Raths 2000). This learning style is the opposite of learning at a distance, where the 'pearls of wisdom' are the product of student interaction and discussion, facilitated by an instructor.

Therefore, culture – not access – may be the main barrier to overcome before the CGIAR partners and target audiences begin to appreciate e-learning. As a result, course compilers are moving away from structured e-learning courses and towards packaged reference guides, fact sheets and stand-alone learning objects that can be translated and customized by national partners to provide training in the local context.

Table 3 summarizes the opportunities for using computer-based ICT, the issues that arise in training and education, and the role CGIAR centres can play in this area.

In March 2003, the World Agroforestry Centre conducted an e-survey of 45 academic agricultural institutions located in various countries in Africa and Asia (Tossell 2003). The survey explored the degree of interest of partner institutions in e-learning activities, their level of Internet usage and their Internet connection reliability in four categories: news updates, on-line databases, on-line courses and on-line communities. The intent was to gauge the degree of interest in using selected e-learning activities. A second part of the survey looked at Internet use and connection availability to establish possible links between personal interest, use and availability.

The results of the survey showed that there was interest in expanding the use of ICT

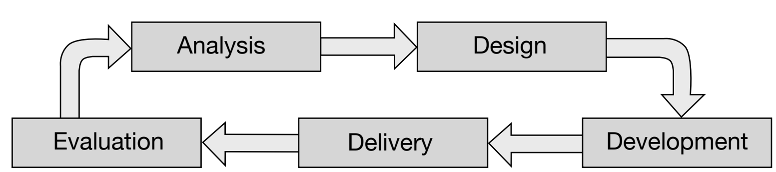

Figure 3. *The instructional systems design process model.*

Box 1. The Rice Knowledge Bank

The Rice Knowledge Bank at the International Rice Research Institute (IRRI) is a repository of training and extension resources. It receives an average of 634 visitors a day, with a total of more than 2.5 million web hits since its launch in April 2002. Its content is screened before publication with three criteria in mind: i) is it credible? ii) is it value-added, i.e. has it been organized in a format and sequenced in a way that promotes easy understanding? and iii) is it demand driven? For the demand-driven criterion, the Knowledge Bank uses statistical web traffic-monitoring software. This provides:

- A live view of the formats users prefer, measured by the frequency of downloads for specific formats.
- Keyword query analysis that indicates the subject areas users are most interested in, as indicated by the frequency of certain keywords that are typed into the knowledge bank's search field and those that are used in the Internet's leading search engines to find content on the knowledge bank.
- Demographic analysis of where the users are located and the types of systems and software they are using to access the Knowledge Bank.

Source: Albert Dean Atkinsen www.knowledgebank.irri.org.

Table 3. *Summary of e-learning tools.*

Type of e-learning source	Function
Web-based on-line courses	Administered through the Internet, have flexible time schedules, alleviate geographical barriers
On-line databases	Network host provides a central repository of information accessible from anywhere in the world
Moderated listserves	Technologically easy to set up, e-mail lists are well adapted to low bandwidth situations Requires consistency in moderating list activities
On-line communities	Builds international links based on research, elaborates on existing education and training courses Less common than e-mail, more affected by bandwidth restrictions
CD-ROMs	Converts hard-copy documents into electronic versions Widespread usability
Virtual universities	Provides on-line courses to those without access to university facilities Requires high-powered networks and computers

for disseminating information and education, despite a lack of reliable Internet connection (Table 4). When asked about personal Internet use, 53 per cent of respondents said they used it frequently, but only 31 per cent thought their connection was reliable. The survey also showed that most institutions viewed on-line databases and news reports as the most useful forms of e-learning.

The relatively low interest in on-line courses and communities suggests a correlation between the level of interest and usage in computer-based technologies and lack of reliability in Internet connections as well as limited relevance of current Internet courses. Those with little access or slow connections and minimal technical support may not see on-line communities as appropriate or feasible. The low figures also suggest that exposure to and understanding of on-line communities is limited, and thus they are not perceived as useful. Similarly, on-line courses are perceived to need a more efficient Internet connection than is currently available in some areas. Using on-line communication as part of an existing course or lesson plan may be more readily accepted.

Using a combination of various types of e-learning or 'blended learning' such as on-line databases, recent agroforestry news updates, on-line communities and on-line courses may be appropriate to match the benefits of ICT in education and training to user needs and capabilities. For example, a particular web site or repository may contain links to on-line databases, provide updated research information and offer short-term courses or sections of training courses. Alternatively, an existing course may contain on-line components or opportunities for discussions pertaining to face-to-face learning and course content.

Table 4. *Interest in different methods of e-learning.*

Method of ICT delivery	Most useful method (%)
News and current events about agroforestry research	32.5
On-line databases of agroforestry information, including research papers and training materials	29.4
On-line courses covering news and current events about agroforestry research	19.7
On-line communities, using group e-mail and special web sites to share information with agroforestry practitioners worldwide	18.2

Source: Tossel (2003).

On-line communities

Various types of e-learning methods can be categorized as on-line communities. They range in complexity from very simple list-serves to more complex interactive conferencing or live chats. Recent workshops and courses hosted by the Centre have used on-line communities to give international course participants access to information before the course (for example, background information on course topics, preliminary reading and contact information of other participants). After the course, the on-line community can act as a venue for follow-up discussion and resource sharing. The concept of the on-line community was tested after two Centre training courses and the investigators found that most members participated at least once, but problems with Internet access limited the consistency of participation.

Developments in ICT allow CGIAR centres to work together when developing learning resources. This helps avoid overlap and duplication of effort in subject matter, such as experimental design, participatory research, scientific writing, data analysis and training methods. Using software such as MicroSoft SharePoint Team Services (see www.microsoft.com/windowsserver2003/techinfo/sharepoint/wss.mspx) or Internet services such as D Groups (see www.dgroups.org) gives research and resource teams the ability to create and manage web sites where they can communicate, share documents and work together on developing training materials of mutual interest, regardless of the physical location of team members. Issues surrounding access to the server from different regions prevents interregional collaboration due to bandwidth restrictions and varied Internet infrastructure. D Groups was designed with low bandwidth regions and limited Internet access in mind. It provides a service for international collaboration, provided the appropriate type of community is implemented, depending on where community members are located. Communities can be based on particular topics relevant to developing countries. For example, a global community was formed to discuss the use of scenarios as a decision-making tool for communities located at the tropical forest margins.

In rural areas, on-line communities can be as simple as a listserve accessible through an internet cafe or telecentre. Recent Centre activities for teachers from eastern and southern Africa used listserves to follow up the course and to share and exchange information. Most participating teachers were based in rural areas with limited access to the Internet. They overcame this by having Internet-based e-mail addresses and using Internet cafes in nearby cities. Thus, the on-line community, in this context, suited the audience and information could be shared.

Virtual universities

Advances in ICT have allowed open and distance learning universities to change the way they provide formal education. Correspondence courses can now be delivered via radio, television, fax, telephone and the Internet. Virtual universities are an alternative to open universities and administer their courses over the Internet as interactive web sites, on-line seminars, e-mail discussions, CD-ROMs and on-line video conferencing. Many of these concepts are used in universities in developed countries and the model is being adapted in an attempt to increase access to education in developing countries.

The CGIAR centres have generated large amounts of scientific knowledge, have the resource persons to impart such knowledge and have contributed to the education of a vast number of students. The CGIAR Global Open Agriculture and Food University (GO–AFU) aims to extend collaboration with national institutions and provides opportunities to enhance teaching and learning in developing countries. This initiative will provide a link between technical and theoretical expertise from well-established university institutions in developed countries and educational institutions in developing countries. Opinions on whether this is needed vary amongst participating centres. Some feel that it goes against the grain of strengthening national institutions and risks competing with and potentially weakening them. Others are concerned about the cost-effectiveness. CGIAR scientists contribute to short-term training and education activities as resource persons, but that is less of a commitment than teaching or supervizing students in an open university.

A similar initiative headed by the Norway office of the United Nations Development Programme (UNDP) will soon begin to offer global courses on environmental and development issues under the Global Virtual University (GVU). "Courses offered by GVU will be primarily directed at students from developing countries" (UNDP 2003). However, the kinds of technologies and software being used are congruent with developed-country standards of e-learning rather than existing electronic technology available in developing countries.

The African Virtual University (AVU) offers on-line courses that are administered in Africa but originate from Europe and America. This World Bank-funded project was established in 1995 to serve students from sub-Saharan Africa. The initial phase took place in Kenya, where the virtual university "rightly focused on science, engineering, business and the medical fields, as a technology-based distance education alternative" (Amutabi and Oketch 2003). Universities in several African countries participate in these courses and act as focal points. Sourcing the project externally, however, increases tuition fees and dependency on global support instead of building local infrastructure that would also build local knowledge. The bulk of the course materials come from Colorado State University, the University of Massachusetts and the New Jersey Institute of Technology (in the USA) and University College Galway (in Ireland), which increases the cost of administration and delivery. In addition, since the course content originates from outside Africa, it is not oriented specifically to African situations. Therefore, the long-term impact on African students depends on the students' employment options and, more importantly, whether they can afford the course.

E-learning resources

Until recently, the CGIAR centres produced materials for their training events in traditional formats (print on paper, slide series, videos and audiotapes). Advances in ICT allow them to develop and produce materials on floppy disks and CD-ROMs or as downloadable files from web sites. One of the main advantages of electronic formats is that they can be updated easily to reflect changes and advances in subject matter, and they can be adapted to suit the needs of different audiences.

E-learning resources can be viewed on-line by anyone interested in training and education in agriculture and natural resource management. In 2003, a number of CGIAR centres decided to collaborate as a training community and proposed a project entitled the CGIAR Learning Resources Centre. The idea is to package learning materials produced by different CGIAR centres (such as documents, models, images, video clips and presentations) into 'value-added' learning materials (i.e. in addition to instructional direction they will provide additional references and course materials, contact persons, etc.). The content is based on individual centre research focus (e.g. natural resource management, genetic resources, livestock, roots and tubers, rice, wheat and maize). Materials are offered in various formats, such as an electronic reference guide, an e-learning course, a fact sheet or a slide presentation. All are designed in a way that allows further formatting depending on the users' needs, while maintaining a common look and feel. It is hoped that the materials will be used by the CGIAR training community, national partners and the international agricultural community in general.

Conclusion

The Internet and computer technology offer many opportunities for supporting training in international agricultural research and development. However, technologies must be practicable for the intended audiences. Content developers must understand how computer-based systems can manage, facilitate and support – but not replace – conventional training methods. Internet access also opens the way for many new and long-distance partnerships. Materials offered by e-learning must be adapted to the local context, usually by consulting with national education institutions. There are various approaches to e-learning, each of which is appropriate in a different situation. Computer-based learning has the potential to increase accessibility to education and training although, in some parts of the world, lack of Internet access currently presents a barrier. A 'blended approach' applies the most suitable ICT to a region and particular audience. Often face-to-face teaching combined with computer-based technology provides added value to the educational process.

The potential for a project like the CGIAR's on-line learning resources can only be realized with sound planning and technical appropriation. Using inexpensive, low bandwidth programmes allows greater access by those directly in need of agricultural and natural resource management information and those with little experience of the Internet or computer technology. Although e-learning no longer carries the hype from previous years, it has the capacity to enhance learning and expand access to education and training in agriculture and natural resource management at the global, regional and local levels.

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Chapter 20

Strengthening Institutions: Working Group Report

Strengthening capacity for scaling up agroforestry technologies

Goal

To create a high level of awareness of the benefits of agroforestry among stakeholders. This will encourage agroforestry development projects and contribute to wider rural development.

Strategic issues

The World Agroforestry Centre needs to define its vision and strategy for scaling up and its role in relation to those of its partners. Successful scaling up means improving the quality and quantity of learning resources available to extension staff. Training in the areas of policy, management, markets, biotechnology, land degradation and indigenous fruits should also be enhanced. Developing support networks and a mechanism to update knowledge on natural resource management should enhance the links between research, education and extension. It is therefore important to conduct a needs assessment for training at this level, and to establish baselines for impact. Another crucial issue is to identify partners who can contribute to scaling up.

New approaches and opportunities

New approaches to capacity building should make use of:

- people-centred and site-specific approaches to sustainable rural development;
- national agroforestry centres of excellence, including national agroforestry training teams;
- information and communication technology (ICT) for natural resources management programmes;
- national agroforestry dissemination centres;
- farmer extension skills;
- networking between institutions and community-based organizations; and
- seminars and demonstration plots.

There is a trend for many developing countries to decentralize government administration and create grassroots ownership of the development process through basing research on local needs. Furthermore, natural resources and agricultural policies are being reviewed to include agroforestry. These developments provide opportunities for strengthening the role of local communities in policy and strategy formulation, which will help in the scaling up and out of agroforestry innovations. The Centre should tap into the potential of existing regional and national education networks and forge links with such regional bodies as the Forum for Agricultural Research in Africa (FARA) and its sub-regional organizations.

Constraints

In many national institutions, the infrastructure to support agroforestry is not well established. Agroforestry is often handled within forestry or classified under 'agriculture' and, in many cases, it appears in both disciplines. Whatever the institutional arrangements adopted by different countries, the key issue is the need for better coordination of agroforestry research, education and development. The sectoral orientation of national agricultural development programmes has not helped matters. Thus, in building agroforestry capacity, the Centre should pay attention to aspects of institutionalization. Agroforestry training materials are available in few languages other than English. For local communities to really benefit from them, they need to be translated and adapted to fit local social, cultural and environmental conditions. In some countries, there are no financial incentives to plant trees. It is important to build capacity at policy level to ensure opinion leaders understand and support agroforestry and tree-planting activities and the links between agroforestry and livelihood improvement.

Strategic partnerships

The Centre's partners include training and extension institutions, non-governmental organizations (NGOs) and government agencies working with farmers, national agricultural research institutions, farmers and farmer organizations, private sector agro-food processors and private investors. The Centre should identify the different roles played by these partners and their comparative advantages for various activities.

Further strengthening of educational programmes

Goals

Agroforestry should be accepted as a broad discipline and institutionalized by educational systems. This would result in stronger curricula, programmes and delivery of resources, as well as a team approach to teaching across disciplines. Stronger links between research, education and extension are essential. Moreover, postgraduate research and theses contribute significantly to research outputs.

Strategic issues

Agroforestry should be marketed as a multidisciplinary field of study. An analysis of education policies, institutions and environment could identify strengths and weaknesses in current agroforestry teaching and learning. Experiential learning for both staff and students is one way forward. Current efforts to improve curricula should be intensified and, possibly, linked to efforts to build programmes in eco-agriculture, biodiversity and environmental management. The greatest challenge is to train more educators. Many institutions still lack adequate human resource capacity in agroforestry. Collaboration and sharing (networking) among institutions would help to temporarily alleviate the shortage, but long-term investment in training educators is an imperative. Institutions of learning also need to forge better links with farming communities. For a long time, educational institutions have taken learning as an objective in itself. There is a need for them to link learning to social and economic development of local communities.

New approaches and opportunities

The Centre should form strategic alliances with funders of graduate studies to increase agroforestry thesis research. The emphasis should be on integrated watershed management (multidisciplinary approaches) and participatory development of methods and tools in agroforestry education. Greater use of information and communication technology (ICT) to distribute teaching materials should be explored and private-sector participation should be encouraged. African leaders have expressed a commitment to enhance agriculture and this is an opportunity to raise awareness of the benefits of agroforestry, which will lead to its wider inclusion in educational programmes.

Constraints

The resources and facilities to support agroforestry education are generally weak. In some countries, unfavourable policies and lack of recognition deter people from entering careers in agroforestry. National governments and institutions should therefore be encouraged to commit more resources to support agroforestry education.

Strategic partnerships

There is a need to work with a broad range of partners – farmers, NGOs, industry, policy makers and international agencies, especially those working on tree products. There should be greater private-sector involvement, for example through agro-industry and equipment manufacturers. Links should be cultivated with micro-finance institutions and entrepreneurs in education and educational technologies, as well as twinning arrangements with developed-country institutions.

Improving national research capacity

Goals

To mainstream agroforestry and integrated natural resource management initiatives into national agricultural research systems (NARS). With good research–education–development links and sound postgraduate programmes at local universities, agroforestry research outputs from local institutions would have greater impact on agricultural development.

Strategic issues

Current research support strategy is to facilitate the development of better agroforestry research programmes by national agricultural research organizations (NAROs). This can happen if agroforestry is accepted as a priority in solving real development problems. However, agroforestry research can only be successful if the various sectors involved collaborate. The Centre should help build capacity for joint resource mobilization and encourage institutional links, especially among different disciplines and across countries and regions. Bringing together researchers in such disciplines as agriculture, forestry and animal sciences is the key to forming links among different disciplines.

Another aspect is the need to raise the human resource capacity, especially through postgraduate fellowships. This is a priority for many institutions, irrespective of disciplinary background. In this context, thesis research should be aligned to national priorities and, preferably, implemented as part of a national agenda. Weak areas, such as biometrics and participatory research, require special attention. Follow-up and support of alumni are necessary to enhance future research collaboration and networking, especially across disciplines.

New approaches and opportunities

It is vital to establish mechanisms to mentor institutions, as well as institutional links, partnerships and networks through North–South and South–South collaborative programmes. One way to do this is to establish peer review mechanisms. Colleges, universities, research institutes and extension organizations generally operate as independent, de-linked institutions and would benefit from mechanisms to facilitate better coordination. Integrated NARS that include research, education and extension, should be promoted.

Strategic partnerships

Strategic partners for national research institutions include universities, international agricultural research centres, investors, regional economic bodies, advanced research institutions and funders of research and postgraduate education.

Improving knowledge management

Goals

To make stakeholders in agroforestry more conscious and more active in advancing knowledge management as well as increasing the application of knowledge to development. This will lead to a better flow of knowledge on agroforestry and natural resources management through knowledge systems at all levels.

Strategic issues

Knowledge is increasingly playing a central role in development. Knowledge management is therefore very crucial for every society and institution. Advances in electronic tools for sharing information are enhancing our capacity to gather, analyse, systematize/organize, store, retrieve and apply knowledge. Indeed, the World Agroforestry Centre is lending support to the Consultative Group on International Agricultural Research (CGIAR) Learning Resource Centre (see Chapter 19, in this volume). All materials posted here must be peer-reviewed and partners must participate in the development and management of web-based tools. However, in some countries the electronic infrastructure is still weak. There is therefore a need to also work with more traditional tools to make sure stakeholders with poor access to electronic resources are not excluded. On-farm practical learning facilities enhance the participation of local communities and guarantee capture and use of indigenous knowledge.

Research scientists should adopt knowledge management principles and practices. To achieve this, it is important to mentor researchers in communication and public awareness. The Centre should also develop a content taxonomy/classification for agroforestry knowledge and shape it to address the needs of different stakeholders (research and academic institutions and development partners).

New approaches and opportunities

There is a need to strengthen the use of networks. Available knowledge is largely in print format and in English. It should be produced in multimedia formats and translated into other languages to facilitate access by the majority of stakeholders.

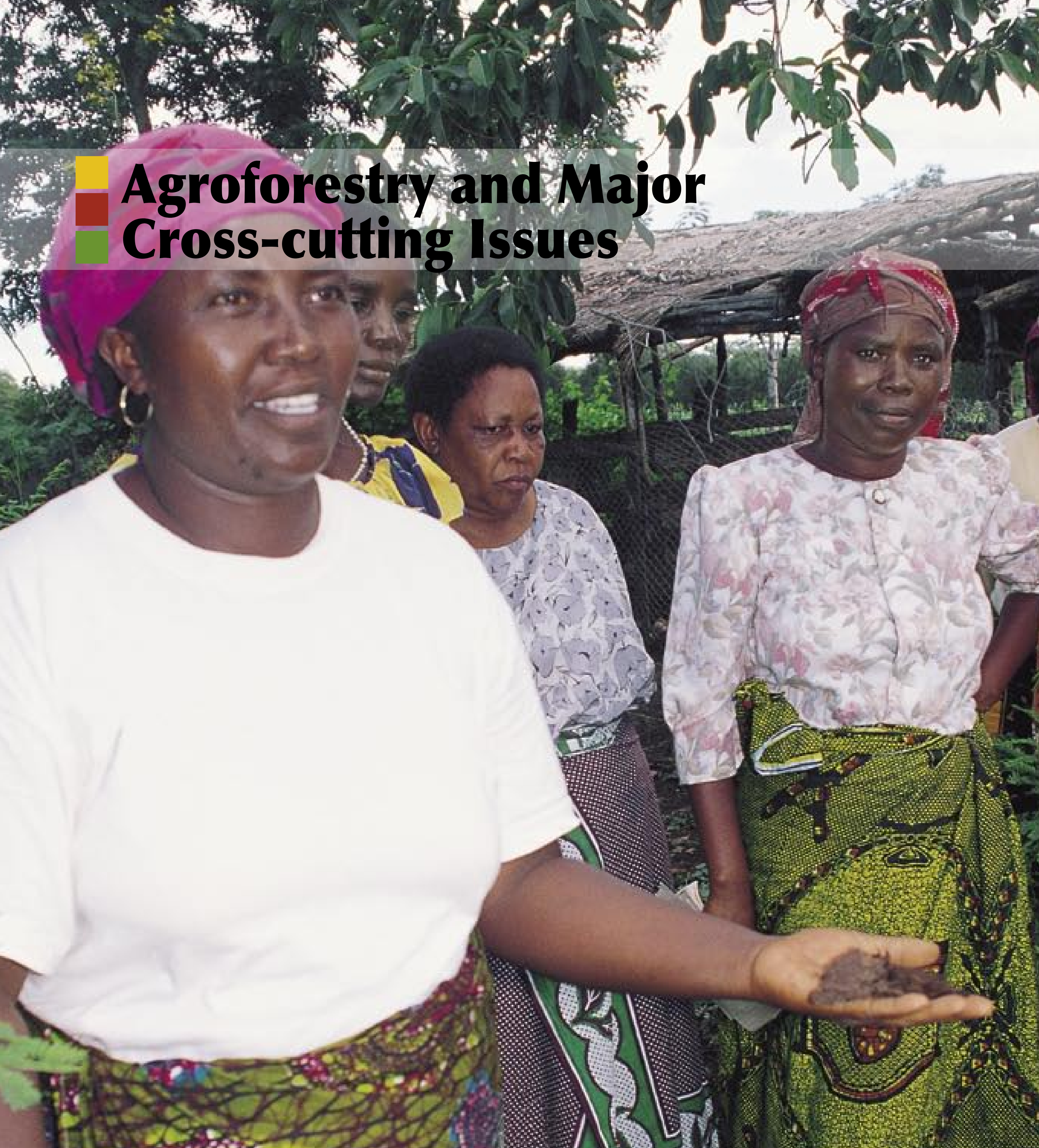
Constraints

In knowledge sharing, there is a real risk of being technology-driven, rather than demand-driven, in delivery strategies. Many partner institutions have inadequate information and communication infrastructure and the Centre should be sensitive to this. Knowledge should be managed in close collaboration with national institutions, so they increasingly take leadership. This is necessary for the long-term sustainability of the effort. Maintenance costs for databases and web sites should be mainstreamed into national and private systems.

Conclusions

The World Agroforestry Centre continues to play a leading role in agroforestry capacity building. In the future, national institutions and regional networks are expected to play increasing roles. They will only succeed if strategies and resources are made available to facilitate the mentoring of national institutions and networks. The Centre will need to work closely with its partners, especially in developing strategic programmes and mobilizing resources. In this context, farmers' organizations should be recognized as institutions and be supported, especially in their approaches to dissemination of knowledge. The Centre's new 'Strengthening Institutions' theme is a timely initiative and will help address the new challenges.

Agroforestry and Major Cross-cutting Issues



"The biological characteristics and wide range of resource types provided by trees on farms makes them invaluable in efforts to promote sustainable rural development and restore damaged ecosystems."

Sadio and Negreros-Castillo

Keywords:
Trees outside forests (TOF), agroforestry, livelihoods, sustainable rural development, improving the global environment, landscape restoration

Chapter 21

Trees outside forests: Facing smallholder challenges

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Abstract

During the past three decades, rapid population growth has been accompanied by increased demand for agricultural land and forest products. As a result, widespread degradation of natural resources, desertification and loss of biodiversity has occurred, together with food insecurity and extreme poverty in the most vulnerable areas. Trees offer great potential to restore degraded ecosystems, to enhance livelihoods based on production of food and medicines and to provide environmental and economic benefits. It is now agreed that a bold approach is needed to promote tree planting and improve the management of trees outside forests (TOF). The sustainable management of TOF resources will play an increasing role in efforts to reduce land degradation and poverty and improve food security, if appropriate policy measures are taken and farmers are placed at the centre of development efforts.

Introduction

During the past three decades, rapid population growth and expansion of agriculture has led to widespread degradation of natural resources. The cumulative effects of this expansion have produced serious global environmental, social and economic problems, including loss of biodiversity and extreme poverty among people living in the more vulnerable areas.

Trees have the potential to rehabilitate degraded lands and ecosystems, restructure the landscape, provide a range of benefits and products (wood and non-wood products for food and medicines), and render environmental and socioeconomic services. The importance of trees in addressing these issues has been well understood by farmers through the centuries and has been clearly demonstrated in traditional tree-based agricultural farming and land-use systems, such as shifting cultivation in the humid tropics and grazing in the semi-arid savanna areas.

The concept of trees outside forests

Although they play an important role in environmental protection, landscape restructuring and livelihoods, trees on non-forest land received little attention from scientists, practitioners, planners, decision makers and policy makers until the early 1990s. At the Kotka meeting in 1993 (FAO 2000), experts recognized the uniqueness and importance of different resource types and defined a new concept of ‘trees outside forests’ (TOF), which considers trees at all levels and in all aspects, emphasizing their social and economic role and promoting their consideration at the policy level and in the assessment of the world's forest resources.

'Trees outside forests' are defined as 'trees found on non-forest and non-wood lands', such as: agricultural lands, urban and settlement areas, roadsides, homegardens, hedgerows, pasture/rangelands and scattered in the landscape (FAO 2000). The concept recognizes the biological characteristics of trees and their ability to provide environmental, social, cultural and economic benefits.

Since 1999, the Food and Agriculture Organization of the United Nations (FAO) has been working to raise awareness of TOF and to dispel the idea that tree resources are only important for small-scale farmers or those that make a limited contribution to sustainable forest resource management.

Multiple roles and benefits of trees outside forests

Food and other essential goods

TOF have been called 'trees that nourish', particularly for many poor and landless people who obtain essential products from them (Manu and Halavatau 1995). Many tree species found in African and Asian agroforestry systems (e.g., *Borassus aethiopum*, *Balanites aegyptiaca*, *Ziziphus mauritiana*) are planted for their ability to produce large quantities of food and other non-wood forest products (see Box 1).

Wood and fuelwood products

In developing countries, TOF provides a large proportion of the fuelwood for domestic energy (cooking and heat). For example, 50 percent of fuelwood used in Thailand, 75–85 percent in Indonesia, Java, Pakistan, the Philippines, Sri Lanka and Vietnam and 83 percent in Keralla, India (FAO 2001a; Jensen 1995) is harvested from farmland and other non-forest land.

In many countries, farmers and smallholders plant trees (especially valuable timber species) as a means of saving for the future (FAO 2001a; Negreros-Castillo and Mize 2002).

Fodder supply

Many pastoralists use TOF as a source of fodder for livestock including cattle, camels, sheep and goats (see Box 2). Recent case studies from Latin America have highlighted the importance of trees in livestock production, since they provide shade, shelter and supplementary fodder, particularly in the dry rangelands and low forest cover areas (Sanchez et al. 1998). In the arid parts of sub-Saharan Africa, three-quarters of the 10 000 woody species that grow in silvipastoral systems are thought to be used as fodder, supplying up to 50 percent of livestock feed (FAO 2001a), particularly in the dry season when grass and crop residues are not available.

Sustainability of agricultural production

The most universally recognized role played by trees in agricultural systems is that of soil conservation and the replenishment of soil fertility (Chivaura-Mususa et al. 2000; Sanchez et al. 1998). In many parts of the world, improved tree-based systems, e.g., shelterbelts, windbreaks, alley cropping, hedgerows and tree cover crops, e.g., coffee, cacao, coconut, olive and citrus have been integrated within croplands (Huaxin 2001; IRDC 2000; Jensen 1995). The use of such nitrogen-fixing woody species in agroforestry parklands in West Africa as *Acacia albida*, *Vitallaria paradoxa*

Box 1. TOF for food

Borassus aethiopum (Fan palm)
The kernel and mesocarp of the fruit can be eaten raw or roasted and provides nourishing carbohydrate, protein and minerals. The jelly-like, immature fruit is delicious, and a decoction of the roots makes a cooling drink for infants. Sprouts grown from the nuts are commonly eaten as a vegetable, the sap is used to make wine and the leaves are suitable for weaving roofs and fences.

Vitellaria paradoxa (Shea nut tree)
The pulp is eaten raw and supplies carbohydrate, minerals and vitamins. The kernel supplies oil used in cooking, cosmetics, candles, and even for waterproofing the walls of farmers' homes. In Burkina Faso, annual yields of 48–65 kg ha^{-1} of fresh nuts are common. Some 40 000–75 000 t are exported to Europe and 10 000–15 000 t to Japan, where they are used in cosmetics, pharmaceuticals and baking.

Source: FAO (2001a)

Box 2. TOF for fodder

A 1989–1990 survey in Bamako, Mali found that home-reared sheep were fed 1.8 kg of *Pterocarpus erinaceus* and *Khaya senegalensis* leaves each day, and over 1 400 t of fresh *Pterocarpus erinaceus* leaves were sold in Bamako daily as feed for small ruminants. In Sri Lanka, leaves of *Gliricidia sepium* are a popular fodder for goats and sheep. Fodder products from trees provide carbohydrates, nitrogen, magnesium, potassium and oligo-elements.

and *Acacia senegal* is a good illustration of a traditional tree-based farming system that helps to restore soil fertility and structure.

Environmental services and socio-cultural values

TOF improve air quality and the micro-climate, particularly in urban areas. Trees are a valuable carbon 'sink' (World Bank 2002) and help to reduce soil erosion by checking wind velocity and water runoff. They are highly valued by many communities living in hot climates as providers of shade and have significant symbolic, social, religious and cultural status. They also provide many other environmental benefits and services, such as minimizing the loss of mineral elements through leaching and improving soil structure.

The way forward

It is generally agreed that increasing agricultural productivity is central to growth and poverty alleviation in rural areas. It is also well understood that increasing production often results in the destruction of forest cover, depletion of fertile soil and severe land degradation.

At national and international levels, the importance of TOF as a resource is often overlooked. Only limited initiatives existed prior to the Kotka meeting in 1993. Since then, many case studies conducted at national and regional levels have identified the serious livelihood challenges faced by smallholder farmers. To be effective, tree issues need to be addressed in a holistic, people-centred vision, focusing on the multiple functions of trees.

Population pressure on land and forest resources

Increasing population pressure on limited agricultural land has led to the breakdown of many traditional tree-based systems. The result has been diminishing vegetation cover, soil erosion and reduced agricultural production. One of the greatest challenges is that of preventing further erosion of forest cover. Promoting TOF systems within the context of land conservation and restoration is one of the most effective ways to improve productivity of the existing agricultural land area, thereby limiting pressure on remaining forest resources.

Appropriate policy to meet local development needs

Millions of vulnerable people living in rural and peri-urban areas rely heavily on tree resources for their livelihoods, but they lack an effective voice in decision making. An urgent challenge is that of extending smallholders' rights in order to give TOF more prominence as a route towards more sustainable livelihoods. Farmers will plant more trees when they are given policy and market incentives. Formal acknowledgement of user rights over trees growing on farmland would provide a major incentive for the conservation of such trees. On-farm tree management generally makes good economic sense when benefits are taken into account in a 'whole farm' evaluation approach.

The best solution would be to integrate TOF into national agriculture and forestry development plans, by focusing on the needs of local people to create their own woodlots, protect their environment and improve their livelihoods. In order to convince the governmental decision-makers and planners to include TOF in their national policies and tree planting programmes, however, it is essential to demonstrate the benefits of trees in the national economy.

Farmers will need to be supported with appropriate legal measures, market incentives and the removal of barriers to land access and tree tenure. National forestry laws seldom favour small-scale on-farm tree planting and private investment in forestry is often limited by rigid land tenure systems and restrictions (FAO 1993). Legal changes to land and tree tenure are critical for TOF promotion because they secure benefits for the stakeholders.

We believe that a bold approach, that gives stakeholders a voice and the right to decide what is necessary, should be the focus of any policy targeting sustainable development. This requires simultaneous action, however, such as multiple-scale activities and careful consideration of how social and political changes influence the success of different interventions and management practices.

Building knowledge and capacities

The past two decades have witnessed the development of techniques to design landscape mosaics based on tree-crop integration and environmental protection. However, results of many recent case studies, meetings and workshops (FAO 2001a; FAO 2002) highlight the need for further technologies and research to enhance the proper use of trees in landscape restoration and for increasing environmental and economic viability. In addition, as a priority action, there is a need to evaluate traditional knowledge and practices for tree management. A combination of natural resource management approaches is likely to be required.

Gender-differentiated management

Women are the first to be concerned with the selection and harvesting of non-wood forest products (leaves, roots, fruits, etc.) and have good overall knowledge of their use, conservation and processing. A study in Java showed that 60 percent of a rural family's food typically comes from homegardens in which trees are prominent, and that these gardens are mostly managed by women (FAO 2001b). This important skill should be taken into consideration and seen as reason enough to enhance and strengthen women's roles in TOF resource management.

Conclusions

The biological characteristics and wide range of resource types provided by TOF makes them invaluable in efforts to promote sustainable rural development and restore damaged ecosystems. They can also help improve the environment of urban areas and raise yields and profits on low-productivity agricultural land. Finally, if the new vision of TOF is embraced by many nations and expressed in the form of policies linking trees to all land-use systems, the accumulated effect will be reflected in a significant improvement in the global environment and progress towards sustainable rural development.

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Keywords:
Gender, property rights, tenure, agroforestry

Chapter 22

Women, land and trees

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Abstract

The distribution of rights to land and trees between men and women has important implications for agricultural productivity, women's empowerment and household welfare. Rights to land and trees tend to shape women's incentives and authority to adopt agroforestry technologies more than other crop varieties because of the relatively long time horizon between investment and returns. Some of the complexities involved in understanding women's control over resources are discussed, not only in the main agricultural fields, but also in important 'interstitial spaces' that are often overlooked. There are many factors affecting distribution of rights and, often, simply changing legislation may not change rights in practice. However, this heterogeneity offers considerable potential for women and outside agencies to work together to strengthen women's rights over land and trees.

Introduction

The World Agroforestry Centre has conducted pioneering work on 'women, land and trees', so this is an appropriate subject for a 25th Anniversary publication. It is also appropriate to look ahead, because these issues continue to affect many of the research themes related to agroforestry. Among its many accomplishments, the Centre and its partners have been successful in increasing understanding of people's rights to trees as separable from (but linked to) rights to land, and how rights to both land and trees are affected by gender (Fortmann and Bruce 1988; Fortmann and Rocheleau 1985).

The recognition of rights to trees has important implications for agroforestry adoption, particularly where women are restricted from planting or have low incentives to plant certain types of trees. But, rather than using these obstacles as a reason to focus on men (who are often easier to reach) the Centre, to its credit, recognizes women as major clients who are likely to play an increasingly important role in agriculture. Researchers have therefore redoubled their efforts to understand women's use of agroforestry and to ensure that new technologies and dissemination programmes reach them. For example, Rocheleau's research (Rocheleau 1988; Rocheleau and van den Hoek 1984) showed the importance of spaces that are often overlooked, such as patio gardens and the 'interstitial spaces' of hedgerows, roadsides, and the space between trees on 'men's' land. Programmes such as biomass transfer have built on this information and developed technologies that use the resources that can be accessed and controlled by women. At the same time, there has been careful attention to men's incentives to plant and maintain trees. For example, the Centre's collaborative research in Malawi and Uganda identified links between tree rights, tree density and marriage and inheritance patterns, where patterns of matrilineal inheritance (land passes to nephews rather than sons) means that men move to their wives' villages, where they have less incentive to plant trees, because the trees would not pass to their own children (Otsuka and Place 2001). Thus, careful attention to gender relations, mobility of residence and control over resources in different locations is needed to maximize the impact of agroforestry programmes.

Why are women's rights important?

Property rights for women are important for agricultural productivity, women's empowerment and household welfare. Rights to land and trees tend to shape women's incentives and authority to adopt agroforestry technologies more than other crop varieties because of the relatively long time horizon between investment and returns. Studies in Cameroon, Kenya, Mali, Uganda and Zambia have found that tenants without long-term land rights are restricted in their rights to plant or harvest from trees because of insecurity of tenure (Place 1994). In communal areas of Zimbabwe, Fortmann et al. (1997) found that the potential loss of land and trees following widowhood or divorce tended to make women feel insecure and limited the amount of trees they planted on household land. At the same time, women and men were equally likely to plant trees on community woodlots because rights over those trees derived from community membership and investment, not marital status, and hence there were fewer gender differences in tenure security. However, differences in socioeconomic status of households were a bigger factor than gender differences alone in explaining tree planting behaviour overall: the poorest households had least ability to plant, and tended to focus on trees for subsistence needs, rather than commercialization.

Because credit, extension, and other services are generally directed preferentially to landowners, the agricultural productivity of women without land rights is further restricted by a lack of complementary inputs. This is particularly a constraint for agroforestry, where access to information and credit are important for adoption. Where women obtain land through their husbands (for example, in the dual-farming systems of Africa), they are often required to work on their husbands' fields in order to obtain their own plots for growing food, which restricts labour availability on women's fields. When men are absent (due to migration, divorce or death), the problems of labour shortage are even more serious (Davison 1988; Lastarria-Cornhiel 1997). The high labour requirements for some agroforestry systems pose a particular problem for women, who not only face less control of others' labour compared to men, but also have high labour requirements for domestic tasks. Studies indicate that reducing the gap between men's and women's control over capital and inputs could increase agricultural productivity in sub-Saharan Africa (SSA), for example, by 10–20 percent (Quisumbing 2003).

There is a growing body of empirical evidence indicating that property rights raise women's status in the household as well as in the community, and this translates into greater bargaining power (Agarwal 1994; Quisumbing 2003). When women control resources, such as land and trees, they are more likely to be managed in a way that is consistent with women's priorities. Long-term rights to land and trees also provide security for women in the event of widowhood, divorce or family crisis. Whether because of this improved fallback position or because of higher status, studies in various contexts have found that women with control over land have more influence over decisions at home, and may be subjected less to domestic violence.

The higher income and stronger bargaining power of women with control over resources has implications for the distribution of welfare within the household, since women and men spend income under their control in systematically different ways (Quisumbing 2003). Women are observed to spend a higher proportion of their income on food and health care of the children (particularly of girls), which has important implications for overall family welfare and long-term poverty reduction. Thus, improving women's status and resources improves child health and nutrition (Smith et al. 2003). Trees can play a role in this, not only as an asset that may increase women's bargaining power, but also as a source of food, medicines, and fuelwood, which all tend to be important to women.

The complexity surrounding women's rights

It is one thing to recognize the importance of women's rights, but quite another to strengthen them, particularly concerning land and trees. It is important to begin with an understanding of existing rights systems, which often involve complex relationships between different uses and users of the resources. Rather than simple 'ownership' of resources, we often find separate bundles of rights; for example, one person may have the right to plant a tree and use its fruits, another to grow an annual crop on the land around the trees, and a third to graze their flocks on the land in the dry season. In other situations, one person has the right to use the land, but another holds the controlling or decision-making rights. The different rights may be held by different households (landlord and tenant), or even by different members within a household (husband, wife and children). The duration of rights also varies, from a growing season (or less) to the long term.

It is also essential to consider the robustness of rights, that is, their ability to withstand challenges from others. For example, in Mozambique, Vijfhuizen et al. (2003) found that women do not usually plant trees when they live in their husband's family homestead because they do not feel they have secure tenure there. However, they do plant trees when they move to an independent homestead with their husbands, or when they are allocated their own land by the chief or in-laws. In the case of women's rights over land, we often find (particularly in SSA), that women acquire the right to cultivate land from their husbands, fathers or sons, but their controlling or decision-making rights are restricted. This is especially problematic for agroforestry, because planting trees is a management (decision-making) right that is often restricted to landowners, particularly male ones. Moreover, if women acquire rights through a man, their rights are highly dependent on their relationship with that man and, if they become widowed or divorced, they may lose those rights. Even when married women have land use rights, they often have to get permission from their husband to plant a tree. As a result, female-headed households with land may be more likely than women in male-headed households to adopt agroforestry, because they have more autonomy (Gladwin et al. 2002; Hansen et al. 2005).

Many analyses of land rights focus on the main agricultural plots or on residential and commercial property. To understand women's property rights, and particularly their rights over trees, it is essential to look beyond these to consider tenure and trees within the whole landscape. In many cases, common lands (which may be officially designated as community or state property) are important sources of trees and tree products, particularly for women. For example, in the Philippines, Flora (2001) found that women depended on the commons more heavily than men for domestic and market-oriented production, but men's interests tended to prevail where markets had developed, both in crop production and in land tenure, and women often lost access when land was privatized.

Rocheleau and Edmunds (1997) draw attention to the importance of such 'interstitial spaces' as homesteads and patio gardens (trees planted between the house and fields), hedgerows (trees or bushes between fields and roads or other fields), and inter-cultivation of annual crops between planted trees in fields. These areas produce valuable products, such as wood, fodder, vegetables, medicines and wild foods; but this type of production may be ignored by government statistics or even by researchers. Interstitial spaces are particularly important for people who have little control over the main farmland. In addition to their productive and livelihood values, they play important ecological roles, particularly in watersheds, where stream banks, hedgerows and wetlands act as filters and sinks for reducing water pollution and controlling soil erosion (Swallow et al. 2001). Rights over these interstitial spaces are often not clearly defined, partly because they are boundary areas and attempts to define them may generate conflict. On the one hand, unclear rights give access to the landless, but on the other, it means that responsibilities are also not clearly defined. Thus, it is important to consider how men and women relate to these interstitial resources, both in terms of their use of the products and their involvement in maintaining the resource.

Another important complication in rights over land and trees arises from the multiple sources of claims for property rights. State title is only one (albeit important) source of property rights and it is one to which many Africans have no access. However, claims may also be based on a range of customary or religious laws or even local norms. For example, a country may have laws specifying that all children are entitled to inherit an equal share of assets from their parents, while Islamic law specifies that daughters receive half the share of sons, and local norms may prescribe that women should not cultivate their land, but give it to their brothers. Even where there is agreement on rights, it may be difficult for people to physically use their claims, particularly in the face of social pressures. On the other hand, men and women use their social connections to access land and the labour to farm it, particularly for agroforestry. Thus, both state law and local norms, particularly the interplay of gender and power relations, play a crucial role in shaping women's rights to land and trees.

Figure 1 illustrates how state law and gender relations are linked to women's rights over land and trees, and how these, in turn, are linked to access to inputs, agroforestry adoption, agricultural productivity and household welfare.

Sources of change in women's rights over land and trees

In spite of their complexity, property rights are highly dynamic; they change over time, as a result of external and women's own actions. Most of the linkages are two-way relationships. For example, women's land rights may influence agroforestry adoption, but agroforestry adoption can also affect land tenure. Similarly, changes in household income or welfare can have feedback effects on women's rights to resources. Figure 2 illustrates how each of the links to women's rights over resources can become

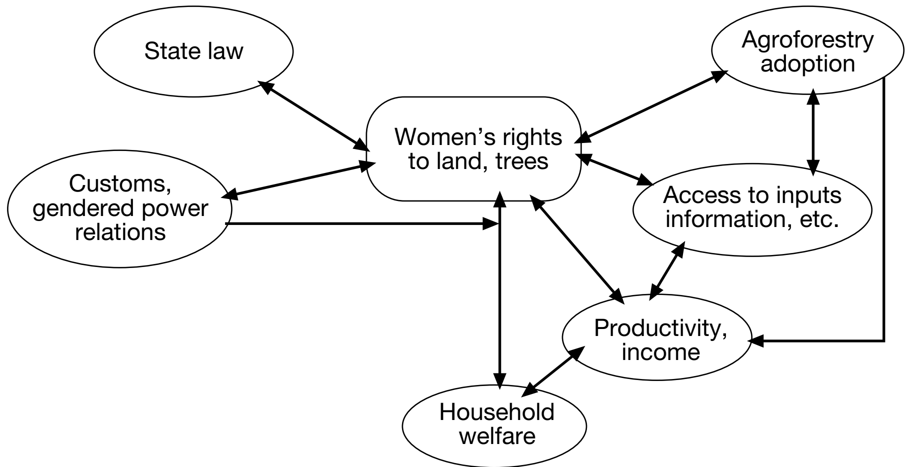

Figure 1. *Links to women's rights over land and trees.*

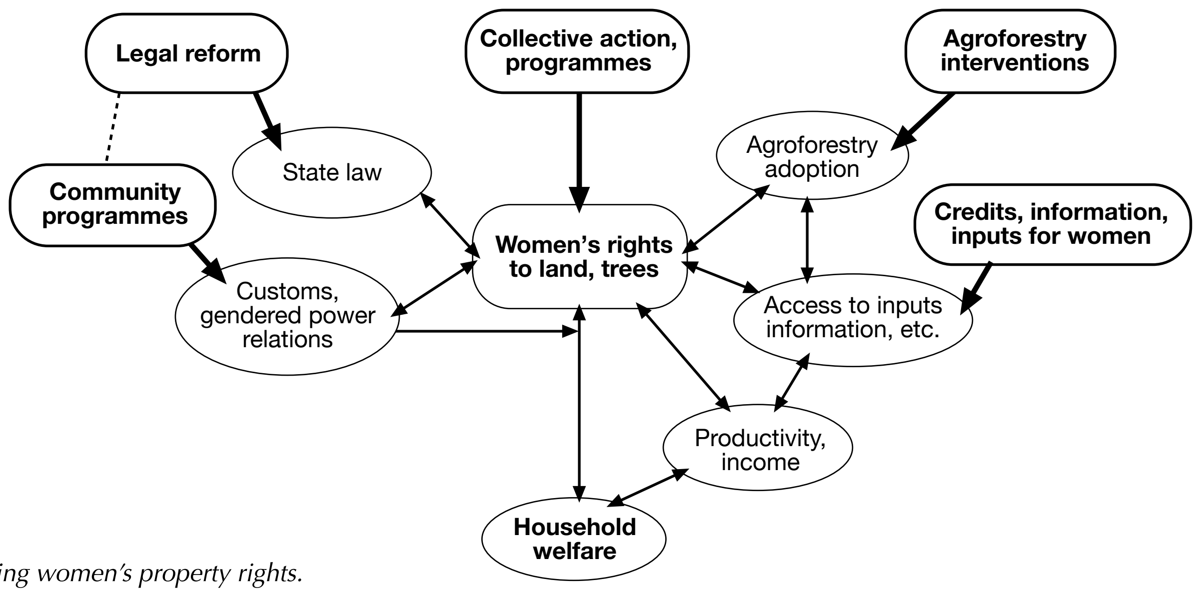

Figure 2. *Ways of influencing women's property rights.*

a point of leverage to increase gender equality. We now consider each of these in turn.

Legal reforms

Legal reforms have received considerable attention from women's movements and others advocating gender equality. Certainly changing state law is an important means of strengthening women's property rights. In some cases this involves repeal of discriminatory laws, such as those of Lesotho and Swaziland that declare women to be legal minors, and therefore unable to hold property. Other legal mechanisms to strengthen women's property rights include reform of inheritance laws or provision for joint titling of land in the names of husband and wife that can provide women with stronger claims on the land while their husbands are living, and greater security in the case of widowhood or divorce. While much of the attention on legal reforms has focused on private lands, strengthening recognition of rights over public or common lands – and in many cases, preventing privatization of the common resources that many poor women depend upon – can be an equally important mechanism for securing women's access to resources.

However, legal changes do not automatically translate into changes on the ground. For new property rights laws to become effective, both the implementers of the law and the public need to be aware of the changes. Legal literacy campaigns are therefore needed for both audiences, and women need to have access to administrative and judicial channels. Access can be restricted physically, by women's more restricted mobility due to childcare or safety concerns. The greater the distance poor rural women have to travel to register a claim or fight for it in court, the less likely they will be to use formal channels to claim their rights. Social distance also matters, for when women have less education or social standing than those to whom they must go to claim their rights, they are less likely to seek redress. For this reason, in Tanzania and Uganda, land management and adjudication bodies at all levels are required to have female representation. However, these bodies require resources to be effective, and governments may not have the personnel, funds or political will to provide for them at the local level. Even with reforms in legislation and implementing bodies, women's rights may not change dramatically if there is major difference between statutory and customary law, but state law does provide a basis upon which they can appeal. Eventually, with enough appeals to such laws, even social norms and power relations can change.

Community programmes

Community programmes offer the potential to change gendered power relations directly. Many programmes run by government or non-governmental organizations (NGOs) use group-based approaches for a range of social development or natural resource management (NRM) goals. In many cases, the programmes introduce new discourse about gender relations and resource rights that affect local customs. If women are included in such groups, either through all-women's groups (as in many microfinance or education programmes), or through active participation of women in mixed-gender groups (as in some, though not all, forestry groups), it can have an empowering effect on them. The interaction between men and women in such groups can also help to change gender-related norms and even power relations. However, in other cases, it can cause a backlash by men toward more 'traditional' practices.

Collective action programmes

Collective action programmes can have a direct influence on women's property rights, as when women group together to acquire land and then cultivate it individually or collectively (Agarwal 1994; Rocheleau and Edmunds 1997; Schroeder 1993). Women's participation in NRM groups has a direct bearing on their property rights. Under many devolution programmes, user groups are charged with managing resources like forests, irrigation, or watersheds that had been under (nominal) state control. Although many government programmes are reluctant to give away explicit rights over resources (preferring to focus on the responsibilities that user groups should undertake), when user groups take over, they effectively acquire management and often exclusion rights over the resource. Thus, effective participation in the user groups is important to ensure that the resources are used in a way that meets women's needs. Without women's participation, for example, watershed management groups in India often close off areas for grazing or fuelwood collection in such a way that poor women lose access and bear the greatest costs, while the benefits go to the richer landholders (often men) downstream. Kerr (2002) found that where NGOs had given special attention to social organization (especially among women and marginalized groups) before starting to address watershed management, those groups were better able to articulate their interests, and the programmes were more equitable and more sustainable. However, collective action programmes can be highly complex (see Box 1).

Agroforestry interventions

Agroforestry interventions have considerable potential to influence property rights because planting or clearing trees is a

Box 1. Collective action in Nepal

The complexities involved in collective action programmes are illustrated by programmes in Nepal, which provide 40-year leases of degraded forest to groups of poor people. The pilot project included 25 percent women members, but even when women were not the members, both husbands and wives were involved. Gender training for all project staff and hiring women as group promoters were seen as instrumental to project success. In addition to significant regeneration of vegetation, the focus on developing fodder and fuelwood sources that were of particular importance to women reduced household time spent on gathering them by an average of 2.5 hours per day (Brett et al. 2004). Women reported that they became more empowered, in part because they learned to have a say in group decision making. However, granting more secure tenure to a subset of the poorest people challenged local power structures and excluded others who had customary use rights over that land (Baral and Thapa 2003). Without strong local organizations to enforce rules, there were conflicts that decreased tenure security.

common means of establishing claims, not only on the trees, but also on the underlying land, particularly in customary African land tenure systems. Indeed, so potent is tree planting for establishing tenure claims that in some societies, women are prohibited from planting trees, or may be restricted in the species that they can plant. In such cases, agroforestry programmes that introduce shrubs or species that women can control are more likely to strengthen women's rights to both land and tree resources. Place (1994) suggests that agroforestry can even be instrumental in changing social norms about women's tree planting, by blurring the distinction between trees and perennial crops. Types of trees that meet women's needs and fit within their resource constraints are also more likely to be adopted. For example, trees that replenish soil fertility have been welcomed by women who lack the cash to buy fertilizers (Gladwin et al. 2002). The World Agroforestry Centre's recent work on fruit and medicinal trees is particularly promising, because these are important to women. When gender relations regarding trees are ignored, programmes can even weaken women's rights, as in The Gambia, when a tree planting scheme introduced for 'environmental rehabilitation' and targeted to (male) landowners pushed out highly productive women's gardens that were cultivated on that land (Schroeder 1993).

Credit, information and inputs

Credit, information and inputs help women to acquire land and invest in trees. Strengthening women's land rights alone is not enough; other constraints need to be addressed if women are to be able to use the land in a productive and sustainable way. In many cases, women's yields are less than those of men because they have less access to seeds, fertilizer and labour (Quisumbing 2003). The land that women acquire is often less productive because of low soil fertility or lack of water. Thus, extension and other programmes that explicitly seek to redress gender imbalances can help women to use their land productively, rather than mortgaging or renting it out. Community nurseries (often managed by women's groups) can provide planting materials and the knowledge needed to grow them effectively. Microfinance programmes have targeted poor women in many countries, but, because of the small size of available savings or loans, often cannot help women to purchase land. However, microfinance can help them to buy trees (which can become a form of savings account) or other necessary inputs. Many extension systems bypass women, particularly when they are not the landowners, and hence they may not acquire information about improved practices, including agroforestry. Recognizing this constraint, the Centre's biomass transfer and improved fallows programmes in Zambia and western Kenya have used group-based approaches and simple dissemination materials to ensure that women are included (Gladwin et al. 2002; Place et al. 2003). The use of a mulch from cut branches of *Tithonia* shrubs from hedgerows (interstitial spaces, which are under women's customary usage) allows those with limited land to adopt this approach to soil fertility enhancement.

In practice, these types of change do not exist in isolation, but interact. Quisumbing and Otsuka's (2001) study of the evolution of land tenure in western Ghana provides an apt illustration (see Box 2).

Challenges for research and action

Recognizing the importance of women's rights over land and trees for productivity, equity and household welfare is only the beginning. Much remains to be done in both research and practice to achieve gender equity in property rights. The first step is to make sure that our understanding of the issues is adapted to the local context. The processes involved are complex, and will vary from place to place and according to a host of intersecting identities, including religion, ethnicity and culture. As the example from Ghana indicates, broad generalizations can be misleading. Thus, it is essential to identify the key gender/tenure interactions at each site, and how these relate to the use of resources and distribution of welfare in society (and within households). Although the specific answers will differ from place to place, Gladwin et al. (2002) show that there are many common factors facilitating or limiting the planting of trees, indicating a core set of questions that researchers can ask about.

Cost-effective diagnostic tools are now available for assessing customary as well as statutory rights (Freudenberger 1994), so attention to these issues is no longer restricted to the research community that can undertake detailed study. Focus group meetings and key informant interviews may start with mapping the local resources, then discussing who uses each resource and the rules governing that use. Time and trend lines can indicate how access to these rights has changed over time. However, it is essential to discuss these issues with women and men, younger and older generations, and to look beyond the private farmlands to the commons and even the in-between spaces and resources. With such an approach, applied projects can and should develop an understanding of the distribution of rights to land and trees in each site.

Although our understanding of property rights is growing, there is a need for further research on the complex interactions

Box 2. Evolution of land tenure in western Ghana

Rapid population growth in western Ghana has put unsustainable pressure on customary systems of acquiring land by clearing forests. As a result, agroforestry (particularly cocoa production) became more profitable than shifting cultivation, which created local pressure to individualize land tenure. While individualization of tenure frequently led to women losing their customary access to land (Lastarria-Cornhiel 1997), in this case the introduction of cocoa increased demands for women's labour. Men needed to provide incentives for their wives to work in the cocoa fields. Although land was customarily held only by men, women acquired use rights through their relationships with men, and traditional 'gifting' ceremonies, witnessed by the community, were adapted so husbands could transfer individual land rights to their wives in exchange for labour on the cocoa fields. Thus, customary practices were used to adapt the land tenure and give women relatively secure rights to land and trees. (While this represents a significant advance in women's rights to land, it does not represent full equality. Women had to plant 40–50 percent of the land to cocoa before receiving rights to it, whereas men only had to plant 20–25 percent of the land before receiving the rights.) At the same time, the statutory law was changed by the 1985 Intestate Succession Law, which provides for a wife and children if a man dies without a will. According to the new law, the distribution of assets was to be 3/16 to the spouse, 9/16 to the children, 1/8 to the parents and 1/8 to the matriclan (mother's extended family). The common interpretation of this distribution, however, was 1/3 each to surviving spouse, children and matrilineal family. Thus, the local law was even more favourable towards women than the formal statute, and legal reforms came after changes in local practice.

Source: Quisumbing and Otsuka (2001).

between land, trees and water, and on how property rights influence the management of these interacting resources. The impacts of these interactions are seen on individual and household welfare and on the landscape. This is particularly important in watershed management. Here, the Centre's work (Swallow et al. 2001) brings together biophysical and social scientists to address these complex relationships. The work indicates that it is not only private land that matters; in many cases, collective rights (or lack of them) to critical landscape features, especially water supply points, wetlands or river banks, has implications for women. For example, work in the Nyando basin of Kenya indicates how privatization of most of the land, including that adjoining rivers, has restricted access to water supplies. When the owners of land around springs are persuaded to set aside the land and plant native tree species for spring protection, this can have important benefits for women's time and resource use, along with environmental benefits in terms of improved water quality and reduced soil erosion.

Moving from research to practice, identifying effective ways to strengthen women's rights to resources remains a key challenge. The framework presented in this chapter suggests several different intervention points that can enhance (or weaken) women's access to and use of land and trees. However, much remains to be done to assess the effectiveness of alternative intervention strategies, and to understand the ways in which different interventions interact with strategies undertaken by women. External policies and legislative reforms can influence change in local norms, but changes in local norms can also influence the implementation of policies. Technologies (including agroforestry) that increase the returns to women's labour can strengthen their bargaining power within the household. Supporting programmes to disseminate technologies and complementary credit and inputs can enhance this process, enabling women to use their land and trees more effectively.

The relationships among gender, tenure, technologies and household welfare are complex. Rather than shying away from this complexity, development researchers and practitioners need to understand the relationships and how they are likely to affect outcomes of projects in any particular context. This web of interactions means that any single intervention, such as legal reform, is not likely to achieve an objective by itself, but it also offers multiple points through which women's rights over resources can be strengthened, with important implications for the adoption of agroforestry technologies and agricultural productivity, and also for women's empowerment and overall household welfare.

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Forestry, health, Africa, herbal medicine, nutrition, agriculture

Chapter 23

The challenge of HIV/AIDS: Where does agroforestry fit in?

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Abstract

In its early stages, the global HIV/AIDS epidemic was predominantly an urban problem. It affected more men than women, and those with relatively higher incomes. The epidemic has moved rapidly into rural areas and now, the majority of people living with and dying from HIV/AIDS are the rural poor. Among them, women comprise a disproportionately high number. Although up to 80 percent of the people in the most affected countries depend on agriculture for their livelihoods, there have been limited responses from governmental and non-governmental actors in the agriculture and natural resource sectors. This chapter discusses the impact of HIV/AIDS on rural livelihoods and the ways in which agroforestry could help mitigate those impacts. The chapter concludes that agroforestry interventions can improve communities' long-term resilience against HIV/AIDS and other external shocks in ways that agricultural interventions alone cannot. Agroforestry technology can be better tuned to respond to the cash, labour, food and asset shortages faced by AIDS-affected communities. By providing options for producing nutritious food, managing labour, generating income and enhancing soil fertility, agroforestry technologies can help reduce hunger and promote food security. The authors recommend that current and future agroforestry programmes and forest policies should be reviewed to assess their effects on key determinants of HIV vulnerability. They also recommend some responses that can be made by agroforestry research and development organizations.

Introduction

"Over the past few years, there has been a major revolution in the world's thinking about HIV. The epidemic has been understood, not just as a health issue that will always remain, but as a major threat to development and to human security."[1]

In its earlier stages, the HIV/AIDS epidemic was predominantly an urban problem, affecting more men than women, and those with relatively high incomes. The epidemic is now moving rapidly into rural areas, hitting those who are least equipped to deal with its consequences. Today, 95 percent of people living with – and an even higher proportion of those dying of – HIV/AIDS live in developing countries. The overwhelming majority are the rural poor and, among them, women comprise a disproportionately high number. The epidemic is responsible for undoing decades of economic and social

[1] Peter Piot, Executive Director, Joint United Nations Programme on HIV/AIDS (UNAIDS), Keynote Address to the UN Symposium on Nutrition and HIV/AIDS 2 April 2001, Nairobi, Kenya.

development and causing rural disintegration. For example, in sub-Saharan Africa, HIV/AIDS is depleting the region of its food producers and farmers and decimating the agricultural labour force for generations to come (FAO 2004a).

Although up to 80 percent of the people in the most affected countries depend on agriculture for their livelihoods, the greatest response to the epidemic has come from the health sector. The agricultural sector cannot continue 'business as usual' in communities where large numbers of adults have died, leaving the elderly and children to produce food. Agriculture and natural resource responses can play essential roles in controlling the epidemic, so researchers will have to revise the content and delivery of services and the process of transferring agricultural knowledge.

This chapter illustrates the specific impacts of the HIV/AIDS pandemic on agroforestry and proposes relevant strategies that could mitigate them. Since agroforestry is the science and practice of integrating trees into farming systems and agricultural landscapes, and there are many types and products of trees, there are many ways in which agroforestry can contribute.

The impact of HIV/AIDS on rural livelihoods

The impacts of HIV/AIDS are many and intertwined. While health and demographic impacts have been studied most, the effects on agriculture and food security have become clearer over the last few years (FAO/UNAIDS 2003; Mushati et al. 2003; Yamano and Jayne 2004). The impacts can be felt most dramatically in the reduction of the labour force, impoverishment and the loss of knowledge that is transferred from one generation to another. All exacerbate food insecurity and poverty. Moreover, the consequences of HIV/AIDS contribute to making the rural poor more vulnerable to HIV/AIDS infection. This devastating cycle must be broken, and agroforestry has a critical role to play.

The impacts of HIV/AIDS that have a long-lasting effect on forestry, agroforestry and rural livelihoods stem largely from: a) reduction of the productive age groups and agricultural labour force; b) acute impoverishment of households; and c) loss of knowledge.

Regarding loss of productive age groups, the Food and Agriculture Organization of the United Nations (FAO) has estimated that some countries could lose up to 26 percent of their agricultural labour by 2020 (FAO 2004a). A lack of available labour was found to be associated with an increase in forest fires in Malawi, where communities resorted to clearing the land by burning the forest rather than selective cutting/processing. Fires destroy larger areas of woodlands than selective cutting and remove all the products and services that woodlands provide to communities (Mike Jurvelius, FAO, personal communication 2002). Other effects of labour shortage are shown as a sharp reduction in the area of land cultivated and a shift from cash to food crops (FAO 2002).

When a member of a household becomes infected with HIV/AIDS there is a need to pay for medical expenses and/or a funeral and productive assets are often sold to meet these expenses. The consequent loss in purchasing power has led to less money being spent on food. For example, a study in Ethiopia calculated the cost of treatment of one AIDS patient was more than the entire farm's average annual income (Demeke 1993).

The loss of a generation to HIV/AIDS is interfering with the transfer of agricultural knowledge, practices and skills that are normally passed from one generation to the next. This knowledge is critical to both sustainable agricultural production and cultural identity. The epidemic is also responsible for a significant loss in institutional knowledge, since staff of such agricultural service institutions as the extension services are also affected.

The overall impact of the epidemic depends on the actual stage of evolution of infection in the population. As shown in Figure 1, the rate of infection of the HIV virus follows distinct phases. In Phase I, which can take several decades, prevalence rates remain low and increase slowly. Phase II starts when somewhere around 5 percent of the population becomes infected and exponential growth rates in infection occur. Phase III represents a levelling off of infection rates, and finally, a decrease occurs in Phase IV. The precise shape of the curve and the duration of each phase will vary from area to area and depend on a range of factors, including policy and action taken to prevent and mitigate the epidemic. Early and decisive action may keep rates low, without ever reaching Phase II, as in the case of most developed countries

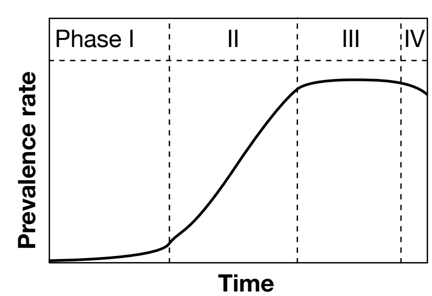

Figure 1. *Phases in the HIV prevalence curve.*
Source: Villarreal (2003).

HIV/AIDS is a slow epidemic with slow impacts. Impacts only start to be obvious at the population level years after a sharp increase in prevalence rates (Villarreal 2003). This time lag varies in duration, but large numbers of deaths can be expected 5–10 years after the onset of Phase II, depending on the level of nutrition of the population and other factors. Death is one of the main impacts, but before death occurs, the person suffers weakness and decreased ability to work for about two years (again, depending on nutritional, medical and other factors). Impoverishment is another effect, starting more or less at the time of decreased work ability. Impacts at the population level that lag some years behind the death curve include the problems faced by children who have lost first one then both parents. These 'double orphans' face tremendous problems in securing both short- and long-term learning and livelihoods. Hypothetical 'prevalence' and 'death' curves are shown in Figure 2.

The time lag between the peaks of prevalence and impact means there may be little observable impact on a population even when prevalence rates are very high. In addition, low prevalence rates may occur at the same time as high levels of impact during Phase IV. Policies, programmes and other initiatives designed to prevent the spread of HIV/AIDS and mitigate its effects need to take account of the stage of the epidemic (Topouzis 2001).

Very importantly for agroforestry initiatives, the lag between rising prevalence and impact creates a 'window of opportunity' for specific interventions. For example, as discussed below, some of the proposed labour-saving initiatives are initially labour- intensive, and only later will produce labour-saving benefits. If they are successful, the people could begin to reap the advantages of such techniques when their need is greatest. Analysis of the progression of AIDS at the household level also shows a time lag between the time of infection of the first adult and the development of full-blown AIDS. Households go through similar stages of prevalence and impact and the death of different family members has different effects on the household.

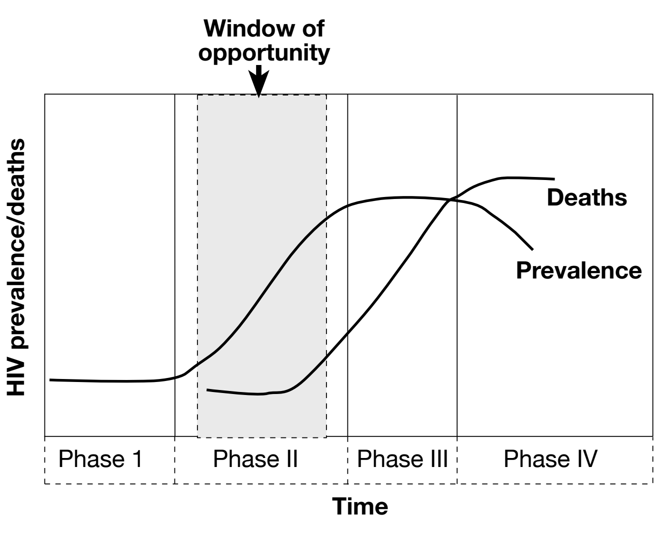

Figure 2. *Prevalence and death curves: Window of opportunity.*
Source: Villarreal (2003).

Recent studies have shown that the precise effects of HIV/AIDS depend upon: a) the previous demographic structure of the household; b) who and how many people in the household are chronically ill or die; c) the length of time that the household has had to cope with the effects of the epidemic; and d) the resources the household had at its disposal for dealing with increased demands (Mushati et al. 2003; Yamano and Jayne 2004).

Figure 3 depicts the different composition of households affected by AIDS over time. There are 13 different types of households that may exist in an area of high HIV/AIDS prevalence. In many communities, all 13 types may exist at the same time. Each type of household has distinct resources, challenges and needs.

Agroforestry possibilities for the mitigation of HIV/AIDS impacts

In this chapter we will be using a landscape perspective on agroforestry: "Agroforestry refers to a dynamic, ecologically based natural resources management system that, through integration of trees in farms and in the landscape, diversifies and sustains production for increased social, economic and environmental benefits of land use at all levels," (Leakey 1996).

Agroforestry can play an extremely important role in ensuring rural livelihoods survive an epidemic of HIV/AIDS because it:

- enhances food security through improving soil fertility;
- produces nutritious foodstuffs (fruits, berries, leaves) that can boost the

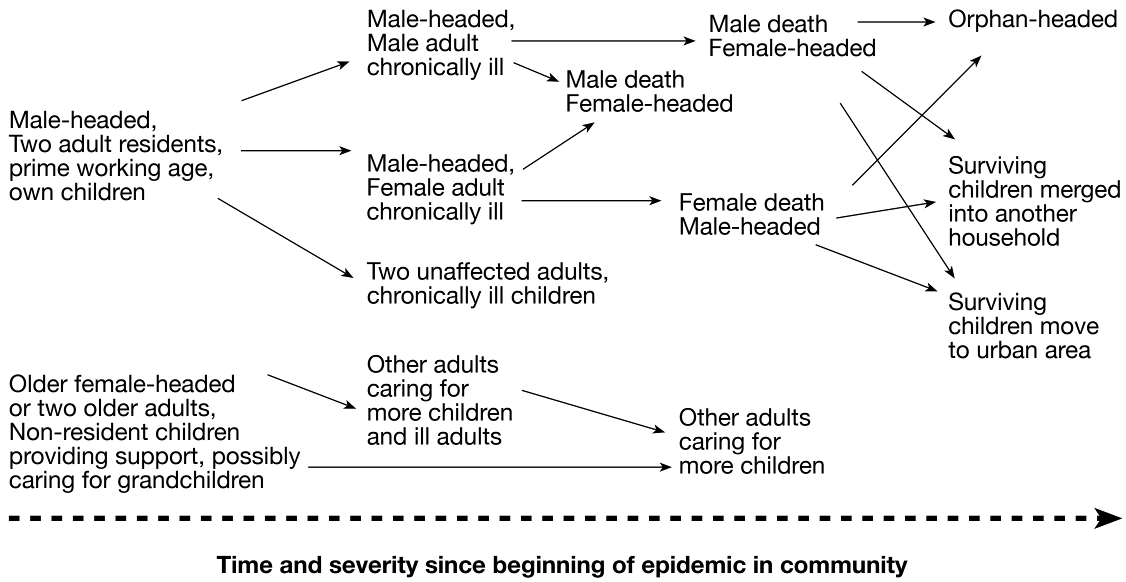

Figure 3. *The evolution and different composition of households affected by AIDS.*

immune system and help protect against opportunistic disease;

- includes medicinal trees and other products that can help treat opportunistic infections;
- provides income generation opportunities that are not labour-intensive;
- offers a safety net of subsistence and income (e.g. firewood for consumption and for sale, animal fodder, potentially high-value tree products, building and thatching materials)
- marks ownership of land; and
- offers short-term and long-term labour management possibilities.

Improving soil fertility

One of the greatest challenges for agricultural households affected by HIV/AIDS is to maintain food production while coping with reduced disposable income for purchasing agricultural inputs. The World Agroforestry Centre and its partners in eastern and southern Africa have developed several agroforestry methods for enhancing soil fertility and maintaining soil quality. In the highly populated bimodal rainfall areas of western Kenya, the emphasis has been on short-duration improved fallows and biomass transfer. In the relatively sparsely populated, unimodal rainfall areas of eastern Zambia, the emphasis has been on 2–3-year fallows. Some farmers in eastern Zambia are using biomass transfer as an input into the production of garlic, a plant known for its anti-oxidant properties. In the densely populated areas of Malawi, leguminous trees are being intercropped with maize. All these systems have met with approval, with a total of some 250,000 farmers now testing or adopting one/some of the practices by 2004. In areas with suitable production characteristics, improved fallows allow farmers to produce maize yields roughly similar to those obtained using recommended levels of inorganic nitrogen fertilizer, and two to five times higher than yields obtained under continuous maize production without fertilizer. Economic returns to land and labour tend to be 20–100 percent greater using improved fallows than with continuous maize production without fertilizer, although the figures do not reach those achieved when maize is grown with fertilizer (Rommelse 2001; Franzel et al. 2002). Table 1 illustrates the success of improved fallows in eastern Zambia.

Studies on these systems generally show that adoption levels are relatively similar for male- and female-headed households and for households with different levels of education. In addition to addressing issues of soil fertility and quality, improved fallows also provide households with nearby sources of fodder and fuelwood, thus contributing to reduced overall labour requirements for the family (Ajayi et al. 2003).

Agroforestry foods

People living with HIV are trapped in a vicious cycle in which repeated episodes of illness weaken the body and accelerate the onset of AIDS. HIV weakens the immune system and people become ill more frequently. Repeated illness reduces appetite and, at the same time, nutrients are lost

Table 1. *Labour requirements, maize production and returns to land and labour of* Sesbania sesban *improved fallows and continuously cropped maize over a 5-year period, using an average farm budget.*

Option	**Work days ha^{-1}**	**Maize t ha^{-1}**	**Returns to land: net present value US\$ ha^{-1}**		**Returns to labour: net returns US\$ work day^{-1}**	
			1996 prices	1998 prices	1996 prices	1998 prices
Continuous maize, no fertilizer	499	4.8	6	6	0.47	0.79
Improved 2-year, sesbania fallow	441	8.5	170	215	1.11	1.64
Continuous maize with fertilizer	645	21.9	229	544	1.04	2.18

Source: Franzel et al. (2002). Note that the economic analysis was conducted under two scenarios, 1996 and 1998 prices. Prices in 1996 were low, following a bumper harvest, while prices in 1998 were high, following a poor harvest.

from the body through vomiting and diarrhoea. Some medicines also cause nutrient loss, while infections interfere with the body's ability to absorb and use the nutrients in food. This has serious consequences for the poor, who are more likely to be malnourished even before they become infected. Malnutrition may also be associated with an increased risk of HIV transmission from mothers to children (FAO 2004b). Epidemiological evidence shows how vitamin deficiency, protein deficiency and low immunity make people much more susceptible to the disease (Stillwagon 2002).

Forest resources can help to provide the nutritional requirements of people who are HIV-positive. For example, leaves from the baobab (*Adansonia digitata*) are a source of calcium, Vitamin A and Vitamin C (Boukari et al. 2001) and protein (Nordeide et al. 1996). In Mali, the World Agroforestry Centre has been working with several women's groups who are managing baobab plants to produce leaves in a similar way to tea. *Moringa oleifera* is a multipurpose tree that originated in the eastern Himalaya and has been introduced to many tropical countries. In recent years, it has been promoted by non-governmental organizations (NGOs) and faith-based organizations to meet the nutritional needs of communities affected by HIV/AIDS. *Moringa oleifera* seeds are very effective in clarifying and treating water; fresh moringa leaves contain very high levels of micro- and macronutrients (protein, carotene, calcium, iron, Vitamins A, B and C); and moringa pods and dried leaf powder are used as nutritional supplements (McBurney et al. 2004).

Throughout sub-Saharan Africa, people harvest indigenous fruits to supplement their diets and incomes. In southern Africa, the Centre and its partners have initiated a research and development programme to promote the on-farm planting and management of selected varieties of indigenous fruit trees. Greatest progress has been made with *Uapaca kirkiana*. Scientists are selecting elite germplasm and looking at propagation and preservation, processing and marketing of fruit products. However, the domestication and dissemination of indigenous fruit species is a challenging process. Mithoefer et al. (2004) estimated that the returns to planting non-improved *U. kirkiana* were only 10–25 percent as high as the returns to gathering the fruit from the wild because of the high costs associated with tree planting and maintenance. Where wild fruit is still available, farmers would find it profitable to plant *U. kirkiana* only if the domesticated trees yield fruit 2–4 years after planting, if the production per tree was increased by a factor of 8, and/or the price per kg of the domesticated fruit was twice that of the wild fruit.

Medicinal plants

Plant products have been used to cure disease since ancient times. In Africa, it is estimated that 80 percent of the population use natural products to treat various ailments. In the Shinyanga region of Tanzania alone, over 300 plants have been identified for their medicinal values (Dery et al. 1999). Although there is no hard evidence to show that traditional medicines can treat HIV and cure AIDS (FAO 2002), it is known that certain tree products can be used to treat opportunistic infections associated with HIV/AIDS and/or to relieve some of their symptoms.

In many villages, basic pharmaceutical drugs are not available, and households rely entirely on wild medicinal plants for treatment of opportunistic infections associated with AIDS (Kolberg and Holding Anyonge 2002). Results of two recent FAO country studies show that in some areas, such plants are becoming scarcer

(Sitoe 2004; Kayambazinthu et al. 2005). Encouraging village forest committees and extension officers to incorporate medicinal species into their management plans could contribute to sustainable management of wild species. There is also potential for the domestication of medicinal plants.

New sources of medicines from plants continue to be discovered. For example, researchers at the University of Lausanne have found that the African tree *Bobgunnua madascarienis* contains an anti-fungal substance that combats *Candida albicans*, the bacteria responsible for fungal skin problems, and mycosis, a condition that commonly affects the eyes of AIDS patients. It is also said to fight *Aspergillis*, a fungus that can cause fatal lung disease (SAF 2004).

Income generation

Trees provide many products (food, fuel, fibre, timber, poles and fodder) that households can use or sell. Livelihoods can also be supported by sale of woodland products such as honey and mushrooms. An NGO in Malawi has encouraged young women to make and sell charcoal briquettes instead of engaging in commercial sex for their income (Ngwira et al. 2001).

Safety net resources

Forest foods have traditionally complemented agriculture and often sustain people during severe food shortages (Shackleton et al. 2001). The 'miombo' woodlands of southern Africa provide such a traditional 'safety net' and they occur throughout the area most affected by HIV/AIDS. Despite the mediocre fertility of the soils, the vegetation provides a wide range of products including foods, medicinal plants, firewood and timber. Studies have found that indigenous fruit can be a significant source of food and cash income, especially for poorer households, women and children. In the communal areas of Zimbabwe, for example, Cavendish (2000) found that the poorest 20 percent of households generated 7–9 percent of their total household income from selling collected wild foods. At two sites in rural Zimbabwe, Mithhoefer and Waibel (2003) found that virtually all households consumed some indigenous fruits (*Uapaca kirkiana*, *Strychnos* sp., *Parinari curatellifolia)* and that 7–20 percent of households sold some *Uapaca kirkiana*. When food is plentiful, it is mostly the children who eat the fruits. However, in times of food scarcity, *Uapaca kirkiana*, *Strychnos* sp. and *Parinari curatellifolia* became the main food for over 70 percent of households at one of the study sites. In total, the three indigenous fruit contributed 5–7 percent of total household income. Returns to family labour invested in gathering, processing and selling indigenous fruit in both villages were found to be higher than returns to crops, livestock, horticulture, exotic fruit trees and casual labour.

Box 1. Rotational woodlots provide food and cash

In the tobacco-growing Tabora region of Tanzania, farmers have traditionally harvested wood from natural 'miombo' woodlands to make poles for drying the tobacco leaves. To protect these woodlands and create an alternative source of income, the Centre and its partners have developed a rotational woodlot system, where farmers plant fast-growing acacia (primarily *Acacia crassicarpa*) in 1-ha plots. They continue to grow maize in the same plots for the first two years, then wait until the fifth year to harvest the wood. Compared to the customary maize/fallow system, rotational woodlots required about 2.5 times as much labour, mostly needed to harvest the wood in the fifth year. Despite the high labour cost and longer payback period, the net current value of rotational woodlots was over six times that of maize alone and the return to labour from rotational woodlots was more than twice that of maize. Many farmers are now adopting the system (Ramadhani et al. 2002). While loss of family members due to HIV/AIDS may create long-term labour shortages, it appears that extra labour can usually be hired for harvesting the wood.

Marking ownership

In many sub-Saharan African social systems, when a man dies, his relatives take over all productive assets (and sometimes other property) from the widow. In some cultures, the widow, land, property and children are 'inherited' by a brother of the deceased. With the spread of AIDS, and worries that they may be 'inheriting' infected people, families of deceased heads of households may refuse to care for the widow and children, yet still claim the land that their brother had farmed. Widows are then left with no productive assets (Drimie 2002). Access to and ownership of land can have an important influence on the viability of HIV/AIDS-affected households. Trees have long been an indicator of tenure in Africa. There is some prospect that planting trees in abandoned fields can preserve the land for the family and, at the same time, rehabilitate wasted soils and provide fuelwood, fodder and fruits. On the other hand, investing in trees could also encourage more powerful family members to take over that portion of land. The interpretation of customary practice with regard to land and tree tenure will vary between adjacent communities sharing the same cultural heritage. More evidence needs to be compiled on how aspects of land and tree ownership can assist people suffering from the effects of HIV/AIDS.

Labour management

Most African agriculture depends on manual labour and there are peaks in labour demand, for example, for land preparation, planting and harvesting. When sickness, death and funerals occur during these critical periods, crop productivity will be greatly affected. Caring for the sick also demands time and energy and reduces availability of labour, especially women's, for agricultural tasks. In Ethiopia, a study found that AIDS-affected households spent 50–66 percent less time on agriculture than households that were not affected (Baryoh 2000). In Tanzania, researchers found that women spent 60 percent less time on agricultural activities when their husbands were ill (Tibaijuka 1997).

Different improved fallows agroforestry systems advocated by the Centre have different implications for total and seasonal labour demand. Short-duration improved fallows, as developed in western Kenya, require less total labour than the typical two-season pattern of maize production, but there is a greater seasonal labour demand during the land preparation phase of the long rain production season. If labour hiring is not a viable option, then shortage of labour may impede adoption (Rommelse 2001). The 2–3-year fallows developed in eastern Zambia typically entail less labour per hectare and per unit output than the continuous maize systems (no fertilizer) that they replace. During the first year of tree establishment, the fallows do require extra labour, but there is quite a wide variation between different fallow systems. Steve Franzel, ICRAF (personal communication) used farm data from eastern Zambia to calculate the extra labour time required to establish 0.27 ha plots of *Sesbania sesban* and *Tephrosia vogelii* fallows. Since the average farm in this region has 1.08 ha of cultivated land, planting 0.27 ha to improved fallow each year for 4 years would allow most farmers to convert their farms to the agroforestry system within 4 years. The calculations showed that pure stands of *S. sesban* and *T. vogelii* require an average of 36 and 22 extra labour days during the establishment year. If, however, the fallows are intercropped with maize during the first year, then only an extra 16 days for *S. sesban* and 3 days for *T.vogelii* are required. Different systems are therefore appropriate for households at different stages of AIDS impact. Households that have already suffered significant labour losses may not be well advised to plant pure stands of *S. sesban*, but they could still manage the extra labour required to intercrop their maize with *T. vogelii.*

Reducing labour peaks

A study in eastern Zambia showed that land preparation, weeding and harvesting account for 70 percent of the labour demand associated with the production of maize under improved fallows (Ajayi 2003: see Figure 4). Land preparation and weeding are the most demanding, since several essential activities have to be carried out over a relatively short time. Any interventions that reduce labour requirements during these phases will therefore be attractive.

Further analysis showed that in agroforestry fields, farmers spent 27 percent of total labour on land preparation compared to 19 percent in non-agroforestry fields (Table 2). However, in the non-agroforestry fields, farmers spent 34 percent of their labour time on weeding activities compared to 26 percent in agroforestry fields. Weeding is time-consuming and must be completed within a short time to prevent a poor harvest. Thus, by reducing the proportion of time allocated to weeding from 34 to 26 percent, improved fallows help labour-constrained households to have a better chance of a good yield. However, fallows entail more labour for land preparation. The trade-off is in favour of fallows because the time 'window' for land preparation is less critical than that for weeding.

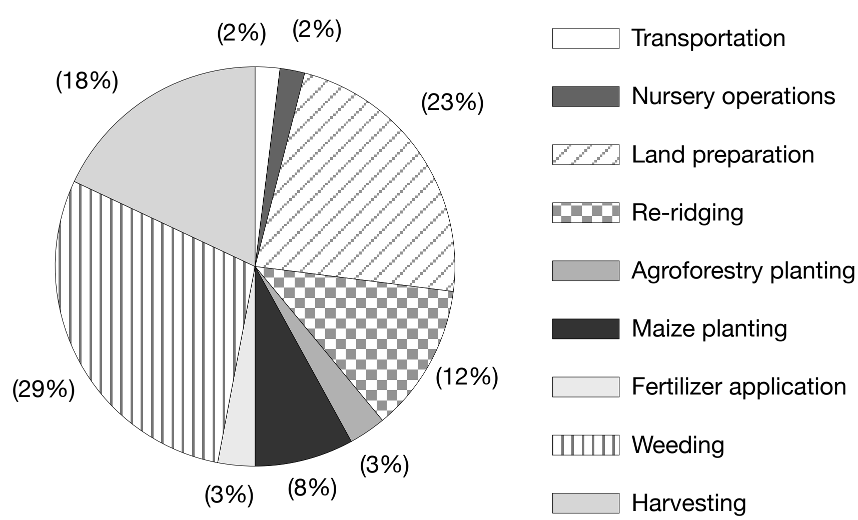

Figure 4. *Distribution of total labour inputs by type of field operation (% of absolute inputs).*
Source: Ajayi (2003).

Long-term labour management

Communities differ in their capacity to recover from external shocks. The time of recovery after a drought, for example, depends on external factors, such as the type of agro-ecological zone, and variable factors, such as labour availability, knowledge, skills and food stocks, including storage facilities and postharvest management. HIV/AIDS affects all the variable factors and creates an increased dependency ratio in households, since it kills mostly productive age adults.

Traditional agroforestry systems vary in different agro-ecological zones and are socially and culturally specific. Appropriate agroforestry strategies can help increase the resilience of communities to external shocks. Combinations of trees and crops can be developed jointly with local communities in line with their short- and long-term needs and according to the current phase of HIV/AIDS. Techniques that have high labour requirements to get them started should be promoted during the low impact phase. Trees planted in the early stages, when labour is still available, will provide a source of food several years later, when labour supplies in the household and community may have dwindled.

So, although some agroforestry technologies appear to be labour intensive, especially in the early stages, they offer a number of benefits towards the mitigation of HIV/AIDS.

1. Increased yields might allow farmers to plant a smaller area of land with maize, reducing labour demand for land preparation, weeding and harvesting. The saving of labour and land would allow the farmer to grow something else, such as vegetables and/or fruits.
2. Most of the agroforestry technologies for improving soil fertility also produce fuelwood on farms thus saving the labour and energy normally spent gathering wood (especially relevant for women).
3. In some societies, planting trees enhances security of land ownership.
4. Improved fallows suppress weeds, thereby cutting down the amount of labour needed for weeding.
5. Agroforestry technologies improve soil fertility and produce fodder, thereby reducing the need for expensive inorganic fertilizer or livestock feed. However, some agroforestry technologies trade low cost with higher demand for labour.
6. Growing medicinal plants on farm prevents over-harvesting of wild varieties.

Table 2. *Time devoted to the three most time-consuming field activities during the cropping season.*

Field operation	With agroforestry (improved fallows) (%)	Without agroforestry (%)
Land preparation	27.1	19.2
Weeding	26.2	33.7
Harvesting	16.9	18.5

Source: Ajayi (2003).

Increasing the relevance of agroforestry to HIV/AIDS mitigation

One of the defining attributes of agroforestry is its complexity. Across the African continent, farmers have adopted agroforestry systems that vary greatly in terms of types of goods and services produced, length of production period, market and environmental risks, ecological complexity, land, labour and managerial intensity, and dependence on input and output markets. While this complexity may make it difficult to recommend a standard set of agroforestry interventions, it also means that the variety of options are relevant to a wide range of circumstances encountered by households and communities affected by HIV/AIDS. For example, households that have absorbed non-family members may be in a position to establish new agroforestry systems on crop fields, while households that have lost family members may adapt trees into their home gardens.

Another defining attribute of agroforestry is its tight connection with forestry. Farmers access and use trees throughout their landscapes, whether on their farms, on communal lands, or on the margins of forests. Access to forests and communal lands affects farmers' decisions on what trees they preserve, what trees they plant, and how they manage trees on their farms. Agroforestry interventions therefore need to be based on a good understanding of the trees and tree products that are already available and the potential of agroforestry and other forest management options for enhancing the supply of consumable and marketable products (such as fodder and fruits) and for soil fertility and conservation.

Preserving and adapting knowledge

Agroforestry systems depend upon local agricultural and biodiversity knowledge to maintain production. When a productive generation is lost, they can no longer pass on their livelihood skills and agroforestry knowledge. The consequence is a young population who are ill equipped to manage the impacts of the epidemic and to maintain successful production. Community knowledge of the environment and local genetic diversity are fundamental for nurturing and preserving cultural identity. Indigenous knowledge and, often, technology-related knowledge are typically gendered, with some aspects passed on by men and some by women. Gaps in knowledge will therefore occur when a parent dies. Effective initiatives in facilitating gendered links in indigenous and community knowledge in single-parent households need to be designed, implemented and monitored, and agroforestry education needs to be targeted to the rural youth.

Strengthening institutions

Strengthening local institutions is an essential component of the sustainability of any agroforestry intervention. Such an approach also marries well with the current trend in extension towards supporting collective action and empowering local communities to design and manage their own development initiatives. Village forestry can be the main cash generator in a community, and tree resources (customary woodlands, village plantations and trees on farms) have seen communities through periods of severe hardship in the past.

It is also important to strengthen formal institutions, since human resources are being lost from ministries of forestry and agriculture, thereby hampering the development and implementation of agroforestry strategies. In general, the loss of all types of government cadres is creating serious governance problems in the most-affected countries. However, instead of developing strategies to replace lost human resources, which is already difficult for the worst hit countries, it is necessary to rethink government functions and streamline them to adapt to the situation. Extension workers, for example, need to be trained to address the emerging clientele (widows, orphans, etc.) with specific information and knowledge to match their needs. Vocational training institutions may also be required to review their staffing, length and priority foci of courses, in light of the impact of the pandemic and changing human resource requirements. Specific staff policies need to be developed in the relevant ministries, including awareness building, behavioural change, communication, stigma and discrimination, voluntary counselling and testing, modification of working conditions of employees exposed to high-risk situations, improved access to medicine, etc.

Forestry policy

Effective forestry policy needs to take the effects of HIV/AIDS into account. For example, policy makers need to be aware of labour availability and the labour implications of interventions. Extension services need to adapt to a new clientele, with very specific knowledge and service needs. Barany et al. (2005) recommend that current and future forest policies and programmes should be reviewed to assess their effects on key determinants of HIV vulnerability. These include social inequalities, exclusion, creation of cash economies/disposable incomes, displacement and migrant labour. A review process would assist project programmers and policy makers to identify where and for whom prevention and mitigation efforts should be targeted and concentrated.

Conclusions

Agroforestry interventions can play a unique role in the mitigation of the impacts of HIV/AIDS. They can improve communities' long-term resilience against this and other external shocks, in a way that agricultural interventions on their own cannot.

Agroforestry technology can be carefully tuned to respond to the AIDS-affected communities' lack of labour and cash, both in the short term and in the long term. By providing labour management possibilities, agroforestry technologies can reduce hunger and promote food security.

The capacity to generate alternative low-input income-generating activities and

Box 2. Strengthening local communities

A project in Katunga, Malawi, aimed to enhance the production of woody vegetation and strengthen the capacity of local communities to manage the resource by establishing eucalypts (*Eucalyptus saligna*) on hillsides surrounding the village. After 13 years, the trees were handed over to the community's natural resource management committee. The area is relatively fertile, with a wide range of crops and trees. Trees, not agriculture, now provide the major source of cash income and the villagers have built a new school classroom. HIV/AIDS is a serious problem in the area and although native medicinal plants are not readily available, funds from the trees support 20 orphans under 5 years old, a basic pharmacy, transport to hospital, and contribute to funeral costs.

Source: Kolberg and Holding Anyonge (2002).

provide essential nutrients means that agroforestry interventions can help break the vicious cycle of impoverishment–malnutrition–AIDS. Medicinal plants and trees frequently provide the only source of symptomatic relief available to the poor.

The specific needs of a new clientele created by the epidemic, with high dependency ratio households and unique compositions, must be taken into account when designing agroforestry interventions. Efforts should be made to ensure that basic agricultural skills are passed on to the younger generation, and that local knowledge, including biodiversity and gender-specific skills, are preserved. If a strategy can be developed that can respond effectively to these needs, a significant contribution will be made to preventing and mitigating the consequences of HIV/AIDS within agroforestry communities.

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Acronyms and Abbreviations

ACIAR Australian Centre for International Agricultural Development
AFTP agroforestry tree products
AHI African Highlands Initiative
AMAN Alliance of Indigenous Peoples of the Archipelago
ANAFE African Network for Agroforestry Education
APSO Agency for Personal Service Overseas (Ireland)
ASARECA Association for Strengthening Agricultural Research in East and Central Africa
ASB Alternatives to Slash and Burn
ATSAL Agroforestry Tree Seed Association of Lantapan
AVU African Virtual University
BACOSA Baraka Agricultural College Old Students' Association (Kenya)
BD bulk density
BPC bits per capita
C carbon
CABI Centre for Agricultural and Biosciences International
CARPE Central African Regional Program for the Environment
CASCA Sistemas Agroforestales de Café en America Central
CBD Convention on Biological Diversity
CDM Clean Development Mechanism
CGIAR Consultative Group on International Agricultural Research
CIAT Centro Internacional de Agricultura Tropical
CIFOR Center for International Forestry Research
CIRAD Centre de coopération internationale en recherche agronomique pour le développement (France)
COP 8 Eighth Session of the Conference of the Parties (UNFCCC)
CSARD Certificate in Sustainable Agriculture and Rural Development
DFID Department for International Development (UK)
DSIR Department of Industrial and Scientific Research (New Zealand)
ECA East and Central Africa
EMBRAPA Empresa Brasileira de Pesquisa Agropecuaria
FAO Food and Agriculture Organization of the United Nations
FALLOW Forest, Agriculture, Low-value Lands or Waste
FARA Forum for Agricultural Research in Africa
FoF farmers of the future
FPP Forest Peoples Programme (Indonesia)
GEF Global Environment Facility
GFAR Global Forum on Agricultural Development
GIS geographic information systems
GO–AFU Global Open Agriculture and Food University
GORTA Freedom from Hunger Council of Ireland
GP global programme (GFAR)
GVU Global Virtual University
HIPC heavily indebted poor country
HIV/AIDS Human immunodeficiency virus/acquired immuno-deficiency syndrome
HULWA Humid Lowlands of West and Central Africa
IACSS InterAcademy Council of Scientific Studies
IBSRAM International Board for Soil Research and Management
ICO International Coffee Organization
ICCO International Cocoa Organization
ICRAF World Agroforestry Centre
ICRISAT International Crops Research Institute for the Semi-Arid Tropics
ICT information and communication technology
IDRC International Development Research Centre (Canada)
IFPRI International Food Policy Research Institute
IFS International Foundation for Science
IGU income generating units
IIED International Institute for Environment and Development
IIRR International Institute of Rural Reconstruction
IISD International Institute for Sustainable Development
ILRI International Livestock Research Institute
IMF International Monetary Fund
INRM integrated natural resource management
IPCC Inter-Centre Panel on Climate Change
IPFE International Partnership on Forestry Education
IPGRI International Plant Genetics Research Institute
IPR intellectual property rights
IRRI International Rice Research Institute
ISD instructional systems design
ISNAR International Support to National Agricultural Research
IUCN World Conservation Union

K	potassium
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
LANAFE	Latin American Agroforestry Network
LGU	local government units
LUCID	Land Use Change, Impacts and Dynamics (ILRI)
LULUCF	land use, land-use change and forestry
MDG	Millennium Development Goals
MISEREOR	The German Catholic Bishops' Organisation for Development Cooperation
MOSCAT	Misamis Oriental State College of Agriculture and Technology
MPR	Minjingu phosphate rock
N	nitrogen
NARO	national agricultural research organization
NARS	national agricultural research systems
NEPAD	New Partnership for Africa's Development
NGO	non-governmental organization
NRI	Natural Resources Institute (UK)
NRM	natural resource management
NTFP	non-timber forest products
NVS	natural vegetative strips
ODI	Overseas Development Institute (UK)
P	phosphorus
PAR	photosynthetically active radiation
PR	phosphate rock
PRGA	Participatory Research and Gender Analysis (CGIAR)
PRSP	poverty reduction strategy papers
RAF	relative agronomic function
RAFTT	Regional Agroforestry Training Team
REF	relative ecological function
RELMA	Regional Land Management Unit
R&D	research and development
RIRDC	Rural Industries Research and Development Corporation (Australia)
RSPO	Round Table on Sustainable Palm Oil
RUE	rainfall use efficiency
RUPES	Rewarding Upland Poor for Environmental Services
SADC	Southern Africa Development Community
SAF	Society of American Foresters
SAP	structural adjustment programmes
SARD	sustainable agriculture and rural development
SAREC	South Asia Regional Energy Coalition
SEANAFE	Southeast Asian Network for Agroforestry Education
SEF	Sahelian Eco-Farm (ICRISAT)
Sida	Swedish Agency for International Development Cooperation
SSA	sub-Saharan Africa
SSSA	Soil Science Society of America
STCP	Sustainable Tree Crops Programme
SWC	soil and water conservation
TOF	trees outside forests
TM	Trees and Markets (ICRAF)
TPN	Thematic Program Network (UNCCD)
Trocaire	Overseas Development Agency of the Catholic Church in Ireland
TSBF	Tropical Soils Biology and Fertility (CIAT)
TSP	triple superphosphate
UNAIDS	United Nations Programme on HIV/AIDS
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention on Combating Desertification
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
USAID	United States Agency for International Development
WaNuLCAS	Water, Nutrient and Light Capture in Agroforestry Systems
WBCSD	World Business Council for Sustainable Development
WWF	Worldwide Fund for Nature
WRI	World Resources Institute

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World Agroforestry into the Future

This book has been compiled from contributions by world experts in agroforestry who met in Kenya in November 2003 to chart the future on the occasion of the 25th anniversary of the World Agroforestry Centre.

The World Agroforestry Centre is recognized as an international leader in agroforestry research, education and development-support. It was established in 1978 as the International Council for Research in Agroforestry (ICRAF), to promote agroforestry research in developing countries, in response to a visionary study by Canada's International Development Research Centre (IDRC). During the 1980s, the Centre operated as an information council focusing primarily on Africa. ICRAF joined the Consultative Group on International Agricultural Research (CGIAR) in 1991 to conduct global research on agroforestry, transforming itself into the International Centre for Research in Agroforestry. ICRAF is one of 15 international centres of the Future Harvest Alliance supported by the CGIAR. Its first strategic plan as a CGIAR member addressed poverty, food security and environmental degradation in smallholder farms of sub-humid and semi-arid Africa. The Centre then expanded to Latin America, South Asia and Southeast Asia, while strengthening its activities in four regions of Africa. In 2002, it adopted the brand name, the World Agroforestry Centre, but retained the International Centre for Research in Agroforestry (ICRAF) as its legal name.

The mission of the CGIAR is to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in agriculture, livestock, agroforestry, fisheries, policy and natural resources management (NRM).

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TRANSFORMING LIVES AND LANDSCAPES

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