Bioversity International

Teaching agrobiodiversity: a curriculum guide for higher education

Per Rudebjer, Boudy van Schagen, Sebastian Chakeredza, Kiarie Njoroge, Henry Kamau, Margarita Baena

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Bioversity International is a world leading research-for-development non-profit organization, working towards a world in which smallholder farming communities in developing countries are thriving and sustainable. Bioversity's purpose is to investigate the use and conservation of agricultural biodiversity in order to achieve better nutrition, improve smallholders' livelihoods and enhance agricultural sustainability. Bioversity International works with a global range of partners to maximize impact, to develop capacity and to ensure that all stakeholders have an effective voice.

Bioversity International is part of the Consultative Group on International Agricultural Research (CGIAR), which works to reduce hunger, poverty and environmental degradation in developing countries by generating and sharing relevant agricultural knowledge, technologies and policies. This research, focused on development, is conducted by a Consortium of 15 CGIAR centres working with hundreds of partners worldwide and supported by a multi-donor Fund.

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Cover photo

The Kyanika Women's Group in Kitui, Eastern Kenya plays a key role in conserving local landraces of crops traditionally grown in the area. Ms Peninah Mwangangi, a leader of the group, shows some of the bean varieties they conserve, displayed in gourd bowls.
Photo: Yusuf Wichira/Bioversity

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Foreword

Agrobiodiversity is the foundation of sustainable agricultural development. It includes the diversity of plants, animals, fish, trees and microbes that are used directly or indirectly for food and agriculture. The human race could not survive without access to this diversity, which enables plant and animal species and agroecosystems to evolve and adapt to changing environmental conditions.

Agrobiodiversity will play an increasingly important role in enabling agriculture to achieve gains in productivity, improve sustainability, support improved livelihoods for the rural poor (and increasingly the urban poor) and meet the challenge of changing production conditions such as those resulting from climate change, population growth, urbanization and an increasingly degraded environment. Changes will be needed in both the nature and the amounts of agrobiodiversity used. Agricultural production systems need to be focused more on the effective conservation and management of biodiversity and ecosystem services in order to address the triple objectives of environmental sustainability, food security and improved livelihoods.

Bioversity International has been at the forefront of global scientific efforts to research and demonstrate the vital role of biodiversity in farming and forest systems for more than 35 years. Bioversity recognizes the important role that education plays in the management and use of agrobiodiversity now and into the future, and has, over the past two decades, contributed substantially to strengthening the capacity for research in plant genetic resources and, more recently, the management and use of agrobiodiversity. Bioversity has collaborated with a number of universities in developing MSc programmes on the conservation and use of plant genetic resources. But the demand has grown for new knowledge and skills to address the multifunctionality of sustainable agriculture and the interconnectedness of biodiversity, ecosystem functioning and human health.

The need for new capacity to address these new research needs has been recognized at a global level, as shown in FAO's Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture, in the Convention on Biological Diversity's Programme of Work on Agricultural Biodiversity, and in the International Treaty on Plant Genetic Resources for Food and Agriculture. At a regional level, it has been recognized in regional strategies and action plans such as the Suwon Agrobiodiversity Framework for managing agrobiodiversity for sustainable agriculture in the Asia-Pacific Region and the Agricultural Biodiversity Initiative for Africa, among others.

To address this challenge, in 2009 Bioversity and its partners in higher education networks on three continents started a process to analyze the knowledge and skills required to equip a new cadre of researchers, development experts, policy specialists and teachers to carry out multidisciplinary research and development interventions on agricultural biodiversity. The process involved a series of

surveys, expert consultations and dialogue with key players in both agricultural research organizations and universities. The result is this publication: Teaching agrobiodiversity: a curriculum guide for higher education. It is an annotated 'road map' for educational organizations interested in introducing an agrobiodiversity component into the academic curriculum of courses and programmes at either the undergraduate or graduate level – or both. It is our hope that agrobiodiversity becomes a regular feature in all educational programmes of relevance to agriculture and natural resource management, as well as related sectors such as health and nutrition. We trust that this guide will ultimately contribute to strengthening the capacity of tomorrow's leaders to address the daunting challenges of environmental sustainability, food security and improved livelihoods.

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The collaboration with networks on higher education in agriculture proved particularly useful in conceptualizing and realizing the writing of the guide. In Africa these networks included the African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE) and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM). In Asia and Latin America, informal networks of universities gave useful support.

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Acronyms

ABIA	Agrobiodiversity Initiative for Africa
ANAFE	African Network for Agriculture, Agroforestry and Natural Resources Education
AnGR	Animal genetic resources
APAARI	Asia-Pacific Association of Agricultural Research Institutions
CATIE	Tropical Agricultural Research and Higher Education Center
CBD	Convention on Biological Diversity
CBO	Community-based organization
CGIAR	Consultative Group on International Agricultural Research
CGRFA	Commission on Genetic Resources for Food and Agriculture
CTA	Technical Centre for Agricultural and Rural Cooperation
EAPGREN	East Africa Plant Genetic Resources Network
EUFORGEN	European Forest Genetic Resources Network
FAO	Food and Agriculture Organization of the United Nations
FNPP	FAO-Netherlands Partnership Programme
FARA	Forum for Agricultural Research in Africa
GRPI	Genetic Resources Policy Initiative
ICT	Information and communication technologies
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual property rights
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture ('the Treaty')
NARES	National agricultural research and extension systems
NBSAP	National Biodiversity Strategy and Action Plan
NGO	Nongovernmental organization
NUS	Neglected and underutilized species
PACS	Payments for agrobiodiversity conservation services
PAPGREN	Pacific Agricultural PGR Network
PAR	Platform for Agrobiodiversity Research
PGR	Plant genetic resources
PGRFA	Plant genetic resources for food and agriculture
RAPA	Rapid biodiversity assessment
REDD	Reducing emissions from deforestation and forest degradation
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
SEARICE	Southeast Asia Regional Initiatives for Community Empowerment
SEUCO	South Eastern University College
SMTA	Standard material transfer agreement
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

Introduction

Why teach agrobiodiversity?

Higher agricultural education plays a dual role: it develops the capacity of future decision makers and it creates and shares knowledge for societal development. Both functions are important for achieving the United Nations' (UN) Millennium Development Goals of poverty alleviation, food security, improved health and nutrition, and environmental sustainability. Agricultural universities and colleges have played a key role in increasing global agricultural outputs, for instance by developing the plant-breeding capacity that underpinned the Green Revolution. Today, as the trade-offs of agricultural intensification threaten the sustainability of agroecosystems, institutions of higher agricultural education seek to develop a broader range of capacities to prepare graduates for a more complex and rapidly changing reality. Global value chains, volatile food prices, intellectual property rights for genetic resources, and the impact of climate change on agriculture are but a few of the important global aspects of this new reality. Changes at the local scale are equally crucial, including farmers' traditional knowledge, land-use practices and decisions, livelihood systems, migration patterns, and the role of local institutions and stakeholders.

To stay relevant, universities and technical colleges review curricula and adjust on-going courses not just to deliver new subject-matter content, but also to provide experiences and activities that help students become effective, life-long learners. This process of reassessing new realities, setting educational objectives and designing and facilitating learning experiences requires universities to engage more proactively in a dialogue with citizens. Such engagement can promote the "co-construction" of knowledge (Aarts et al. 2011), drawing on both scientific and local knowledge. Capacity building is then not just about transferring skills and technologies, but also about changing the wider system through the knowledge, skills and, crucially, attitudes (values, mindsets and behaviours) that society needs.

Agrobiodiversity is one such emerging area of learning. The environmental impact of development came into full view at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, which led to the three 'Rio conventions' on climate change, biodiversity and desertification. Realizing the strong links between biodiversity and sustainable agriculture, the Convention on Biological Diversity (CBD) then added, in 1996, a thematic programme on agricultural biological diversity ('agrobiodiversity' for short). Several other policy instruments on agrobiodiversity have followed suit, including the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, or 'the Treaty') in 2004.

Institutions of higher agricultural education play a key role in implementing this expanding agrobiodiversity agenda, through both capacity development and knowledge creation and sharing, and there are signs that the interest in teaching agrobiodiversity is increasing. Regional conferences have endorsed the idea, and universities in Colombia, Kenya and Nepal, to mention a few, are at various stages

of developing agrobiodiversity curricula. However, many agricultural universities and colleges are at an early stage of this process or have yet to start. Integrating these new topics, concepts and practices into an already full curriculum is always going to be a challenge, but one that is important to meet. To quote the CBD: "Maintenance of this biodiversity is essential for the sustainable production of food and other agricultural products and the benefits these provide to humanity, including food security, nutrition and livelihoods" (CBD 2011). Ultimately, students learning about agrobiodiversity can make a difference to people's lives, and to the planet.

What is agrobiodiversity?

Agrobiodiversity is the subset of biological diversity important to food and agriculture. It is the human element that sets agrobiodiversity apart from 'wild' biodiversity: agrobiodiversity is the outcome of the interactions among genetic resources, the environment and farmers' management systems and practices. It is the result of both natural selection and human intervention over millennia. The CBD's thematic programme on agrobiodiversity identifies four dimensions of agrobiodiversity (CBD 2011):

- **Genetic resources for food and agriculture**, including plants, animals, trees, fish and microbes. These include cultivated and domesticated species, managed wild plants and animals, and their wild relatives.
- **Components of biodiversity that support the ecosystem services** of agricultural systems. These include a wide range of organisms that contribute to water and nutrient cycling, pest and disease regulation, pollination, climate regulation, carbon sequestration and other processes.
- **Abiotic factors**, such as local climatic or chemical factors that affect agrobiodiversity.
- **Socio-economic and cultural dimensions**, including traditional and local knowledge of agrobiodiversity, cultural factors and participatory processes, as well as tourism associated with agricultural landscapes.

Crucially, agrobiodiversity concerns three levels of genetic diversity: agroecosystems, species (inter-specific diversity) and within species (intra-specific diversity). The genetic variation **within species** includes wild relatives, landraces and modern cultivars, as well as materials in *ex situ* collections. This variation within a genepool allows breeders and farmers to develop new varieties that improve productivity, quality, tolerance to drought or resistance to pests and diseases. This variation also allows species' continued evolution and adaptation to changing environments, including climate change.

> *"Agricultural biodiversity is a broad term that includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agroecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agroecosystem, its structure and processes."*
>
> *Convention on Biological Diversity (COP decision V/5, appendix)*

Using this Guide

The context for curriculum development in higher agricultural education is specific to each institution's internal and external setting, such as its geographical location, its societal and policy environment and the job market that it serves. A curriculum guide on agrobiodiversity would thus need to meet very diverse needs. This Guide, therefore, does not seek to provide a ready-made, full-fledged syllabus for an agrobiodiversity programme or course. Rather, it presents a **flexible framework:** what we believe are essential elements of agrobiodiversity education, which a university or technical college might want to consider teaching in its own unique setting. This Guide would be one of several resources used in curriculum development or review.

The Curriculum Guide is organized in three main sections:

PART I. Background to agrobiodiversity processes. We discuss agrobiodiversity in the context of global food security. Key drivers behind the rapid decline in agrobioversity are reviewed: agricultural intensification, habitat loss, market globalization and climate change. We also explore how the global community is responding through improved policies and strategies for conservation of agrobiodiversity. Finally, we reflect on the role of higher agricultural education in addressing these issues.

PART II. Key issues in agrobiodiversity education. Drawing on recent surveys of agrobiodiversity learning in universities, and consultations with higher education institutions in Africa, Latin America and Asia-Pacific, we discuss the current status of agrobiodiversity education. We report how the topic is currently being taught (or not, as is often the case). Gaps in curricula are identified and competencies required for agrobiodiversity-related jobs are listed. Key issues in mainstreaming agrobiodiversity in education programmes are identified.

We suggest five strategic options that universities and colleges might want to use as they seek to integrate agrobiodiversity into existing or new curricula: informal curriculum adjustment, adding new courses, establishing new programmes, stimulating thesis research and offering short courses on agrobiodiversity. A list of possible **entry points** for integrating agrobiodiversity into courses and programmes is presented (Table 5, page 32).

PART III. Curriculum framework for agrobiodiversity learning. Here we introduce a conceptual framework for agrobiodiversity learning (see Figure 1, page 38). This flexible framework contains **14 key topics for agrobiodiversity learning**, clustered in four learning areas:

- Global context for agrobiodiversity management
- Genetic resources for food and agriculture
- Agrobiodiversity products and services
- Sustainable management of agrobiodiversity

Each topic is then presented as follows:

- An **Introduction** gives a background orientation on the topic and outlines the key issues to be covered. This brief summary of only one or two pages is intended as a starting point for further exploring the topic.
- **Main key learning points** are suggested, which capture the key message of the topic in a few bullet points (typically six to eight).
- **Contents** provide an indicative list of topics for teaching the subject.
- A **Bibliography** provides a suggested list of key literature on the topic in question. Where possible, we have selected publications that are available for free on the internet. Sometimes the hyperlink is given. If not, a search for the title will often yield a PDF file that can be downloaded.
- **Internet resources** list key organizations and portals providing further information on the topic.

Depending of the needs in the particular university or technical college, lecturers and curriculum developers could use these topics in any combination, to inspire the improvement of on-going courses and programmes, or to inform a more formal curriculum review.

We also suggest some options for providing practical learning experiences – experiential learning – such as using case studies for stimulating discussion in the class and creating links with communities that manage and conserve agrobiodiversity.

Brief summary of topics covered in this Guide

Global context for agrobiodiversity management

The learning area covers four topics that provide a global context to the management of agrobiodiversity:

- **Global change and agrobiodiversity** gives a historic overview of agricultural development and the global food system from a perspective of genetic resources for food and agriculture. Past and current changes and trends within and outside of the agricultural sector and how these affect agrobiodiversity are reviewed.
- **Impact of climate change on agrobiodiversity** gives a more detailed account of climate change scenarios and their impact on genetic resources for food and agriculture. The role of agrobiodiversity in adaptation to climate change and variability is studied.
- **Policies for agrobiodiversity conservation and use** gives an overview of the key international policy instruments of relevance to agrobiodiversity. Issues regarding their implementation at the national level are discussed.
- **Institutional aspects of managing agrobiodiversity** looks at the capacity of research, educational and extension organizations for managing agrobiodiversity. The needs for working in multidisciplinary teams and for analysing complex systems are highlighted. Networking, multi-stakeholder platforms and other ways of engaging with local organizations are pointed out.

Genetic resources for food and agriculture

This learning area covers three topics that deal with the dynamic change in genetic resources for food and agriculture, including efforts to conserve them:

- **Processes shaping agrobiodiversity** presents the dynamic genetic, socioeconomic and cultural processes that shape and maintain agrobiodiversity, and the effects of modern agriculture on these processes.
- **Status and trends of agrobiodiversity** gives an overview of the status of plant, forest and animal genetic resources. It describes global monitoring of agrobiodiversity at the ecosystem, species and genetic level, and discusses genetic erosion.
- **Conservation of agrobiodiversity** gives an overview of strategies for conserving agrobiodiversity *ex situ*, *in situ* and on farms in agricultural landscape mosaics. Information systems for genebanks are described.

Agrobiodiversity products and services

Four topics focus on the use of agrobiodiversity, with emphasis on the functions of livelihood support and of the environmental service of agrobiodiversity:

- **Agrobiodiversity and livelihoods** gives an overview of how agrobiodiversity, on-farm and off-farm, contributes to people's pursuit of sustainable livelihood, food security and income. Risk management and 'neglected and underutilized species' are key concepts.
- **Food and nutrition systems** discusses the role of agriculture and food systems in providing food and nutritional security and improving human health. The need for better links between the agricultural sector and the health sector is emphasized.
- **Traditional knowledge** describes the evolution of traditional and local knowledge of agrobiodiversity, its role today and the erosion of local knowledge that follows societal change.
- **Environmental services** focuses on the public values of managing agrobiodiversity and the role of ecosystem services for sustainable agriculture. The role of farmers in providing such services and ways of rewarding them for doing so are discussed.

Sustainable management of agrobiodiversity

This final learning area focuses on institutional aspects and participatory, multidisciplinary, multi-stakeholder processes for enhancing the sustainable use of agrobiodiversity:

- **Farmer's seed systems and participatory breeding** describes the role of both the formal and the informal seed systems, and the role of farmers in participatory plant breeding.
- **On-farm conservation and management of agrobiodiversity** conveys a deeper understanding of how farmers conserve and manage agrobiodiversity on farms, and of the related challenges and opportunities.
- **Value chains of neglected and underutilized species (NUS)** presents an approach to improving farmers' gainful participation in markets, looking at a broad range of issues 'from farm to fork'.

Felipe de la Cruz / Bioversity

PART I

BACKGROUND TO AGROBIODIVERSITY PROCESSES

Agrobiodiversity and food security

A total of 925 million people were undernourished in 2010, according to the United Nations Food and Agriculture Organization (FAO) (FAO 2010c). Reducing hunger and malnutrition, while also feeding a growing population, is a great challenge for the global food system. Global agricultural production will need to increase by 70% to feed an additional 2.3 billion people by 2050 (FAO 2009a). Production will need to rise even more in Africa where the population growth rate is highest and the increase in cereal yield has been modest.

Shifts in land use also need to be considered. The consumption of meat tends to increase as people get richer, which raises the demand for feed. In addition, bio-fuel production has reduced the area planted with food crops in some areas. Urbanization and infrastructure development convert significant agricultural areas – often areas of high soil fertility – to non-agricultural uses.

Meeting the world's demands for more and better food and feed while sustaining ecosystem services will be critical. With few remaining opportunities for expanding global agricultural areas, these needs will have to be met largely through agricultural intensification that builds on sustainable management of agrobiodiversity.

This agrobiodiversity is under threat. The Millennium Ecosystems Assessment (2005a) reported that 60% of the ecosystem services examined were either being degraded or used unsustainably. While deforestation shows signs of slowing down, 13 million hectares of forest were still lost each year in the last decade, most of that in Africa and Latin America (FAO 2010a). Deforestation and forest degradation, and the resulting landscape fragmentation that restricts geneflow, lead to genetic erosion in forest ecosystems and woodlands, threatening both wild species and crop wild relatives. Agricultural landscapes also suffer genetic erosion as traditional landraces and 'minor crops' are rapidly disappearing, replaced by modern varieties. At the same time, this trend is linked to changing food habits and dietary simplification. Urbanization and infrastructure development also convert land where agrobiodiversity is found.

Such genetic erosion means that future options for domestication, breeding and evolution could be irreversibly lost, a fact that is being recognized through the development a 'Red List' for cultivated species.

Climate change will speed up these processes. The rate of loss of genetic resources is projected to increase as the world gets hotter, a process that will affect agrobiodiversity. The 'area suitability' of species will change with the climate, and marginal populations will be threatened with extinction unless they can migrate or adapt quickly enough. Loss of genetic diversity will, in turn, reduce the options for adaptation to climate change. Agrobiodiversity holds the key to adapting to climate change through the movement of germplasm or the breeding of new varieties that can withstand drought stress or flooding, or that can resist new pests and diseases.

Key processes influencing agrobiodiversity

In introducing this Guide, we have briefly reviewed key drivers behind the rapid decline in agrobioversity: agricultural intensification, habitat loss, market globalization and climate change. We have explored how society is responding through strategies for conservation of agrobiodiversity and the development of international policies. Our aim is to demonstrate the broad nature of agrobiodiversity in terms of 'disciplines' and stakeholders involved, and in terms of scale – of actions from the local to the global level. Obviously, these multidisciplinary, multi-stakeholder and multi-scale aspects will be crucial to the design and implementation of agrobiodiversity education.

Agricultural intensification

The breeding of new plant and animal varieties in high-input agricultural systems has dramatically increased yields (in what is often referred to as the 'Green Revolution'), and this agricultural intensification has been critical to meeting the needs of growing populations. However, this success has come at high environmental costs, and our food basket is increasingly based on a very limited number of species of crops and animals. (Half of our energy intake from plants comes from only three species: wheat, rice and maize, and globally, 90% of the energy and protein in our food comes from only 15 plant and eight animal species.) This intensification has had an alarming impact on many traditional agricultural systems, leading to a loss of genetic resources. For example, in Nepal, modern crop varieties replaced landraces on three-quarters of the land area cultivated to rice between 1960 and 2000. Similarly, one-fifth of the world's livestock breeds may be at risk from the intensification of farming as the global demand for meat and other animal products rises (FAO 2007).

Food simplification has had a detrimental impact on health and nutrition. Changing food habits in both urban and rural households has led to an overdependence on energy-rich but nutrient-poor staple crops. This has led to a global increase in the proportion of the population that is overweight or obese. Dietary changes, which are perceived to play a role in many of the health problems among the poor, also affect more affluent groups. The lack of diversity in diets is linked to malnutrition caused by a deficiency of micronutrients (vitamin A, iron and zinc, in particular) and a steep increase in diet-related non-communicable diseases.

Habitat loss

Population growth, agricultural expansion and intensification, infrastructure development and other factors are leading to substantial changes in land use that have a broad impact on global ecosystems. Around 13 million hectares of forest were converted to other uses or lost through natural causes each year during the decade 2000 to 2010. This was partly offset by an increase in forest plantations (which are much less diverse than natural forests) and a natural expansion of

forests in some countries. Still, the net loss in forest area in the period 2000–2010 is estimated at 5.2 million hectares per year (FAO 2010a). Other ecosystems show similar signs of stress. For instance, the Millennium Ecosystems Assessment reported that some 10%–20% of drylands are already degraded (Millennium Ecosystems Assessment 2005b). Much of this loss occurred in tropical forests and woodlands with high genetic and species diversity.

Associated with such habitat loss and land use change is habitat fragmentation, which has severe consequences for many species (Millennium Ecosystems Assessment 2005c). Because fragmented landscapes can restrict a species' geneflow, this trend contributes to genetic erosion in many useful wild species and crop wild relatives. Loss of agrobiodiversity can also result in a substantial decrease in the resilience (the capacity to absorb shocks) of farmers' agroecosystems and, consequently, increase in farmers' vulnerability.

In addition, the pressure on marine and aquatic ecosystems is threatening fish genetic resources. For marine fisheries, the FAO reports that 40% of the stocks were underexploited or moderately exploited in the mid-1970s. In 2007, that figure was down to 20%, and the proportion of fully exploited stocks was about 50%. Between 25% and 30% of the stocks were overexploited, depleted or recovering (FAO 2009b). Changes in the oceans due to climate change, including acidification, also pose a critical threat to marine biodiversity (CBD 2009).

Market globalization

Supermarkets play an increasing role in the global food market, as well as in developing countries that only recently had very few such outlets. Urban populations are shifting from traditional to 'modern' foods, and supermarkets play a key role as powerful market actors behind this transition. Farmers respond accordingly. The supermarkets' demand for quality, quantity, uniformity and regularity of supply favour large-scale mono-culture farming.

While the more diverse agricultural production systems of small-scale farmers might not meet these demands unless supported by strong institutions, market globalization can also bring new opportunities for small-scale farmers. A growing demand for exotic food and 'speciality' organic or fair-trade food has created global value chains that give farmers – even in remote areas – new sources of income. Today, any large supermarket in Europe can stock a range of exotic foods that only a decade ago were largely unavailable to consumers there.

Climate change

Climate change is expected to speed up the loss of agrobiodiversity at both the species and genetic level. At the species level, biodiversity that is already endangered or vulnerable will face an increased extinction rate. Although less well documented, there will also be an impact on intra-specific genetic diversity – genes within a population – as vulnerable varieties are lost.

Crop suitability models predict that Sub-Saharan Africa and the Caribbean will be most affected in terms of the reduction of suitable areas for a range of crops (Lane and Jarvis 2007). The magnitude of change could be such that existing crop varieties would no longer be suitable in a particular location. This genetic erosion could be particularly serious for wild relatives of crops, which might contain valuable genes for plant-breeding programmes to increase heat and drought tolerance or resistance to pests and diseases. The virulence and distribution of insects and pathogens are also likely to change, increasing the risks of crop failure to smallholder farmers.

The local and global scale

Two examples can illustrate the importance of scale in managing agrobiodiversity. A case study from Kenya provides insights into the rapid change in agrobiodiversity at the local level. Another example shows how global policies are responding to such changes.

At **the local level**, the FAO, in conjunction with the government of Kenya, established a programme on agrobiodiversity in 2005. The programme, sponsored by the FAO-Netherlands Partnership Programme (FNPP), worked with local communities in two districts with contrasting environments. The Mwingi District in the Eastern Province is a semi-arid area with an agropastoral agroecosystem. The Bondo District in the Lake Victoria basin in Nyanza Province represented a sub-humid lake zone where the agroecosystem is composed of aquatic and terrestrial components. Focus group discussions established the number of indigenous species that had been lost, or were becoming scarce, and the number that had been added to the farming systems. The districts both reported a significant loss of species and a simplification of the agricultural production system (Table 1).

Table 1. Balance sheet for indigenous and introduced species in Mwingi and Bondo Districts, Kenya

	Mwingi	Bondo
Indigenous **crop species** lost or being lost	16	22
Introduced crops	7	11
Net loss	-9	-11
Indigenous **livestock species** lost or being lost	3	3
Introduced livestock	2	3
Net loss	-1	0
Original **fish stock species**	-	16
Lost or unavailable	-	12
Currently available	-	4
Net loss		-12

Source: Michieka (2009).

At the **global policy level**, the Commission on Genetic Resources for Food and Agriculture (CGRFA) was formed under the FAO in 1983, initially to deal with plant genetic resources. The Commission's mandate broadened in 1995 to cover the conservation and sustainable use of all components of relevance to food and agriculture.

Being the only permanent forum for governments to discuss matters on agrobiodiversity, the Commission negotiates, coordinates and/or monitors a series of international conventions, codes of conduct and instruments:

- Code of Conduct for Plant Germplasm Collection and Transfer
- Code of Conduct for Responsible Fisheries
- Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration
- Global Plan of Action on the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture
- International Plant Protection Convention
- International Treaty on Plant Genetic Resources for Food and Agriculture

An important function of the Commission is to monitor the state of the world's plant, animal, aquatic, microbial and forest genetic resources for food and agriculture. To this end, global reports on the state of the world's plant genetic resources were published in 1996 and 2009, and on animal genetic resources in 2007. A report on forest genetic resources is scheduled for 2013. Other goals of the Commission include striving for an international consensus on policies and action programmes on genetic resources for food and agriculture, to strengthening national and regional policies, and to promote cooperation in capacity building.

These two brief examples illustrate the need for agricultural education to cover both the local management of agrobiodiversity and the international policy framework. As policy instruments on genetic resources for food and agriculture are integrated into national policies and programmes, these two levels meet, requiring the capacity for implementation at the national and local scale. **Universities and technical colleges play a key role** in developing such competencies in their students.

Agrobiodiversity conservation strategies

In the past decades, the global community has focused on two strategies for conserving genetic resources: *ex situ* conservation in genebanks and *in situ* conservation of ecosystems in protected areas and reserves. The need for conserving agrobiodiversity on farms has gained attention more recently.

Some 1750 genebanks have been established globally to conserve genetic resources *ex situ*. With some 7.4 million accessions (FAO 2010b), this global network of genebanks manages genetic diversity that is important for food and agriculture. But there are gaps in the collections and not all species can be conserved using this approach because their seeds cannot be stored long-term and alternative

methods, such as field genebanks and *in vitro* storage, are costly. Another, crucial, consideration is that the natural processes of adaptation and evolution cannot be maintained in genebanks.

The forest areas where *in situ* conservation of biological diversity is the prime objective have increased by more than 95 million hectares since 1990. These forests now account for 12% of the total global forest area, or more than 460 million hectares. Most, but not all of them, are located inside protected areas (FAO 2010a). A large proportion of species' genepools are still found outside of protected areas, in production landscapes.

The *in situ* and on-farm conservation of crop wild relatives is an important but often neglected strategy for biodiversity conservation. The genetic resources embedded in crop wild relatives represent a very important part of the genepool of domesticated species, which is invaluable to the continued evolution and adaptation of these species, as well as a source of genetic material for researchers and breeders.

In spite of such efforts, the conservation of agrobiodiversity depends to a large extent on agricultural production systems: on-farm conservation. Farmers are important custodians of agrobiodiversity and their local knowledge is therefore an inherent element of agrobiodiversity.

The current situation leads to a number of key questions:

- How should researchers and extension staff in agriculture, forestry, livestock and fisheries work with farmers and local communities to enhance 'conservation through use' of agrobiodiversity?
- How can farmers be rewarded or compensated for managing agricultural diversity that might not contribute in an immediate fashion to their livelihoods?
- How should the private and public values of agrobiodiversity be defined and balanced?
- How could health and nutrition professionals interact with the agriculture sector to promote the production of more diverse and more nutritious food?

Policy response

International policies are increasingly addressing agrobiodiversity issues. As mentioned above, the three conventions on biodiversity, climate change and desertification do, in various ways, recognize the role of agrobiodiversity for agricultural sustainability. The need for capacity development is also noted: the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture, adopted in 1996, stated that "Governments should recognize the appropriateness and importance of education concerning plant genetic resources for food and agriculture at all levels" (FAO 1996). The necessity for international collaboration in managing shared genetic resources is captured in the International Treaty on Plant Genetic Resources for

Food and Agriculture, adopted in 2001, which entered into force in 2004. The Treaty has created a multilateral system of access and benefit sharing for the 64 most important crops and fodder species (FAO 2002). These, and other related policy instruments, call for universities and technical colleges to raise their profile in agrobiodiversity education.

There are several recent regional initiatives and meetings that send out similar messages:

- the Suwon Agrobiodiversity Framework, adopted at the International Symposium on Sustainable Agricultural Development and Use of Agrobiodiversity in the Asia-Pacific Region, on 13–15 October 2010 in the Republic of Korea and endorsed by the Asia-Pacific Association of Agricultural Research Institutions (APAARI)
- the Agrobiodiversity Initiative for Africa (ABIA), established under the Forum for Agricultural Research in Africa (FARA) on 19–20 July 2010 in Burkina Faso
- the 6th Henry A. Wallace/CATIE Inter-American Scientific Conference, 'Agrobiodiversity in Mesoamerica: from Genes to Landscapes', held on 20–24 September 2010 in Costa Rica

High-level policies have to be balanced with bottom-up implementation strategies in order to bring policy goals to fruition.

Needs for agrobiodiversity capacity

Genetic diversity is part of the solution to many problems. For example, agrobiodiversity provides the genetic materials required for breeding new varieties that can adapt to climate change. Many underutilized species have potential for commercialization and development of value chains that increase farmers' income. Agrobiodiversity can contribute to food diversification that leads to positive outcomes for health and nutrition. The use of well-adapted local agrobiodiversity may be particularly important to agricultural development in marginal environments where risk mitigation is a key farming strategy. The capacity to conserve and manage agrobiodiversity is thus needed at the individual as well as the institutional level.

Universities and colleges play a key role in developing the human capacity to conserve, manage and use agrobiodiversity, to develop new knowledge through research and to share knowledge through outreach activities. Some universities have recently begun teaching agrobiodiversity in a more structured way, in response to new realities. Others are in the process of developing new courses and, in some cases, full agrobiodiversity programmes. For many universities and colleges, the journey is just beginning. This Curriculum Guide aims to raise awareness about agrobiodiversity and to facilitate its integration into the curricula of higher education. It seeks to contribute to building the capacity that society needs in order to conserve and manage agrobiodiversity sustainably.


Musa Usman / IITA

PART II

KEY ISSUES IN AGROBIODIVERSITY EDUCATION

Agrobiodiversity education: current status, needs and challenges

Given the background presented in Part I, what competencies and skills are required for managing agrobiodiversity sustainably, and how do those differ from what universities are currently developing in their graduates? What is the current status of such education? What are the gaps and needs? Below, we study some challenges that universities face in teaching agrobiodiversity, and present options and strategies for mainstreaming this topic in higher education.

Situation analysis of agrobiodiversity teaching and learning

Bioversity International and partners from higher education and research institutions held a series of regional consultations in 2009 and 2010 to review the status of and need for education in agrobiodiversity. The workshops and symposia took place in Sub-Saharan Africa, East and Southeast Asia, and Latin America. They assessed current issues in capacity building for agrobiodiversity conservation and use, analysed the current status of teaching and learning, and outlined the needs and strategies for change. The key findings from the three regions are reported below.

Sub-Saharan Africa

The workshop **'Learning agrobiodiversity: options for universities in Sub-Saharan Africa'** was held in Nairobi, Kenya, from 21 to 23 January 2009. Representatives from universities, university networks and international organizations in 16 African and two European countries attended (Rudebjer et al. 2009). The consultation found the following:

- There was no designated course, or programme, on agrobiodiversity in any of the universities represented at the workshop.
- Aspects of agrobiodiversity are taught in a fragmented fashion in a variety of programmes, but a holistic approach is lacking.
- There are critical gaps in curricula relating to agrobiodiversity (see Table 2).
- Graduates in agriculture or forestry often become involved in a range of situations that require competence in agrobiodiversity (see Table 3).
- Universities identified a series of constraints to the mainstreaming of agrobiodiversity in higher education (see Table 4).
- A draft curriculum framework was developed based on these findings, which (post-workshop) further evolved into this Guide.

Similar findings were reported in a survey of 10 universities in Eastern and Southern Africa, conducted by Bioversity International. Generally, three types of agrobiodiversity-related education were found. Typically, universities offer specialized programmes and courses on crop science, genetics, plant breeding, etc., primarily focusing on commodity crops. A second family of programmes and courses deals with conservation ecology, environmental impact assessment, landscape restoration and the like. A third, popular with students, covers

biotechnology, bio-informatics, genomics, etc. In summary, many courses and programmes do include topics of relevance to agrobiodiversity; however, courses and programmes that tackle agrobiodiversity from a multidisciplinary, multi-stakeholder and multi-scale perspective are, by and large, absent from curricula (van Schagen 2009).

East and Southeast Asia

A regional workshop on **'Reviewing Plant Genetic Resources Education in East and Southeast Asia'** at the University of Tsukuba, Japan, on 17–19 November 2009 gathered participants from 11 universities in Fiji, Japan, Malaysia, the Philippines, South Korea and Thailand (Rudebjer et al. 2010). Key findings and results showed that:

- Very few students in the region specialize in plant genetic resources (PGR). The resulting lack of capacity is a potential threat to national and international plant breeding programmes.
- According to the students, the lack of scholarships and job opportunities for graduates dissuade them from studying PGR.
- Broadening programmes with a multidisciplinary focus is a way forward to increase relevance and attract new categories of students. The MSc programme in Bio-diplomacy at the University of Tsukuba is one such innovative example.
- An action plan for strengthening PGR education in Eastern and Southeastern Asia and in the Pacific was agreed upon. Five strategies were suggested: course enhancement, enhancement of degree programmes, short courses for working professionals, networking and strengthened collaboration, and creating awareness.

Latin America

The conference **'Agrobiodiversity in Mesoamerica – from genes to landscapes'**, held in Turrialba, Costa Rica in September 2010, aimed to strengthen the use and management of agrobiodiversity and promote sustainable land management in Mesoamerica. The conference, the sixth in the Henry A. Wallace Inter-American Scientific Conference Series, was organized by the Tropical Agricultural Research and Higher Education Center (CATIE) and Bioversity International. A preconference case study on the handling of agrobiodiversity in higher education in Costa Rica and Mexico was carried out and presented to the conference (Vásquez Morera et al. 2010). In one conference session, Bioversity, CATIE and six universities in Mesoamerica then discussed the current coverage of agrobiodiversity in university curricula and how to move forward:

- Job market and career opportunities: the job market for agrobiodiversity-related graduates in Mesoamerica is perceived as limited and is reflected in low enrolment.
- Institutional and political support: within universities there tends to be limited support for or awareness of agrobiodiversity. The topic is currently not well understood in all its dimensions and its benefits are not fully recognized. Agrobiodiversity is therefore neglected by university authorities as well as by politicians.

- Interdisciplinarity and alliances: being a multidisciplinary field of study, agrobiodiversity education requires collaboration that crosses traditional institutional boundaries. Currently, collaboration within a faculty is common, but broader internal and external alliances are required, particularly with research organizations of different kinds.
- Resources: public universities where the topic of agrobiodiversity is covered, albeit on a limited scale, are now competing with increasing numbers of private universities for resources coming from the government. This might weaken their capacity to develop programmes in agrobiodiversity education.
- Relations with communities: education needs to be well connected with communities and rural producers to be relevant and focused on solving real-world problems in a participatory way.

Recent initiatives to develop agrobiodiversity curricula

Several universities in Africa, Latin America and Asia have recently developed courses or programmes on agrobiodiversity, or are in the process of doing so. A few examples could be mentioned:

- The Faculty of Agriculture at the University of Peradeniya, Sri Lanka, developed three courses on crop wild relatives and their conservation, thus addressing an identified gap in undergraduate and postgraduate curricula. The courses commenced in 2008.
- Universidad Nacional de Colombia, Palmira campus, Colombia, has a long association with Bioversity International through its graduate programme on plant genetic resources. Further interactions with faculty have led to the approval of a pilot course on agrobiodiversity for both graduate and undergraduate students. Bioversity and university staff are collaborating on the design of this course.
- Tribhuvan University's Institute of Agriculture & Animal Science, Rampur, Chitwan, Nepal, has formed a curriculum-development committee under the chairmanship of the Dean to design and implement courses required to run a post-graduate programme: MSc in Agrobiodiversity Management.
- South Eastern University College (SEUCO), Kenya, a new institution specializing in dryland agriculture, has initiated a process to develop an agrobiodiversity curriculum for teaching and research. The objective is "to enhance long-term support of agricultural diversity, crop development and improvement, thereby contributing to improving the quantity and quality of crops for food security and poverty alleviation in the semi-arid eastern drylands of Kenya". To this end, several new courses are under development.
- Scuola Superiore Sant'Anna, Italy, offers a PhD programme in agrobiodiversity aimed at the enhancement of human resource capacity in the use and management of genetic variation in agricultural and natural systems. The programme is structured into two curricula: Plant Genetic Resources and Functional Biodiversity in Agroecosystems.

Emerging picture: status and needs

Drawing on the results from these regional symposia and on recent surveys of agrobiodiversity education in Africa, Southeast Asia and the Americas, a broad picture of the status of and needs for agrobiodiversity education emerges:

- Agrobiodiversity is rarely offered as a stand-alone course or full programme, which partly reflects a lack of clear career opportunities for graduates.
- Many courses contain elements of agrobiodiversity but might not cover the dynamic, multidisciplinary dimensions of the subject.
- The concept of agrobiodiversity is often not well understood among students, or even educators, and many definitions are unclear.
- Very few educators have been trained in the area of agrobiodiversity.
- There is a lack of integration of agrobiodiversity across sectors and insufficient integration of indigenous, local knowledge with scientific knowledge.
- Existing curriculum structures may hinder the absorption of a new discipline such as agrobiodiversity, and few subject-specific learning resources are available.
- Better links between training, research and practice or between conservation organizations and universities would stimulate uptake of the subject.
- National and international policies on agrobiodiversity are still not well known in the national agricultural research and extension system, and capacity for implementation is weak. This also influences the way universities teach the subject.
- New agrobiodiversity-related policies create new opportunities for universities to act.
- Education needs to be well connected with communities and rural producers as well as urban ones, to be relevant and focused on solving real-world problems in a participatory way.
- There are signs that universities are increasingly interested in developing agrobiodiversity courses and programmes.

These findings indicate that universities need to accelerate their efforts to integrate or 'mainstream' agrobiodiversity in their courses and programmes. Some universities have started to respond to the needs for teaching agrobiodiversity, but much remains to be done to keep curricula up to date with current knowledge and policies on agrobiodiversity conservation and management.

Gaps in curricula

Participants in the workshop **'Learning agrobiodiversity: options for universities in Sub-Saharan Africa'** in Kenya in 2009 analysed gaps in curriculum content relating to agrobiodiversity. According to these results, a broad range of topics would need to be better covered (Table 2).

Table 2. Gaps in content relating to agrobiodiversity

Area of content	Topics
Agrobiodiversity value chains	• Underutilized and neglected species • Commercialization of agrobiodiversity • Value-chain enhancement, traditional vs. modern • Effect of trade on agrobiodiversity • Marketing and development of new products • Utilization and value addition: processing and postharvest enhancement
Effect of climate change and other global threats on agrobiodiversity	• Impact of climate change on agrobiodiversity: modelling of scenarios • Impact of agricultural intensification • Threats to agrobiodiversity and management of threats
Food, nutrition and rural livelihoods	• Food and nutritional security: agrobiodiversity and livelihood links • Inter-linkages between agrobiodiversity and nutrition and health • Food composition and dietary diversity • Nutrition and food science • Bio-fortification
Ecosystem services, including carbon sequestration	• Links between agrobiodiversity and ecosystem services • Economic valuation of agrobiodiversity • Payments for environmental services • Eco-tourism
Genetic resources	• Plant/forest/animal genetic resources • Microbial biodiversity and below-ground biodiversity • Domestication of agrobiodiversity • Breeding • Pollination ecology, pollination aspects and effects • Taxonomy • Neglected and underutilized plants
Stakeholder involvement in agrobiodiversity conservation	• Private-public partnerships • Optimization of public/private interests • Awareness/promotion of agrobiodiversity potential

Policy on plant genetic resources (PGR)	• Policies and institutional arrangements • Laws and regulations (national, international) • International and national treaties and protocols on PGR and agrobiodiversity • Material-transfer agreements • Access and benefit sharing • Land tenure and management of agrobiodiversity • Intellectual property rights (IPR) on PGR
Conservation strategies	• Inter- and intra-specific genetic diversity • Influence of fragmentation on natural habitats, mosaic landscapes • What to conserve? • How much to conserve? • *Ex situ* conservation strategies • Agrobiodiversity conservation *in situ* and on-farm • Revitalizing disappearing crops and animals
Local knowledge	• Traditional conservation strategies • Agrobiodiversity and farmers' innovations • The value of indigenous knowledge on agrobiodiversity • Databases
Cross-cutting areas of knowledge	• Data-collection methodology, biometrics and statistics • Participatory approaches to agrobiodiversity conservation and use

Source: Adapted from Rudebjer et al. (2009).

Job profiles of graduates

What should a graduate be able to do, in order to competently address issues involving agrobiodiversity? The following job profile, developed by participants in the above mentioned 2009 African workshop, gives one example of the competencies desired in graduates (Table 3). Naturally, each university and colleges operates in its unique environment and each educational program has its own aims and objectives, which will determine how to approach teaching and learning of agrobiodiversity in each institutional setting.

Table 3. Example of job profile of graduates in relation to agrobiodiversity

Area of competence	Tasks
Sustainable livelihoods	• Determine relationships between agrobiodiversity and livelihoods • Manage agrobiodiversity to enhance sustainable livelihoods • Demonstrate the contribution of agrobiodiversity to sustainable livelihoods and ecosystems • Manage and integrate different forms of knowledge, both scientific and indigenous, in the use and conservation of agrobiodiversity
Conservation of genetic diversity	• Assess diversity in agroecosystems, using participatory methods to better understand community-based agrobiodiversity management and to enhance understanding among rural communities of the importance of these resources • Understand ecological principles of agroecosystems • Design conservation strategies, *ex situ, in situ* and on-farm
Markets and value chains	• Strengthen value chains, including augmenting a more constructive role of traders (middlemen) in these chains • Promote the value chains of neglected and underutilized species
Integrated natural resources management	• Apply a systems approach to management and conservation of agrobiodiversity • Identify, map and characterize all components of existing agrobiodiversity • Manage integrated, complex systems • Design and implement adaptive management strategies for agrobiodiversity • Communicate agrobiodiversity issues at various levels to raise awareness and garner support • Operate constructively in multidisciplinary teams • Mobilize and coordinate activities of all stakeholders for effective management and sustainable use of agrobiodiversity • Create and facilitate multi-stakeholder platforms for interaction, dialogue and joint action on agrobiodiversity issues

Policy advocacy and implementation	• Advise farmers, policymakers, etc., on policy issues • Lobby, advocate and create dialogues to influence policy reforms to promote and integrate agrobiodiversity in value chains • Articulate and apply policy and legal requirements in practice at national, regional and international levels • Implement policies, e.g., the International Treaty on Plant Genetic Resources for Food and Agriculture • Ensure fairness and equity in sharing the benefits of agrobiodiversity
Research and development	• Facilitate and undertake research on agrobiodiversity • Design and conduct research in agrobiodiversity using available tools and methods • Think critically and facilitate collective initiatives for conservation, rehabilitation and restoration of agrobiodiversity • Stimulate and support enterprise development for increasing benefits of agrobiodiversity to individuals and to society (value addition)

Source: Adapted from Rudebjer et al. (2009).

Key issues in mainstreaming agrobiodiversity

The mainstreaming, or integration, of agrobiodiversity in higher education programmes is constrained by a number of institutional issues (Table 4). Some are related to the capacity of teachers in the field of agrobiodiversity. Others are related to institutional capacities to foster the management and conservation of agrobiodiversity, in particular, the capacity to deal with multidisciplinary and multi-stakeholder processes. Other issues involve the external environment, such as the declining interest in studying agriculture in general, or the wide scope of agrobiodiversity.

Table 4. Critical issues for mainstreaming agrobiodiversity in higher education

Key issue	Constraints to mainstreaming agrobiodiversity in higher education
Make agriculture-related disciplines relevant and attractive to stimulate students' interest	• Limited job and career opportunities • Little interest in studying agriculture
Clarify the concept of agrobiodiversity	• Concept of agrobiodiversity not well understood • Unclear definitions of agrobiodiversity • Wide scope of agrobiodiversity is a challenge
Integrate relevant disciplines and develop a holistic approach to agrobiodiversity education	• Lack of systems approach in agrobiodiversity-related education, extension and research • Weak multidisciplinary collaboration • Lack of convergence between traditional disciplines constrains the teaching of value-chain approaches • Local knowledge neglected and not well integrated with scientific knowledge
Develop mechanisms for covering agrobiodiversity issues in all levels of university training	• No agrobiodiversity curriculum • Rigid structures in existing curricula: need to regularly review curricula and change when necessary • Identifying suitable courses to serve as 'entry points' for agrobiodiversity learning
Re-orient academic staff to facilitate agrobiodiversity learning	• Lack of human capacity and expertise in agrobiodiversity among teaching staff • Tendency to emphasize teaching, rather than facilitating learning
Build and sustain partnerships and networks in support of agrobiodiversity education	• Poor/unclear linkages between research and action • Weak networks of research and training • Weak links between conservation organizations and universities
Mobilize resources to support integration of agrobiodiversity in higher education	• Limited financial support • Lack of learning resources • Unclear policy on agrobiodiversity • Infrastructural development for teaching and learning

Source: Adapted from Rudebjer et al. (2009).

Options for integrating agrobiodiversity in higher education

Currently, agrobiodiversity is not visible in the curricula of most universities, as noted earlier. Most universities and technical colleges do not offer specific courses or programmes on agrobiodiversity, and there is little awareness of the subject. The consultations with universities in Africa, the Americas and Asia-Pacific mentioned above resulted in recommendations to accelerate the mainstreaming of agrobiodiversity in higher education.

The roadmap towards integrating agrobiodiversity into curricula will depend on the unique situation of each educational institution. Several strategic options are available, each of which is described here:

1. Encourage **informal adjustments to curricula** to integrate agrobiodiversity into existing courses and programmes
2. Add new **agrobiodiversity courses** during curriculum reviews
3. Establish **new programmes** on agrobiodiversity
4. Stimulate **thesis research** on agrobiodiversity
5. Offer **short courses on agrobiodiversity** for working professionals (on-the-job training)

Job-market issues and institutional constraints make it difficult to offer new programmes on agrobiodiversity, so this option is likely to remain rare in the short to medium term. Therefore the focus could be on raising the profile of the subject using the other four strategies, perhaps in some combination.

In many ways, collaboration among universities and networking at the national or regional level can facilitate and accelerate the implementation of these strategies. The availability of information and communication technologies (ICT) can enhance such collaboration, by allowing the offering of joint e-learning courses, for example, or the sharing of training materials.

Informal curriculum adjustment

Higher education curricula are often crowded and change slowly. What can then be done to strengthen existing courses without a formal curriculum review? In the short run, the **integration of agrobiodiversity content into existing courses** is likely to be the preferred and fastest option for most universities. Often, just a few contact hours are needed to provide students with at least an overview of agrobiodiversity issues. While this would not be sufficient to accomplish all desired improvements, it is a practical and useful start. The quickest way forward is often for a lecturer to informally and opportunistically introduce new topics into an existing course. This is a part of a teacher's never-ending, continuous improvement of his/her course. Later on, such 'soft integration' can be expanded and formalized during the next curriculum review.

Table 5 below presents a number of opportunities – **entry points** – for informally integrating agrobiodiversity issues into existing courses and programmes. The success of this option depends on the interest and initiative of the individual lecturer, and his/her competence in teaching the subject. Therefore, actions to create awareness and train teachers will be important to accelerate this process. Availability of suitable training materials (such as case studies that could be used to stimulate class discussions) will also be critical for success.

Table 5. Entry points for introducing agrobiodiversity content in curricula

Entry point	Examples of agrobiodiversity content
Adaptation to climate change	• Matching crop varieties to new climates • Breeding for adaptation to climate variability • Farmer resilience and adaptability
Agricultural economics	• Value chains for neglected or underutilized species as well as for other species • Marketing of speciality foods
Agricultural policy	• The International Treaty on Plant Genetic Resources for Food and Agriculture • The Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture • The FAO 'State of the World' reports on plant, animal and forest genetic resources
Agronomy	• Farmers' informal seed systems • The use of diversity to mitigate risk
Crop science and plant breeding	• Genebank management • Participatory plant breeding • Pre-breeding • Wild relatives of crop species
Ecosystems conservation	• Pollination • Payment for environmental services • *In situ* and on-farm conservation (e.g., of landraces, non-timber forest products and crop wild relatives)
Ethnobotany	• Selection and management of wild plants • The cultural significance of crops and wild plants • Pharmacologically active plants
Health and nutrition	• Food diversity and food composition • Nutrition and traditional foods • Agrobiodiversity and traditional medicine
Soil and water management	• Resilience in agroecosystems • Microbial biodiversity

Add agrobiodiversity courses during curriculum reviews

When a regular curriculum review is due, this is obviously a good moment to revisit how agrobiodiversity is taught. In many cases, there will be an opportunity to introduce a new course – whether core or optional – on agrobiodiversity.

Strong arguments for such introductions include:

- the importance of agrobiodiversity to farmers' livelihoods and well-being
- the role of agrobiodiversity in adaptation to and mitigation of climate change
- understanding the role of agrobiodiversity management in conservation strategies
- the need for capacity to implement international agreements such as the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture
- the role of a diverse, agrobiodiversity-focused food system for human health and nutrition
- the potential of neglected and underutilized species to contribute to food and nutritional security and to improved rural livelihoods

We highly recommend that all students in relevant disciplines, such as agriculture, forestry, natural resources management, environmental studies, etc., have the opportunity to study agrobiodiversity. In order to reach the maximum number of students possible and to allow them to benefit from this valuable knowledge, it is advisable to include agrobiodiversity among the core courses.

Establish new programmes on agrobiodiversity

In some cases, particularly at the post-graduate level, universities may see the opportunity for introducing an entirely new programme on agrobiodiversity. Such programmes could be attractive not only to agricultural students, but also to environmentally oriented learners. Clear opportunities also exist for creating innovative multidisciplinary programmes that bridge sectors such as health and nutrition with agriculture. In such situations, this Guide will be extremely helpful to curriculum developers, along with other resources and inputs, such as training-needs assessments, policy instruments, commissioned studies and stakeholder workshops.

Stimulate thesis research on agrobiodiversity

There are many opportunities for increasing the focus on agrobiodiversity in under- graduate research assignments, Masters' theses and Doctoral dissertations. For example, there are many little-studied minor crops that provide excellent research topics. Stimulating students' **thesis research** on agrobiodiversity topics can therefore be a powerful way of raising the profile of the subject. This also generates new knowledge while building capacity, and involves both faculty and students.

Opportunities exist for research fellowships in international research organizations, such as the Centres supported by Consultative Group on International Agricultural Research (CGIAR), or in leading universities.

Offer short courses for working professionals

On-the-job training is an important aspect of life-long learning, and an effective way for training to have a quick impact. Because trainees are already at work, they are able to immediately start implementing new knowledge, provided that the institutional environment embraces new knowledge and methods.

Short courses can be designed quickly because they do not need a lengthy formal approval process. They can be tailor made for specific clients. There may also be opportunities to generate income from paying trainees.

An added advantage is the mutual learning that takes place when working with experienced trainees – learning that benefits the regular programme of the higher education institution as well.

Per Rudebjer / Bioversity

PART III

CURRICULUM FRAMEWORK FOR AGROBIODIVERSITY LEARNING

A conceptual framework for agrobiodiversity curricula

Once a university or a college has decided to strengthen the agrobiodiversity content in curricula, and after choosing a suitable strategy for doing so, then the process of planning the curriculum follows. Part III of this Guide is seeking to facilitate this process by presenting a flexible curriculum framework that could be validated in consultation with key stakeholders. A background on such 'participatory curriculum development' can for example be found in Rudebjer et.al. (2001).

Development of the curriculum framework

The findings and recommendations presented in Part II all contributed to the development of this Curriculum Guide. The starting point was a framework for education in agrobiodiversity that was developed by the participants in the regional workshop in Nairobi in January 2009. Ten 'clusters' of topics were identified as essential elements of agrobiodiversity education. These topics were then further evaluated and refined by a Task Force on Agrobiodiversity Education,[1] which met three times in 2009 and 2010. An on-line dialogue on Wikispaces in the spring and summer 2009 generated additional suggestions, although participation was low. Further validation of the curriculum framework was done in conjunction with two regional workshops in East and in Southeast Asia and symposia in Latin America. Finally, suggestions from reviews were taken into consideration.

Broad set of competencies

Agrobiodiversity comprises all organisms living in agricultural landscapes, their habitats and genetic diversity. It is the subject of study of a wide range of disciplines and involves multiple levels from the local to the global. The processes that shape agrobiodiversity vary in time from slow evolution or domestication to rapid shocks, such as habitat loss. Farmers, frequently the decision makers about how agricultural land is managed, are key players.

Understanding the drivers of change, their impact on agrobiodiversity and the processes for its effective conservation and management thus requires a broad set of competencies in multiple disciplines. Teaching such a broad array of interrelated topics might be a challenge to educational systems that traditionally separate forestry, agriculture and animal science, although there is an increasingly recognized need for interdisciplinary approaches to education. Also, agrobiodiversity is closely linked to the local knowledge of farmers in regard

[1]*The Task Force on Agrobiodiversity Education was made up of representatives of the following organizations: Bioversity International, the African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE), the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) and the Technical Centre for Agricultural and Rural Cooperation (CTA).*

to its management and use, thus adding a socioeconomic dimension. Students of agrobiodiversity need insights into the importance of scale, from the farm to the global level, and how these levels are connected and interdependent. While farmers are the custodians of agrobiodiversity at the local level, their actions are influenced by an array of policy instruments, institutions, market forces and other drivers (including climate change) at the national, regional or even global level.

Therefore, students need to understand the 'big picture' as well as the grassroots level of agrobiodiversity management, and how these are related. The student will need to balance local knowledge with (frequently global) scientific knowledge in a multi-stakeholder, multidisciplinary setting – a broad view that is not conducive to a 'cook-book' approach to teaching. Rather, it opens up many options for its integration into a wide range of courses and programmes, not only for students in agriculture but also for students in forestry, public health, environmental management and other areas. Agrobiodiversity education can be approached in many different ways.

Here we present a flexible framework for agrobiodiversity curricula. Its use will vary according to the level of education and the specific needs and objectives of each university or technical college, as well as the time and resources available. Depending on the target group, the framework could form the basis for developing multiple skill sets, for example:

- understanding basic concepts
- applying generic concepts in a local context
- appreciating the perspectives of multiple stakeholders on changes in agrobiodiversity
- planning for actions to reduce loss of agrobiodiversity

Key elements of agrobiodiversity learning

We propose four broad learning areas, each further subdivided in three to four topics, which might be covered in an agrobiodiversity education and training situation (Figure 1):

- global context of agrobiodiversity management
- genetic resources for food and agriculture
- agrobiodiversity products and services
- sustainable management of agrobiodiversity

It is important to remember that these four areas are connected in a complex web of drivers and actors that can involve many disciplines. Changes to agroecosystems (and their consequences) may lead, in turn, to feedback to those drivers and actors, and so on. Even though a curriculum framework tends to fragment knowledge into small manageable pieces, one should not lose sight of this interconnectedness and the dynamic processes that make agrobiodiversity evolve in one direction or another. For similar reasons, it is not always possible to keep a certain area of knowledge squarely within one 'box' of the framework: some overlap is unavoidable but is also an opportunity for repetition that enhances learning.

Each of the 14 topics is presented using the following general outline:

- **Introduction:** Gives a background orientation on the topic and outlines the key issues to be covered. This brief summary of only two pages or so is intended as a starting point for further exploring the topic.
- **Main key learning points:** Captures the key message of the topic in a few bullet points (typically six to eight)
- **Contents:** An indicative list of content areas for teaching the topic
- **Bibliography:** A suggested list of key literature on the topic in question. Where possible, we have selected publications that are available for free on the internet. If the hyperlink is not given, typing the title in an internet search engine will usually yield a downloadable file.
- **Internet resources:** Key organizations and portals providing further information on the topic.

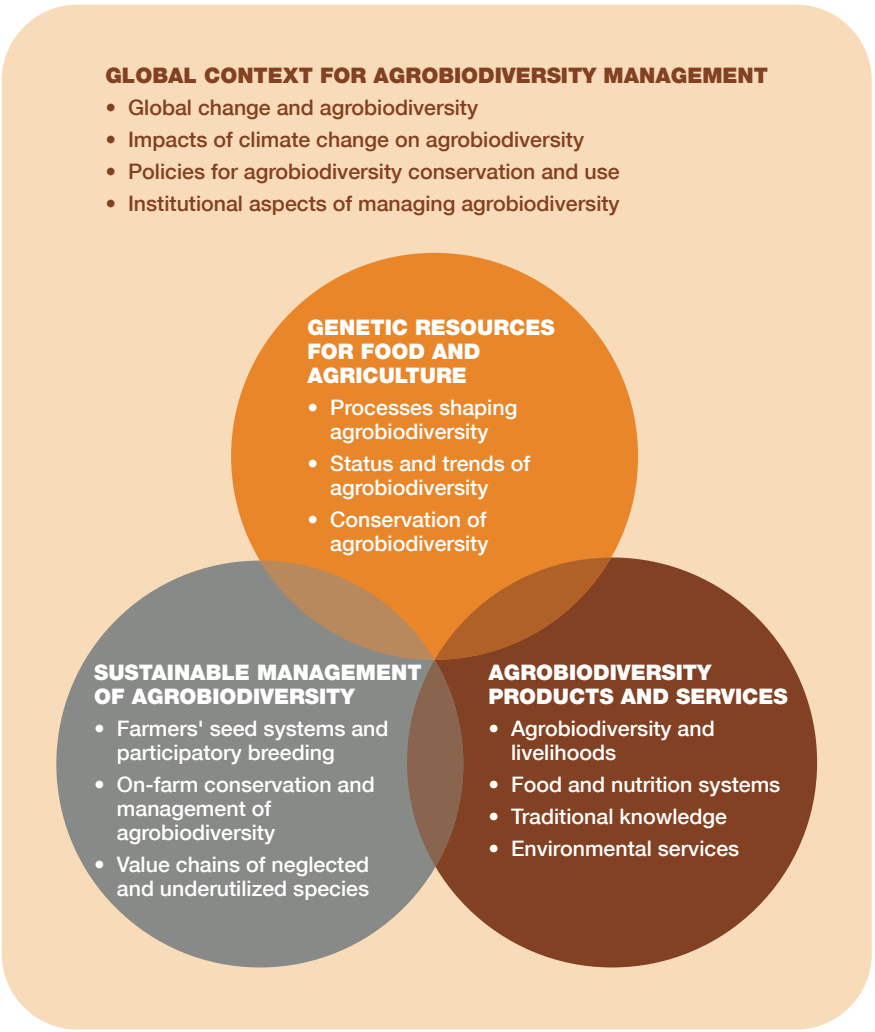

Figure 1. A framework for agrobiodiversity learning

Undoubtedly, this curriculum framework would have some gaps and omissions. For example, the topic 'Status and trends of agrobiodiversity' could well be expanded to cover each component of agrobiodiversity separately: plant genetic resources (PGR), animal genetic resources (AnGR), forest genetic resources (FGR) and microbial and fungal genetic resources. Likewise, the topic 'Conservation of agrobiodiversity' could be further subdivided into separate topics on *ex situ* conservation (including genebank management) and *in situ* and on-farm conservation. The framework does not elaborate on plant, animal or forest-tree breeding on the assumption that such topics would be fairly well covered in agricultural and forestry programmes. However, aspects such as pre-breeding might well merit better coverage in curricula on plant breeding.

A note on teaching materials and methods

As noted in the introduction to this Guide, developing curricula is not only about new subject-matter content, but also about providing experiences and activities that help students' 'learning for life'. Textbooks and scholarly journals are often the mainstay of academic teaching materials. This Guide therefore cites key references and internet sites where such materials are available.

Equally important is the use of teaching materials and methods that encourage experiential learning, questioning, interactions with communities, and other student-centred approaches. In order to avoid duplication, we have not listed such methods specifically under each topic in the framework. However, it is advisable for teachers of agrobiodiversity to explore the range of options available for interactive, practical, student-oriented teaching methods, including those now available through ICT applications. As a starting point, we suggest the following:

- Useful teaching materials for working in participation with communities can often be found in subject areas related to agrobiodiversity, such as agroforestry, eco-agriculture, community-based natural resources management, etc. Websites to visit might include:
  - World Agroforestry Centre, www.worldagroforestrycentre.org
  - Ecoagriculture Partners, www.ecoagriculture.org
- Social media are a rapidly expanding source of learning materials. Many organizations, including Bioversity International and its sister organizations in the CGIAR, make their photo libraries available on sites such as Flickr, or upload videos onto YouTube:
  - www.flickr.com/photos/bioversity
  - www.youtube.com/user/Bioversityvideo
  - http://photos.ifad.org/asset-bank/action/viewHome
- Case studies written to stimulate discussion in the class have long been a mainstay for teaching in business schools and law schools. The method can also work well for agrobiodiversity topics. For instance, Bioversity is developing a library of case studies on forest genetic resources. This training guide, along with other training materials, are available at: www.bioversityinternational.org/training.

- Learning about agrobiodiversity management from communities' local knowledge is perhaps the most important of all methods. Field visits, field assignments and other activities where students get hands-on experience in communities are essential.

Global context for agrobiodiversity management

This first learning area of the curriculum framework aims to introduce the global context for the conservation and management of agrobiodiversity in four topics:

- **Global change and agrobiodiversity** gives a historic overview of agricultural development and the global food system from a perspective of genetic resources for food and agriculture. Past and current changes and trends within and outside of the agricultural sector and the impact they have on agrobiodiversity are reviewed.
- **Impacts of climate change on agrobiodiversity** gives a more detailed account of climate change scenarios and the impact they might have on genetic resources for food and agriculture. The role of agrobiodiversity in adapting to climate change and variability is also covered.
- **Policies for agrobiodiversity conservation and use** gives an overview of key international policy instruments of relevance to agrobiodiversity. Issues regarding their implementation at the national and local levels are discussed.
- **Institutional aspects of managing agrobiodiversity** looks at the capacity of research, educational and extension organizations for managing agrobiodiversity. The needs for working in multidisciplinary teams and for analysing complex systems are highlighted. Networking, multi-stakeholder platforms and other ways of engaging with local organizations are pointed out.

Global change and agrobiodiversity

Introduction

The changes in biodiversity due to human activities have been more rapid in the past 50 years than at any time in human history (Millennium Ecosystem Assessment 2005a). This global change has far-reaching consequences for agrobiodiversity – the subset of biodiversity of relevance to food and agriculture. The purpose of this topic is to equip students with knowledge about the global context that affects agrobiodiversity management, now and in the future.

Agricultural development has always been associated with changes in land use as agriculture expands into forests, woodland, wetlands and grasslands. With the growing human population and most productive land already converted to agriculture, the frontier of agriculture is pushing farther into forests and marginal areas. The loss of arable land to urban development and the growing demand for biofuels adds to this imbalance. As a consequence, habitats are lost or degraded, and valuable genetic resources, such as wild food, medicinal plants and crop wild relatives, are threatened.

Domestication of agricultural species involves a continuous selection of varieties with preferred traits at the expense of less-favoured varieties. Over time, farmers' domestication activities have created a wealth of landraces, sometimes radically different from their wild relatives. More recently, modern breeding has created new varieties that now dominate the production of most important staple crops and animal breeds. The diversity created through domestication – the local landraces – is rapidly lost as farmers shift to modern varieties. Still, landraces continue to be important, especially in marginal areas where modern varieties are not readily available or accessible, or when farmers for one reason or another would prefer locally produced seed sources. Likewise, hundreds of minor crops – neglected and underutilized species (NUS) -- remain important to rural livelihoods and may have potential for further domestication and commercialization in a more diverse food system.

Supermarkets are a powerful driving force behind agricultural change. Their growing influence on the supply chain has an impact on local agriculture even in remote areas, because producers and consumers are connected in increasingly global markets. Urbanization is linked to changes in food habits as consumers change from traditional, diverse diets to an energy-rich, cheap, but often nutrient-poor, simplified diet. The increasing demand for meat, as countries become more affluent, also has an influence on agricultural land use and, thus, on agrobiodiversity.

Climate change and variability adds a new dimension to this global context. Area-suitability models predict that rising temperatures and changing rainfall patterns will significantly alter farming systems to the extent that farmers might need to switch to entirely new varieties or new crops (refer to the section on climate change for further information).

These and other key drivers, such as invasive species and pollution, put global agroecosystems under enormous stress. Yet, the world's global food system must produce more and better food to reduce hunger and malnutrition, and to feed a global population that will grow from 6.9 billion in 2010 to 9.1 billion in 2050 (UNFPA 2010). Most of the future increase in agricultural production must come from increased productivity, rather than area expansion. And this increase in productivity must happen while ecosystems services are maintained or enhanced, under a scenario of climate change. Future agriculture will also need to pay more attention to food quality, particularly the relationship between food and nutrition. Agrobiodiversity will play a crucial role in all these processes.

Main learning points

- To describe global human population trends in relation to food and nutrition security
- To be familiar with the key drivers of land-use change and its impact on agrobiodiversity
- To appreciate that domestication, conducted by farmers, herders or fishermen, has generated a rich diversity of landraces, including neglected and underutilized species
- To recognize the role of globalization, supermarkets and urbanization in changing consumption and production patterns that apply new pressures on agricultural value chains
- To appreciate the role of agrobiodiversity in enhancing the world's food and nutrition system

Contents

- Global population trends and implications for food security
- The Millennium Development Goals related to food, nutrition and agriculture
- Land-use change and its impact on agrobiodiversity
  - Millennium Ecosystem Assessment
- Drivers of land-use change
  - Agricultural
  - Non-agricultural
- Domestication processes
  - Landraces
  - Neglected and underutilized species
- Globalization of food systems and supermarkets, and their influence on agricultural supply chains
- Urbanization and changing consumption patterns

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Internet resources

- Bioversity International, web-based publications catalogue: www.bioversityinternational.org/publications.html
- Food and Agriculture Organization of the United Nations (full-text electronic versions of publications available in the corporate document repository): www.fao.org/documents/en/docrep.jsp
- Millennium Ecosystem Assessment: www.maweb.org/en/index.aspx
- Platform for Agrobiodiversity Research (PAR): http://agrobiodiversityplatform.org
- Regoverning Markets, Small-Scale Producers in Modern Agrifood Markets: www.regoverningmarkets.org/en/global
- World Bank Documents & Reports (Go to 'Documents & Reports' for free downloadable documents): www.worldbank.org/reference

Impact of climate change on agrobiodiversity

This topic aims to provide information about the expected impact of climate change on agrobiodiversity, and to develop an understanding of the role agrobiodiversity can play in adapting to climate change and variability.

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) predicts widespread increases in temperature across the globe, along with

changes in rainfall patterns over the next 100 years and beyond (IPCC 2007). Climate variability is also expected to increase (Lobell et al. 2011), resulting in more frequent incidents of extreme weather events. The projected impact of these changes on agriculture is dramatic. While some regions may gain from a climate that suits agriculture better, East and West Africa and the Indo-Gangetic plains are particularly vulnerable, and poor people will be disproportionately affected (Ericksen et al. 2011). Agriculture and related activities also contribute to climate change. Agriculture contributes an estimated 13.5% of global greenhouse-gas emissions, and forestry (including deforestation) approximately 17.4% (IPCC 2007).

Climatic changes, in combination with other drivers, are expected to substantially alter agrobiodiversity. At a species level, biodiversity that is already endangered or vulnerable will face an increased rate of extinction. There will be a loss of intra-specific diversity and disappearance of marginal plant populations, including a serious threat to crop wild relatives.

Drylands, already under stress, are particularly vulnerable: small climatic changes can have a serious impact on their biodiversity. Crop suitability models predict that Sub-Saharan Africa and the Caribbean will be the most affected in terms of reduction of suitable area for a range of crops (Lane and Jarvis 2007). The magnitude of change may be such that existing crop varieties will no longer grow in a particular location. This will influence the overall distribution of agroecosystems and will have a profound impact on the livelihood systems of the people inhabiting them.

The distribution and virulence of insects and pathogens are also likely to change, increasing the risk of crop failure among smallholder farmers. Significant movements of crop and livestock species and varieties are likely to be needed as production environments change. New varieties of many crops will also be required to match new combinations of temperature, water availability and photoperiod. Crucially, local agrobiodiversity can be better adapted to such stress than their 'modern' relatives. Traditional, informal seed systems therefore play a key role in adaptation. Genebanks, too, are extremely important in providing farmers with the seeds they need for adapting to climate change.

Broad efforts to reduce the vulnerability of production systems to climate change will be required in agriculture, forestry and agroforestry systems, including fisheries and animal husbandry. At any given location, three basic options for adapting cropping systems to climate change are especially important: (1) movement of crop varieties to fit new climate zones, (2) adaptation of varieties through selection and breeding and (3) crop substitution. The genetic diversity embedded in agrobiodiversity holds the key to all three strategies.

Main learning points

- To be familiar with climate projections generated by the Intergovernmental Panel on Climate Change (IPCC)
- To be acquainted with international negotiation processes and agreements in regard to climate
- To be familiar with the most likely climate scenario in your region
- To be aware of the risk for extinction of species and marginal populations – loss of intra-specific diversity – as a result of climate change
- To understand the concept of 'area suitability' of species and varieties and to be able to discuss how changing area suitability would affect farmers
- To be aware of how risks for pests and diseases might be altered due to climate change
- To be able to explain the three basic options for adapting cropping systems to climate change: movement, adaptation and substitution of varieties and species

Contents

- Climate processes and agreements: the UN Framework Convention on Climate Change (UNFCCC); The Kyoto protocol; Clean Development Mechanism (CDM); Reducing Emissions from Deforestation and Forest Degradation (REDD) and 'REDD+', etc.
- Climate models
  - Temperature
  - Rainfall
  - Climate variability
- Impact of climate change on agrobiodiversity at a species and genetic level
- Farmers' risk mitigation and adaptation to climate change and variability
- The concept of area suitability
- Pests and diseases in a changing climate
- Coping mechanisms
  - Movement of germplasm
  - Breeding
  - Substitution

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Internet resources

- Intergovernmental Panel on Climate Change: www.ipcc.ch
- The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Resources: www.ccafs.cgiar.org/resources
- Food and Agriculture Organization of the United Nations, Climate Change: www.fao.org/climatechange/en
- United Nations Framework Convention on Climate Change (UNFCC): http://unfccc.int

Policies for agrobiodiversity conservation and use

Introduction

The purpose of this topic is to introduce the international policy and legal framework for agrobiodiversity conservation and management, and to discuss options for implementing these at the national and local level.

Most countries' food systems are based on crops that have their genetic centre of origin and genetic centre of diversity elsewhere. The potato, a staple in much of northern Europe, originates from the Andes in South America. Maize, staple food in several East African countries, was domesticated in Mexico. Wheat originates from the Middle East, and so on. The free movement of genetic resources has been instrumental to this domestication and improvement of crops and farm animals. Access to germplasm in its centres of origin and diversity is still important for agriculture and food security.

Traditionally, open access to germplasm was the norm, thus securing a flow of genetic resources for domestication and breeding. The situation changed radically with the Convention on Biological Diversity (CBD), which, with its entry into force in 1993, recognized the sovereignty of nations over their genetic resources, including plant genetic resources for food and agriculture (PGRFA). The access to PGRFA suddenly became an issue that threatened research, breeding and the exchange of seeds among farmers. To ensure future access to the genetic resources that underpin our food security, new policy instruments were required. A period of intensive policy dialogue on PGRFA followed, which included the adoption of the 'Global Plan of Action' (FAO 1996).

It was the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA or 'the Treaty'), which entered into force in 2004, that established a multilateral system of access and benefit sharing for the germplasm of the world's 64 most important food and fodder crops. In exchange for placing their own genetic resources for food and agriculture in a common pool, countries that are members of the Treaty get access to such resources from other countries, as well as to collections held by international organizations. However, many species fall outside the Treaty and, in consequence, exchange of their germplasm can be complicated.

National implementation of the Treaty is now a priority, because as yet only a few countries have mainstreamed the Treaty into their national policies and programmes. This requires a national policy dialogue among multiple stakeholders and sectors, such as that piloted by the Genetic Resources Policy Initiative (GRPI). The access to genetic resources and the sharing of benefits associated with their use requires a concerted effort of training, awareness, identification of policy options and implementation. Aspects related to the rights of farmers to a fair and equitable share in the benefits arising from the use of their genetic resources may require particular attention.

A range of other international policies are also of relevance to the conservation and use of agrobiodiversity, such as policies related to trade, food safety, plant protection and environmental conservation. This requires coordination at all levels, from global to local. At the global level, the FAO Commission on Genetic Resources for Food and Agriculture plays this important role.

The practical implications of these international policies and the corresponding national legal processes are far-reaching. Knowledge of policies and laws, and the ability to interpret how they affect the day-to-day management of agricultural production systems, is therefore essential for agricultural professionals, extension agents and other actors who are involved in or who influence the local implementation of polices of relevance to agrobiodiversity.

Main learning points

- To be familiar with key international treaties and conventions related to agrobiodiversity
- To be aware of the impact of national sovereignty over genetic resources on the access to genetic resources for breeding and research, as well as for use on farms
- To discuss the significance of the Treaty and its main elements, and to explain its relationship with the CBD
- To be familiar with the key concepts and principles of the Treaty, including property rights, farmers' rights, access and benefit sharing, breeders rights, and the coverage of species in Annex 1
- To understand and use the standard material transfer agreement (SMTA)
- To understand the process of implementing the Treaty and its multilateral system of access and benefit sharing at national and local levels

Contents

- Intellectual property rights in relation to agrobiodiversity from a historic perspective
- International policies of relevance genetic resources for food and agriculture (particularly the CBD and the Treaty)
- Implementation of the Multilateral System
- The Treaty's Annex 1
- Species not covered in the Treaty's Annex 1
- Farmers' rights
- Access and benefit sharing
- Standard material transfer agreement (SMTA)
- Key organizations and institutions involved in genetic resources policy

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- Bioversity International, Training materials on genetic resources policy: www.bioversityinternational.org/training/training_materials.html
- Convention on Biological Diversity (CBD), Agricultural Biodiversity: www.cbd.int/agro
- FAO, Commission on Genetic Resources for Food and Agriculture: www.fao.org/nr/cgrfa/en
- FAO, Implementing the Global Plan of Action for Animal Genetic Resources: www.fao.org/ag/againfo/programmes/en/A5.html
- Genetic Resources Policy Initiative (GRPI): www.grpi.org

- Global Plan of Action (GPA), Portal for plant genetic resources for food and agriculture: www.globalplanofaction.org
- International Plant Protection Convention (IPPC): www.ippc.int
- International Treaty on Plant Genetic Resources for Food and Agriculture: http://www.planttreaty.org/content/training_edm1
- Platform for Agrobiodiversity Research (PAR): www.agrobiodiversityplatform.org

Institutional aspects of managing agrobiodiversity

Introduction

This topic aims to create awareness of the institutional setting for managing agrobiodiversity, and for teaching it. The emphasis is on multidisciplinary and multi-sector aspects, which calls for collaboration, partnerships and networking in research and extension, as well as education.

Government ministries, national agricultural research institutes and the extension service in developing countries tend to be organized according to sectors (agriculture, forestry, health, etc.). In addition, the bulk of investments in agricultural research and development are allocated to a limited number of staple crops and animal breeds. As result, the institutional setup at the national or local level might not be conducive to handling multidisciplinary and multi-sector issues, such as developing underutilized species that require more holistic, participatory approaches than those used for commodities.

Universities and technical colleges, which supply the human capacity for research and development, tend to follow this sector orientation as they respond to signals from the job market. It is not surprising that investments in building human and institutional capacity for research, extension and marketing of agrobiodiversity have been limited. Other institutional aspects also differ: for example, the research support system (which includes professional associations, networks and publication opportunities) that exists for commodity crops is, by and large, lacking for neglected and underutilized species (NUS).

The competence required to manage a broader range of agrobiodiversity can differ significantly from what is required to manage the modern agricultural system of staple crops. A simple comparison between modern and traditional agricultural systems illustrates these contrasts (Table 6). For example, strengthening value chains for NUS requires an approach that takes into account all steps from the farm to the market, and all actors involved, including traders/middlemen. This requires participatory action research that involves multiple disciplines and multiple stakeholders, including the private sector. But setting up such projects could be a challenge to institutions designed to focus on staples. A related issue is that young scientists interested in NUS or participatory breeding might lack the mentors and role models that are so important for developing capacity.

Table 6. Comparison of modern and traditional agricultural approaches

Modern agriculture	Traditional agriculture
• Focus on high yield	• Risk management, resilience and multiple uses
• Few commodity species	• Many species, including 'neglected and underutilized species'
• Global value chains and specialized actors	• Value chains primarily local to regional
• Supermarket dominance	• Subsistence + local/regional markets
• Standardized products, to meet market requirements	• Variable products, lack of standards and regulations
• Modern varieties, including hybrids, designed for specific environments	• Locally adapted landraces
• Breeding by research centres and seed companies	• Traditional variety selection by farmers
• Formal seed systems, including private sector	• Informal seed systems, often exchanged for free through social networks
• High input of seeds, fertilizers, agrochemicals, irrigation	• Low external inputs
• Advanced agricultural technologies, including food processing	• Limited/low-tech postharvest processing
• Policy intensive, including competition with subsidized production in the North	• Neglected by policymakers
• Scientific knowledge system	• Traditional knowledge system, gender dimensions

Multidisciplinary collaboration among and within institutions may require particular attention. Because of the integrated nature of agrobiodiversity, new alliances might be needed in research, development and education, as well as within a single organization. For instance, influencing the food system to make better use of agricultural diversity requires partnerships between the agricultural and health sectors. Domestication of local fruits might require the agricultural and forestry sectors to team up. Public-private partnerships, and participation of community-based organizations (CBOs) and nongovernmental organizations (NGOs), can be very important in the development of value chains. The challenge is to link these entities in a way that is beneficial to all. Working with policymakers and the media can also help create awareness and promote agricultural diversification.

International collaboration is essential for both the conservation and the use of genetic resources for food and agriculture. To facilitate such collaboration, many regional networks have been established, such as the East Africa Plant Genetic Resources Network (EAPGREN), the Pacific Agricultural PGR Network (PAPGREN), the European Forest Genetic Resources Network (EUFORGEN), or crop-specific networks like ProMusa (a network that brings together scientists and other stakeholders working on banana). Other means of collaboration include the Platform for Agrobiodiversity Research (PAR), a framework that links existing initiatives and organizations concerned with agrobiodiversity. Networks, multi-stakeholder platforms, and activities for engaging with local organizations are all vital tools for research, innovation and education.

Universities and colleges play an important role in providing budding scientists with opportunities for experience in research on agrobiodiversity. In addition to integrating agrobiodiversity into education programmes – the purpose of this Guide – universities can offer opportunities for thesis research on a broad range of agrobiodiversity topics. Partnerships with international research and development organizations (such as Bioversity International, the World Agroforestry Centre, and Crops for the Future) or leading universities can be strategic. Similarly, there are many opportunities to link with the private sector in the study of market chains for NUS.

Main learning points

- To analyse how national agricultural research and extension systems, as well as farmers, CBOs, NGOs and private firms, manage agrobiodiversity
- To be aware of institutional constraints on the capacity to conduct research and development on topics like value-chain enhancement and neglected and underutilized species
- To describe how competencies for enhancing traditional agricultural systems might differ from those required for staple crops
- To describe why multidisciplinary and multi-stakeholder collaboration are important to strengthen human and institutional capacity for managing agrobiodiversity
- To be familiar with key global, regional and thematic networks on genetic resources
- To be able to identify institutional opportunities for thesis research on agrobiodiversity
- To recognize opportunities for public-private partnerships and links with other actors, including CBOs and NGOs

Contents

- Institutional capacity for agrobiodiversity conservation and use at the national level
  - The nature and dynamics of complex processes
  - Inventory of key institutions and their mandates
  - Analysis of capacity issues

- Capacity requirements in modern vs. traditional agricultural development
- The concepts of multidisciplinary and multi-stakeholder collaboration
  - Benefits and challenges
- Global, regional and thematic networks on the conservation and use of genetic resources
  - Inventory of key networks and their mandates
  - Benefits and opportunities for collaboration
- International research on agrobiodiversity
  - Key actors and their mandates
  - Opportunities for thesis research
- Role of the private sector in enhancing the value chain of NUS
- Role of CBOs and NGOs in enhancing the value chain of NUS

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- Bioversity International: www.bioversityinternational.org
- Eastern Africa Plant Genetic Resource Network (EAPGREN): www.asareca.org/eapgren
- European Forest Genetic Resources Network (EUFORGEN): www.euforgen.org
- Food and Agriculture Organization of the United Nations, Commission on Genetic Resources for Food and Agriculture: www.fao.org/nr/cgrfa/en
- Institute for Development Studies (IDS), Participation, Power and Social Change Team: www.ids.ac.uk/ids/particip
- Institutional Learning and Change (ILAC): www.cgiar-ilac.org
- International Livestock Research Institute (ILRI): www.ilri.org
- Platform for Agrobiodiversity Research (PAR): http://agrobiodiversityplatform.org
- Global Crop Diversity Trust: www.croptrust.org
- World Agroforestry Centre (ICRAF): www.worldagroforestry.org

Genetic resources for food and agriculture

This learning area aims to clarify the status of genetic resources for food and agriculture, especially in their centres of origin, and to contribute to an understanding of the key drivers and trends that influence their conservation status. The three proposed topics are as follows:

- **Processes shaping agrobiodiversity** presents the dynamic environmental, genetic, socioeconomic and cultural processes that shape and maintain agrobiodiversity, and the effects of modern agriculture on these processes.
- **Status and trends of genetic resources for food and agriculture** gives an overview of the status of plant, forest and animal genetic resources. It describes global monitoring of agrobiodiversity at the ecosystem, species and genetic level, and discusses genetic erosion.
- **Conservation of agrobiodiversity** gives an overview of strategies for conserving agrobiodiversity *ex situ* and *in situ*, as well as on farms and in agricultural landscape mosaics and how these strategies are complementary. Information systems for genebanks are described.

Processes shaping agrobiodiversity

Introduction

The aim of this topic is to orient the learner about the dynamic environmental, genetic, socioeconomic and cultural processes that shape and maintain agrobiodiversity. Strategies for conservation are covered, and the importance of information on genetic resources is emphasized.

The Convention on Biological Diversity (CBD 2011) observes that "Agricultural biodiversity is the outcome of the interactions among genetic resources, the environment and the management systems and practices used by farmers". This is the result of both natural selection and human influence over millennia. Understanding how this agrobiodiversity has been created, is maintained and continues to adapt and evolve thus requires insights into a wide range of processes – natural as well as human-driven.

On the genetic side, awareness is needed of the three levels of agrobiodiversity: ecosystems, species and within-species (intra-specific) diversity. The concepts of genepool and geneflow are central. Genetic variation within a genepool (intra-specific diversity) is a requirement for the natural processes of evolution and adaptation that take place over time in a species. These processes will only occur in well-functioning agroecosystems.

The concepts of genepool and geneflow also underpin human domestication of agricultural species. Taking advantage of existing variation and the occasional beneficial mutation, farmers have domesticated hundreds of species, which has resulted in a rich diversity of landraces in crops, farm animals – including some insects (mini-livestock!) – and important trees. The degree of domestication varies greatly. An estimated 7000 plant species have been used for food or animal feed globally at one time or another. Many are simply collected from or (to varying degrees) managed in the wild. Others have been domesticated to a lesser or greater extent, initially in the 'Vavilov Centers of Diversity' – areas that hold high genetic variation in cultivated landraces, along with a presence of crop wild relatives. For some crops, secondary 'centres of diversity' have emerged outside of the crop' centres of origin.

Some species have been subject to intensive improvement through conventional breeding programmes or, increasingly, via biotechnology. Some 150 species are commercialized on a global scale. Of these, only 30 crops provide 95% of our food energy and just three crops – maize, wheat and rice – provide half of our caloric and protein intake (Wilson 1992). While improved varieties of these crops play a key role in modern agriculture (the 'Green Revolution'), landraces of the same species continue to be important to many farmers. The modern and traditional types often occur in parallel, a fact that is often overlooked.

Hundreds of neglected and underutilized plant and animal species continue to be important locally or sub-regionally, particularly in poor communities in

marginal areas. Such species can have the potential to contribute to agricultural diversification and commercialization, but are neglected in research, policies and education. Indigenous local knowledge about such species, accumulated over generations, is a key asset that is quickly lost in the wake of demographic and cultural change and the impact of the wider development process, globalization, market development, etc.

Human activities that alter ecosystems and landscapes have a great impact on these processes. The impact of agricultural practices on biological diversity can be far-reaching at all levels of diversity. However, the debate over biodiversity conservation tends to focus on the loss or degradation of natural ecosystems, such as forests or wetlands, or the vulnerability and threats to wild species. Less known and less visible is the loss of the intra-specific diversity that is a prerequisite for a species' continued evolution, adaptation and domestication, and which also provides the genetic traits that breeders might use. The development of a 'Red List' for cultivated species (IUCN 2011) is one attempt to draw attention to this genetic erosion.

Understanding the reproductive biology of target species is very important for managing healthy populations and devising conservation strategies. For instance, the distribution of trees in the landscape can be critical to maintaining the species' geneflow between protected areas. The pollination required to maintain this geneflow can be affected by changes in land use and fragmentation of landscapes. For such reasons, a 'landscape approach' is increasingly being recognized as a key component of conservation strategies, thus linking natural ecosystems and managed agricultural landscapes.

Climate change and increasing variability (see page 42) are going to have a significant effect on the genepool of agricultural species, due to changing temperatures and rainfall patterns, more extreme weather events (drought, flood, etc.) and threats from pests and diseases. Marginal populations of landraces or crop wild relatives will be lost at a faster rate. The area suitability for a certain crop, or crop variety, might shift substantially in a future climate. For example, a scenario of climate change might threaten marginal populations with extinction. The genepool then becomes narrower and future options for evolution, domestication and breeding are lost.

When part of a species' genepool disappears, it affects the natural processes of evolution and adaptation as well as opportunities for domestication and breeding.

Main learning points

- To understand the three levels of genetic diversity: ecosystem, species and within-species (intra-specific) diversity
- To understand the concepts of 'centre of origin' and 'centre of diversity'
- To be familiar with the concepts of genepool and geneflow and to appreciate the importance of maintaining intra-specific genetic diversity
- To be able to describe natural processes of evolution and adaptation and how these are influenced by global changes, including climate change

- To be able to describe the history of domestication and modern breeding and how these relate to the current uses of species and varieties
- To understand the role of pollination and reproductive systems in maintaining diversity in a population
- To be able to describe the landscape approach to conservation and appreciate the role of trees for maintaining geneflow in managed landscapes
- To understand the role and potential of neglected and underutilized species

Contents

- Dimensions of agrobiodiversity
  - Plant, aquatic, animal, microbial and fungal
  - Support for ecosystems services
  - Abiotic influences
  - Socioeconomic and cultural dimensions
- Three levels of agrobiodiversity: ecosystem, species, intra-specific
- Genepool, geneflow
- Pollination and reproductive systems
- Evolution and adaptation
- Domestication processes, Vavilov Centers of Origin, centres of diversity
- Breeding
  - Traditional
  - Biotechnology
- Neglected and underutilized species
- Human influence on agrobiodiversity processes
- Impact of climate change on agrobiodiversity processes

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Status and trends of agrobiodiversity

Introduction

This topic aims to bring about an understanding of the status and trends of the world's agrobiodiversity: plants, forests, animals, and fisheries and aquaculture.

The status and trends of agrobiodiversity need to be monitored at all three levels: ecosystem, species and intra-specific diversity. Such knowledge is necessary for devising conservation strategies to avoid genetic erosion and for planning sustainable management of these genetic resources.

At the level of the ecosystem, countries monitor land use with varying degrees of precision. Using such data, the FAO publishes a forest resources assessment every five years, most recently in 2010 (FAO 2010a). The FAO also compiles and makes available statistics on a range of other land uses. International efforts to monitor conditions and trends in the world's ecosystems include the Pilot Analysis of Global Ecosystems in 2000 and the Millennium Ecosystems Assessment in 2005. At the species level, the IUCN Red List (IUCN 2011) provides information on vulnerable and threatened species. Efforts are now underway to develop a Red List for cultivated crops. Knowledge about the status of intra-specific genetic resources is less developed.

Genetic erosion – the loss of parts of the genepool – is threatening the future adaptability and evolution of agrobiodiversity and reduces the options for domestication and breeding. Of particular interest to conservation efforts are the status and trends of genetic resources in the centres of diversity of agrobiodiversity identified by the pioneering Russian scientist N. I. Vavilov.

Since the early 1960s, the FAO has provided assistance to countries in characterizing their genetic resources and developing conservation strategies. In 1995, the Commission on Genetic Resources for Food and Agriculture (CGRFA) was established to cover all aspects of agrobiodiversity. A series of publications – "State of the World" reports – has since been published to help monitor the world's plant, animal, and fish genetic resources, respectively. A report on the status of the world's forest genetic resources is due to be published in 2013. The emerging picture is that agrobiodiversity is under stress. For example, for fish, a quarter of the stock groups monitored by the FAO were either overexploited, depleted or recovering from depletion (and thus yielding less than their maximum potential) owing to excessive fishing pressure (FAO 2009b). For animal genetic resources,

around 20% of reported livestock breeds are classified as 'at risk' and 62 breeds became extinct during one six-year period (FAO 2007).

There is a shortage of information about the status of the genepool in key agricultural species. For crops, this genepool includes crop wild relatives in their centre of origin, the landraces that farmers manage *in situ* and on farms, and the genetic resources conserved *ex situ* in genebank collections. The amount and distribution of genetic diversity of such genepools, much less the trends and possible losses of genetic diversity – genetic erosion – are not well documented. Furthermore existing studies of the extent of genetic erosion show contradictory results in many cases. Data on intra-specific diversity is still limited to key species, although biotechnology advances are making DNA fingerprinting and sequencing more affordable.

The status of genetic resources conserved in genebanks is also important, both regarding the coverage (are there gaps in collections?) and the quality and integrity of the germplasm they store (because genetic diversity might be lost during regeneration as a result of genetic drift). The Global Crop Diversity Trust is supporting priority genebank collections to regenerate accessions that are unique and at risk. This effort will make previously inaccessible accessions available to users for the first time, and in addition, it will generate enough seeds for safety duplicates.

Main learning points

- To be familiar with international programmes and organizations monitoring genetic diversity at the ecosystem, species and intra-species level
- To be aware of the work of FAO's Commission on Genetic Resources for Food and Agriculture (CGRFA) and familiar with the key findings of the 'State of the World' reports on genetic resources
- To be able to describe the status and major trends of forest, plant, animal and fish genetic resources
- To be aware of the risks for and effects of genetic erosion in natural ecosystems, agroecosystems and genebanks
- To identify the threats related to genetic erosion and to explain their influence on genetic resources for food and agriculture

Contents

- Monitoring the status and trends of agrobiodiversity
  - Ecosystem level
  - Species level
  - Genetic level
- State of the world's genetic resources for food and agriculture
  - Plant genetic resources
  - Animal genetic resources
  - Forest genetic resources
  - Fish genetic resources

- Genetic erosion
  - Crop wild relatives
  - Landraces
  - Genetic erosion in genebanks

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- Domestic Animal Diversity Information System (DAD-IS): www.fao.org/dad-is
- Domestic Animal Genetic Resources Information System (DAGRIS): http://dagris.ilri.cgiar.org
- FAO Commission on Genetic Resources for Food and Agriculture: www.fao.org/nr/cgrfa/en
- FAO Global Forest Resources Assessment 2010: www.fao.org/forestry/fra/fra2010/en
- Global Crop Diversity Trust: www.croptrust.org/main
- Millennium Ecosystems Assessment: www.maweb.org/en/index.aspx
- IUCN Red List of Threatened Species: www.iucnredlist.org
- The Agroforestree Database: www.worldagroforestry.org/Sites/TreeDBS/aft.asp

Conservation of agrobiodiversity

Introduction

This topic gives an overview of strategies for conservation of agrobiodiversity – *ex situ*, *in situ* and on-farm conservation – and how these strategies are related. The differences in conservation strategies for plant, animal and forest genetic resources warrant particular attention.

The conservation and sustainable use of genetic resources for food and agriculture is the subject of several international conventions including the CBD and the Treaty. However, only recently has the need for incorporating agrobiodiversity into National Biodiversity Strategies and Action Plans (NBSAPs) been highlighted.

Industrialization of agriculture in the 20th century and a shift towards improved crop varieties and animal breeds has led to a rapid loss of traditional landraces and breeds around the world. Changes in land use, deforestation and forest degradation, overharvesting, invasive species, pose further threats to agrobiodiversity, including crop wild relatives and forest genetic resources. Climate change may accelerate some of these processes. Conservation strategies thus need to take into account a complex range of factors.

In response to the loss of crop diversity, scientists started collecting landraces and crop wild relatives for *ex situ* conservation in genebanks. A pioneer of this effort was N. I. Vavilov of the All-Union Institute for Plant Industry in Leningrad, Russia, in the 1920s. Since then, a global network of around 1750 genebanks has been established, with some 7.4 million accessions among them (FAO 2010b). The Global Seed Vault in Svalbard, established by Norway in 2008, functions as back-up storage for genebanks globally.

Not all plant species can be conserved in genebanks. Species that have long life cycles, are vegetatively propagated or have recalcitrant seeds (which cannot tolerate drying and are sensitive to low temperatures) need to be conserved in field genebanks, *in situ* or *in vitro*. The conservation of crop wild relatives also often requires *in situ* approaches, but the capacity and awareness in this field tends to be rather weak. Furthermore, if genebanks are not well managed, the integrity of collections may be threatened over time due to physiological and genetic processes – genetic erosion in genebanks. To make better use of materials conserved *ex-situ* or *in situ*, including crop wild relatives, pre-breeding may be required. Pre-breeding refers to activities designed to identify useful traits in non-adapted materials and transfer these into intermediate materials that breeders can use to produce new and improved crop varieties.

Twenty percent of animal breeds are at risk of extinction, and the population status of many breeds is still unknown. Many developing countries lack comprehensive strategies, policies and technical capacity for the conservation of animal genetic resources. Guidelines for *in vivo* conservation and cryo-conservation of animal genetic resources, in preparation by the FAO, will be important tools for addressing these needs. While cryo- and *in vivo* conservation complement each other, the latter has the added advantage of allowing continued evolution in the local environment.

Conservation strategies for forest genetic resources require attention to such factors as a very large number of species, limited genetic knowledge about them, distributions that can cover multiple countries, their ecology and their reproduction systems. Comprehensive *ex situ* conservation strategies might only be realistic for a limited number of priority tree species. For thousands of species, *in situ* conservation remains the only realistic option. *In situ* conservation is also a prerequisite for maintaining natural evolutionary processes. Protected areas are commonly used for conserving ecosystems and species in their natural habitats, but the genetic aspects within a species are seldom taken into account.

On-farm conservation in agricultural landscapes is an important complement to *ex situ* and *in situ* conservation. The major part of agrobiodiversity is maintained and adapted by farmers in dynamic biological, social and cultural interactions. Farmers thus play a key role in conserving landraces, domestic animals and agroforestry species in agricultural systems on farms. The conservation and use of agrobiodiversity are thus closely connected, and rural people (women in particular) play a key role. Therefore, the continued conservation of agrobiodiversity depends

on farmers' objectives and the incentives and driving forces they respond to. This contribution of farmers towards creating and maintaining agrobiodiversity is recognised in policy instruments (e.g., Article 9 of the Treaty). Benefit-sharing and other compensations for providing such environmental services are therefore an important consideration. Meanwhile, a 'new rurality' is rapidly changing the character of rural areas and will unquestionably have an impact on strategies for *in situ* conservation.

While information on genetic resources is critical for setting priorities for conservation, it is equally important for research, breeding and production. Global portals on genetic resources (such as Genesys, which is a gateway to several databases on plant genetic resources) now provide such information online. The Domestic Animal Diversity Information System (DAD-IS) provides a similar service on animal genetic resources. These databases provide comprehensive information on each accession/breed, such as collection data, characterization and evaluation data, and storage data.

Main learning points

- To describe the rationale for agrobiodiversity conservation of crops, animals and trees and for including it into National Biodiversity Strategies and Action Plans (NBSAPs)
- To be able to give a historic overview of *ex situ* conservation in genebanks from the early 1920s to today
- To understand processes and protocols for *ex situ* conservation, as well as limitations, such as storage behaviour of seeds, maintenance of genetic integrity and coverage of the genepool
- To be able to describe approaches and challenges related to *in situ* conservation, including conservation of crop wild relatives
- To describe conservation strategies for animal genetic resources
- To describe conservation strategies for forest genetic resources
- To explain how *ex situ*, *in situ* and on-farm conservation complement one another
- To be aware of the role of gender and local knowledge in on-farm conservation of agrobiodiversity
- To be able to design conservation strategies for target species, in collaboration with multiple stakeholders

Contents

- Threats to agrobiodiversity, considering three levels of diversity: the agroecosystem, species and genetic level
  - Population genetics
  - Landraces
  - Crop wild relatives
  - Neglected and underutilized species

- Species conservation strategies
  - Using genetic and characterization data for priority setting
  - Use of GIS and modelling for conservation planning
- The global system for *ex situ* conservation
  - Genebanks
  - Processes for genebank management
  - Protocol for orthodox seeds
  - Protocol for recalcitrant and vegetatively propagated species
  - Information management: global portals (e.g., Genesys)
  - Pre-breeding
- Conservation of animal genetic resources
- Conservation of forest genetic resources
- *In situ*, *circa situ* and on-farm conservation
  - Farmers' traditional conservation strategies
  - Conservation through use
  - Landscape approach to conservation
  - Connectivity and geneflow
  - Environmental service payment and benefit sharing mechanisms

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- Global Crop Diversity Trust: www.croptrust.org/main
- Pre-breeding for effective use of plant genetic resources. An e-learning course: http://km.fao.org/gipb/

Agrobiodiversity products and services

Per Rudebjer / Bioversity

This learning area focuses on the interaction between agrobiodiversity and livelihoods. The products and services provided by agrobiodiversity are discussed, including health and nutrition, traditional knowledge, and the environmental services that agrobiodiversity provides and which are essential for sustainable agriculture.

- **Agrobiodiversity and livelihoods** gives an overview of how agrobiodiversity, on-farm and off-farm, contributes to sustainable livelihoods, food security and income. Risk management and underutilized species are key concepts.
- **Food and nutrition systems** discusses the role of agriculture and food systems in providing food and nutritional security and improving human health. The need for better links between the agricultural sector and the health sector is emphasized.
- **Traditional knowledge** describes the evolution of traditional and local knowledge of agrobiodiversity, its role today and the erosion of local knowledge that follows societal change.
- **Environmental services** focuses on the public values of managing agrobiodiversity, and the role of ecosystem services for sustainable agriculture. The role of farmers in providing such services and ways of rewarding them for doing so are discussed.

Agrobiodiversity and livelihoods

Introduction

The purpose of this topic is to raise awareness about how agrobiodiversity in a broad sense contributes to sustainable livelihoods, as well as how rapid rural change influences the provision of products and services through new opportunities and threats.

Agroecosystems, whether intensively or extensively managed, provide food, fodder and fibre. Farmers depend on a diverse range of plants, trees and wild species, livestock and wild animals, and aquatic species for sustaining their livelihoods. This diversity includes landraces, neglected and underutilized species (NUS) and agroforestry trees, as well as the range of products generated from them. Farmers' local knowledge of species and their use, passed on and refined from one generation to the next, is an integral part of this agrobiodiversity. Fruits and plants collected from forests and woodlands provide valuable supplements to food and income, and a safety net if crops fail. 'Bush meat' and fish are the main sources of protein in many communities, and insects can also be important. Many people (both rural and urban) depend on wood energy and natural medicines, and raw materials for handicrafts can be a significant source of income for many rural people. At the same time, people's means of livelihood have a great impact on biodiversity.

A 'new rurality' associated with rapid change and globalization will provide new opportunities for developing agrobiodiversity-based value chains, but it will also put pressure on agroecosystems that are already under threat.

Risk mitigation is a key strategy in many poor farmers' agricultural systems, and reducing risks can be more important than maximizing production. A diversified agriculture may often be the preferred option, especially in low-input rain-fed systems. Locally adapted landraces might tolerate drought better and be more resistant to pests and diseases than the modern varieties that seed companies and the national extension systems provide. The livelihood systems of resource-poor farmers might therefore combine traditional landraces and minor crops with modern varieties of staple crops. Diversity is used as an insurance policy to counter unreliable climatic or market conditions.

This diversity includes not only landraces of staple crops, but also a wide range of NUS. An estimated 7000 species of plants have been used for food globally and some 2500 tree species have been recorded in agroforestry systems. Many such NUS are essential to farmers' livelihoods, particularly in marginal environments with rain-fed agriculture. They can be nutrient-rich and important to the local culture. However, landraces and NUS are in decline and their potential is not fully tapped. They might be associated with a stigma as a 'poor man's crop'. One concern today is how to reverse the trend towards an energy-rich but nutrient-poor cereal-based diet. NUS could play an important role in a healthier

and more diverse diet. As a successful promotion of African leafy vegetables in Kenyan supermarkets has demonstrated, many NUS have potential for further commercialization if constraints in their value chains can be addressed, as discussed further in the section dedicated to this topic.

Agroforestry is important to rural livelihoods in many ways. The use of trees in agricultural landscapes helps improve the food security, nutrition and income of rural people. Agroforestry trees can provide benefits relating to health, shelter, energy resources and environmental sustainability. Nitrogen-fixing 'fertilizer trees' can help restore soil fertility and, hence, increase the productivity of crops in agroforestry systems. Indigenous fruits have potential for domestication and commercialization. The importance of trees on farms tends to increase as the pressure on forests increases, and some communities have started to receive an income for storing carbon in such systems.

Ecotourism is expanding, and part of this economic segment can be captured by communities that conserve and manage rich agrobiodiversity.

The increasing global dependence on a limited number of varieties of key staple crops and animal breeds is a cause for concern, as it is linked to rapid erosion of agricultural diversity. Conservation through the use of agrobiodiversity can counter these trends. Farmers play a key role as custodians and managers of agrobiodiversity, thereby providing environmental services to global society. Payment schemes or other rewards for such services are contributing to farmers' livelihoods (see section on environmental services). To recognize and enhance the role of agrobiodiversity in rural – and urban – livelihood systems, institutional issues need to be addressed. In particular, the capacity for facilitating multidisciplinary and multi-stakeholder processes might need strengthening. There is often a need to create awareness and provide tools for the mainstreaming of agrobiodiversity into policies and programmes.

Main learning points

- To recognize the multiple roles and functions of agrobiodiversity in farmers' livelihood strategies
- To appreciate the range of agrobiodiversity products produced in agroecosystems
- To understand how farmers use agrobiodiversity to mitigate risk
- To be able to describe the role of neglected and underutilized species (NUS) in the livelihood strategies of resource-poor farmers
- To be aware of the role and potential of agroforestry in rural livelihoods
- To recognize the need to compensate farmers for environmental services
- To be aware of institutional requirements for facilitating agrobiodiversity management and to be able to advocate and communicate agrobiodiversity issues

Contents

- Sustainable livelihood framework
- Role of agrobiodiversity in livelihood strategies
  - Food and nutrition
  - Fodder
  - Income generation
  - Medicines
  - Energy and raw materials
  - Culture and belief systems
- Agrobiodiversity products and agroecosystems
  - Home gardens
  - Farms
  - Communal lands
  - Forests and woodlands
  - Marine and aquatic systems, including fish farms
  - Indigenous knowledge
- Risk-mitigation strategies and the role of agrobiodiversity
  - Climate change and variability
  - Pests and diseases
  - Market-related risks
- Neglected and underutilized species (NUS) and livelihood security
  - Reversing the decline of NUS by enhancing the value chain and raising public awareness
- Agroforestry tree products and their role in rural livelihoods
- Institutional aspects and support for agrobiodiversity management
  - Multidisciplinary approaches
  - Multi-stakeholder participation
  - Public awareness
  - Mainstreaming agrobiodiversity in institutions

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- Crops for the Future: www.cropsforthefuture.org
- FAO Natural Resources and Environment: www.fao.org/nr/nr-home/en
- Institute for Development Studies, Participation, Power and Social Change Team: www.ids.ac.uk/go/research-teams/participation-team
- Platform for Agrobiodiversity Research (PAR): http://agrobiodiversityplatform.org
- World Agroforestry Centre, Learning Resources: www.worldagroforestrycentre.org/learning/resources

Food and nutrition systems

Introduction

The aim of this topic is to increase awareness of the role of agrobiodiversity in improving dietary diversity and quality, and providing a food system that ensures food and nutritional security and improved human health.

Food and nutritional security is central to the Millennium Development Goal 1 ("eradicate extreme poverty and hunger"). Target 1C requires halving

the proportion of people who suffer from hunger by the year 2015. Yet, hunger and malnutrition, including micronutrient deficiencies in women and children, are widespread in many countries, particularly in Sub-Saharan Africa and South Asia. According to FAO estimates, a total of 925 million people were undernourished in 2010.

In parallel, the number of people who are overweight and obese is rapidly increasing globally. The World Health Organization (WHO) reports that 1.5 billion adults were overweight or obese in 2008, with a corresponding increase in the incidence of noncommunicable diseases, such as cardiovascular disease, diabetes and some cancers. These trends are linked to a shift in dietary patterns to cheap, energy-rich but nutrient-poor food.

Over the years, food policies have focused on providing enough food for a population, with the emphasis on quantity, but not quality. More recently, the emphasis shifted to increase the intake of minerals and vitamins by enriching food with micronutrients, or by bio-fortification of staple crops through conventional breeding. Only recently has the global nutrition and health community taken an interest in the health attributes of food-based approaches and food systems in general, as well as the role that traditional food and local agrobiodiversity could play in ensuring a community's food and nutrition security.

Food from local agrobiodiversity has been grossly neglected in most national policies and intervention strategies against food and nutrition insecurity. With the focus on quantity rather than quality, earlier nutrition intervention strategies also neglected the positive interactive effects of food nutrients when consumed together in a meal. There is today a growing consensus among food and nutrition specialists that dietary diversity is strongly linked to better nutrition and health. Studies of traditional food systems show that they do contain a wide variety of food that is rich in micronutrients and health-protecting non-nutrient bioactive compounds. Local agrobiodiversity can thus contribute to diversity in food systems, leading to diversity in food choices, along with improved nutrition and health.

The medicinal values of agrobiodiversity are increasingly being recognized. Medicinal plants are widely used by local communities and are the main pharmaceutical resource for millions of people – both rural and urban. Trade in natural medicines is an important income source in many rural communities. Some species, such as *Prunus africana* (the bark of which is used to treat prostate cancer), have a global market with the demand outstripping a sustainable supply. This situation calls for domestication and provides opportunities for including such species in farming systems.

There are institutional implications, too: the agricultural and the health and nutrition communities will need to work more closely together towards a food system that better links agriculture, diet and human health.

Main learning points

- To be familiar with key global datasets monitoring hunger, poverty and human health
- To be aware of the close relationship between lack of dietary diversity and a high prevalence of diet-related health problems, particularly in children, pregnant women and women of childbearing age
- To describe national food policies as they relate to health and nutrition
- To describe the health and nutrition attributes of both traditional and 'modern' food systems
- To be familiar with key methods for measuring agricultural diversity and dietary diversity
- To facilitate the collaboration between the health and nutrition and the agricultural communities

Contents

- Millennium Development Goal 1C
- Health and nutrition indicators that relate to hunger
  - Micronutrient deficiencies with a focus on the major five: vitamin A, iron, folate, zinc and iodine
- Prevalence of underweight and stunted children below five years of age
- Health and nutrition indicators: overweight and obesity
  - Data on incidence of overweight and obesity
  - Data on non-communicable diseases
- Food policies
  - Quantity vs. quality
  - Changes in agriculture, food and nutrition policies over time
- Diversity in modern food vs. traditional food systems
  - Assessing agricultural diversity
  - Measuring dietary diversity
  - Traditional medicines
  - Functional diversity vs. species richness
  - Sociocultural and anthropological aspects of food choices
  - Gender aspects
- Institutional aspects
  - Linking the agricultural and health sectors
  - Role of other actors, such as the food industry/processors (industrial and small-scale processors)
  - Multi-sectoral nature of interventions against food and nutrition insecurity

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- Bioversity International, Nutrition: www.bioversityinternational.org/research/nutrition.html
- FAO, Nutrition and consumer protection: www.fao.org/food/en

- Millennium Development Goal Indicators: http://mdgs.un.org/unsd/mdg/Default.aspx
- World Health Organization, Obesity and overweight, Fact Sheet N°311: www.who.int/mediacentre/factsheets/fs311/en/index.html
- Worldwatch Institute, Nourishing the planet: www.worldwatch.org/nourishingtheplanet

Traditional knowledge

Introduction

This topic aims to create awareness about the evolution of traditional and local knowledge of agrobiodiversity, the erosion of local knowledge that follows societal change, and new approaches to build on such knowledge.

For centuries, communities have managed their agroecosystems as part of their traditional knowledge systems. Before the advent of industrial agriculture and modern plant breeding in the 20th century, farmers had domesticated hundreds of species globally. Millennia of experimentation, accidental mutations, selection of preferred varieties and informal exchange of seeds created a wealth of local varieties (landraces) of agricultural plant and animal species. Sometimes, these varieties were fundamentally different from the wild relatives they originated from, and the resulting centres of diversity could be located outside the species' centre of origin. This diversity, along with crop wild relatives, today provides the core materials for modern breeding.

Likewise, farmers have developed a deep knowledge of useful wild species for food, fodder, medicine, raw materials for building and handicrafts, and so on. The study of such knowledge has emerged as a field of its own: ethnobotany. Cultural expressions in rural societies were and still are closely connected with the conservation and management of agrobiodiversity and cover a wide range of fields such as seed handling, cooking or medical uses, or use in rites and ceremonies. A community's local knowledge of where, when and how to use this diversity is central to farming strategies. There is also a strong gender element in this traditional knowledge.

Many farmers, particularly in marginal areas, rely on informal seed systems that involve exchanging seeds via social networks. 'Custodian farmers', who are knowledgeable about local diversity, play a key role in such networks.

The change towards monoculture-dominated farming systems not only reduces agrobiodiversity but also has an impact on associated local knowledge. The rural-urban migration and associated changes in food habits has a profound effect and a strong generational dimension. The erosion of traditional knowledge is substantial and rapid.

The modern varieties created by breeders are predominantly designed for high-input agriculture in more productive areas. While successful in increasing crop

and livestock productivity, they tend to be less suited to marginal environments subject to variable conditions. They often lack the multiple-use traits and the nutritional, taste and cooking qualities valued in diverse food systems. Over the last 20 years, a growing body of knowledge and experience has been acquired as scientists work more closely with farmers, using participatory variety selection and breeding to improve and expand the use of traditional landraces. The critical role of traditional knowledge has also been recognized in such policy frameworks as the International Treaty on Genetic Resources for Food and Agriculture (which contain articles on farmers' rights and on benefit sharing) and the Convention on Biodiversity (CBD).

Main learning points

- To acknowledge and recognize the role of culture and traditional knowledge as an integral part of agrobiodiversity
- To appreciate the gender aspects of agrobiodiversity knowledge
- To recognize the role and function of informal seed systems
- To be able to explain how societal change impacts on traditional knowledge of agrobiodiversity
- To be able to use tools and methods for participatory management of biodiversity
- To appreciate the benefits of integrating traditional and scientific knowledge systems
- To be familiar with the concepts of 'farmers' rights' and 'benefit sharing'

Contents

- Traditional knowledge and culture in the conservation and management of agrobiodiversity
  - Traditional value systems and agrobiodiversity
  - Traditional methods of conserving germplasm
  - Custodian farmers
- Evolution of traditional knowledge
  - Domestication
  - Ethnobotany
- Traditional knowledge in modern society
  - Impact of modern agriculture on the use of traditional varieties
  - Erosion of traditional knowledge
  - Gender and generational aspects
  - Urbanization and traditional knowledge
- Informal seed systems
- Bridging traditional knowledge and modern science
  - Participatory biodiversity assessment, plant breeding and variety selection
  - Diversity field fora
  - Seed fairs
  - Strengthening the market chain for traditional species
- Policies and traditional knowledge related to genetic resources: farmers' rights, benefit sharing

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Internet resources

- Bioversity International, Training: www.bioversityinternational.org/training
- People and Plants International, Archived publications: www.peopleandplants.org/archives
- The World Bank, Indigenous Knowledge Program: www.worldbank.org/afr/ik/what.htm

Environmental services

Introduction

This topic aims to demonstrate the role of agrobiodiversity in providing environmental services, a prerequisite for sustainable agriculture. Farmers play a key role in providing such services as they conserve and manage local agrobiodiversity. A key question is how society might reward or pay them for continuing to do so.

The environmental services – commonly classified as provisioning, regulating, supporting and cultural services – of agrobiodiversity are significant, since an important sub-set of biodiversity is found in managed agroecosystems. The continued evolution and adaptation of genetic resources for food and agriculture depend on this *in situ* and on-farm conservation. Processes that allow genes to recombine and mutate, which in itself adds to genetic diversity, need functional agroecosystems. Such processes also include the continued evolution of pests and diseases.

The regulation of water, nutrient cycling, soil fertility and soil health depend on functional flora and fauna, including microbial fauna, both above and below ground. Agrobiodiversity therefore contributes to maintaining agroecosystem resilience, geneflow and evolutionary processes, as well as maintaining traditional knowledge (which all count as indirect-use values). Furthermore, it ensures that future option values are maintained.

Pollination is an essential environmental service, both for the geneflow that maintains the genetic variation of a genepool and for securing agricultural production, but pollinator services may suffer in intensively managed agroecosystems. In recent years, this pollinator deficit has worsened as a result of global declines in pollinator abundance and diversity.

Capturing and storing carbon in agroecosystems helps mitigate global climate change. A UN-led financial mechanism has been set up to provide incentives for "Reducing emissions from deforestation and forest degradation in developing countries" (REDD). Expanding the concept, REDD+ also includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks, which can extend this mechanism from forests into agricultural landscapes.

From the point of view of environmental services related to agrobiodiversity, the contrasts between traditional and modern agriculture are important. Traditionally, farmers maintain diversity in plant and animal genetic resources in their landraces and local breeds. They may also conserve crop wild relatives *in situ* and on farms. Significantly, this often occurs among poor farmers in disadvantaged and remote rural areas in developing countries. While the benefits of such services are increasingly recognized, their full value is often not fully acknowledged by

individuals and society. An important policy question is how to create incentives for farmers to maintain important agrobiodiversity on farms while simultaneously improving their livelihoods.

As reported in more detail elsewhere in this Guide, such services are under threat in many agroecosystems. The increasing yield of modern agriculture has come at environmental costs, such as loss of landraces, local livestock breeds and underutilized species. Excess fertilizers and agrochemicals accumulate in agroecosystems. Large tracts of forests and woodlands continue to be lost to agriculture, resulting in loss of biodiversity, including crop wild relatives. The impact of climate change on the suitability of areas for agricultural species and varieties is also expected to be significant in many areas.

Incentives such as payments or other rewards to providers of environmental services will often be required to sustain the services for the future. Such schemes have been devised for watershed functions, the conservation of biodiversity hotspots and the sequestration of carbon in agroecosystems (or, as mentioned above, the avoidance of deforestation.

Incentive mechanisms that specifically target payments for agrobiodiversity conservation services (PACS) are now being developed. A basic principle is that the costs of conservation tend to be local (i.e., at the farm level), while the benefits tend to be regional, national or even global. Poor farmers cannot be expected to conserve plant and animal genetic resources purely for the benefit of the wider society without adequate incentives to do so. The objective of PACS schemes is therefore to 'capture' public conservation values at the farmer's level, thereby creating incentives for the conservation of agrobiodiversity. This requires the development of appropriate economic methods, decision-support tools and strategies for policy interventions.

Main learning points

- To be able to classify environmental services: provisioning, regulating, supporting and cultural services
- To be familiar with the contribution of agrobiodiversity towards key environmental services: maintaining agroecosystem resilience, geneflow and evolutionary processes and traditional knowledge, as well as future option values
- To appreciate the role of pollinators for landscape functions and agricultural production
- To understand carbon stock-and-flow dynamics in agricultural landscapes
- To describe farmers' practices for conserving diversity in plant and animal genetic resources, and to understand the threats to this conservation
- To be familiar with key mechanisms for payments for environmental services
- To understand the principles underlying incentive mechanisms for agrobiodiversity conservation and sustainable use
- To plan and undertake the conservation and rehabilitation of agrobiodiversity

Contents

- Principles of environmental services in agricultural landscapes
- Types of environmental services in agroecosystems:
  - Provisioning
  - Regulating
  - Supporting
  - Cultural
- Pollination
- Carbon storage in agroecosystems
- Farmers' agrobiodiversity management and its evolution over time
- Farmers' role in conserving plant and animal genetic resources, incentives and disincentives
- Tools and methods for assigning value to the environmental services of agrobiodiversity
  - Rapid biodiversity assessment (RAPA)
  - Stated and revealed preference valuation methods
- Global mechanisms related to payments and rewards for environmental services:
  - REDD+
- Conserving and restoring the environmental services of agrobiodiversity – working with communities
- Payments for agrobiodiversity conservation services (PACS)
- Advocacy for and communication of the environmental services of agrobiodiversity

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Internet resources

- Alternatives to Slash and Burn (ASB): www.asb.cgiar.org
- Bioversity International's web pages on payments for agrobiodiversity conservation services (contains video, downloadable publications, etc.): www.bioversityinternational.org/research/sustainable_agriculture/pacs.html
- Ecoagriculture Partners: www.ecoagriculture.org/index.php
- Ecology and Society: www.ecologyandsociety.org
- Global Action on Pollination Services for Sustainable Agriculture: www.internationalpollinatorsinitiative.org
- Millennium Ecosystem Assessment: www.millenniumassessment.org/en/index.aspx
- Rewards for, Use of and Shared Investments in Pro-Poor Environmental Services (RUPES): http://rupes.worldagroforestry.org
- UN-REDD programme: www.un-redd.org

Sustainable management of agrobiodiversity

This final learning area focuses on three related topics of importance to the sustainable management of agrobiodiversity on farms:

- **Farmers' seed systems and participatory breeding** describes the role of both the formal and farmers' informal seed systems, and the role of farmers in participatory plant breeding.
- **On-farm conservation and management of agrobiodiversity** presents a deeper understanding of how farmers conserve and manage agrobiodiversity on farms and of the related challenges and opportunities.
- **Value chains of neglected and underutilized species (NUS)** presents an approach to improving farmers' gainful participation in markets, looking at a broad range of issues 'from farm to fork'.

Farmers' seed systems and participatory breeding

Farmers' access to seeds of high quality – with traits that match the local environment and consumers' demands – is central to agricultural development. The formal seed system, run by government agencies and private companies, is providing such services, primarily with a focus on staple crops. However, farmers' informal seed systems are also important.

Farmers' traditional informal seed systems may dominate in some areas, particularly in marginal areas, such as the Sahel region of West Africa and the mountain region of the Hindu Kush, where local seed sources may be the only option for many underutilized species. Farmers may prefer local diversity to monocultures of high-yielding varieties and grow a blend of robust, local crop varieties that are selected for traits such as drought tolerance or pest resistance, or for a specific local cuisine. This diversified approach acts as insurance against biological or climate-related risks.

Local diversity is the product of household-level selection and exchange between farmers. These seeds tend to be sourced via social networks, where custodian farmers play a key role. Such informal seed systems are important complements to the formal, modern seed system. They are key to farmers' management of genetic diversity, and they tend to be more resilient in coping with adversity.

Seed systems have multiple functions: they provide a germplasm base for a diverse and flexible selection. They ensure production of good-quality seeds of sufficient quantity, with attention to germination and seed health. They ensure the availability and distribution of seed through seed sources, networks and markets. And they maintain knowledge and information, including growing methods, utilization, traits and trade-offs. Informal and formal seed systems have different strengths and weaknesses regarding these functions.

Scientists have recently taken a deeper interest in participatory processes for enhancing local landraces of staple crops and of neglected and underutilized species. Methods such as participatory plant breeding and varietal selection have proved successful. For example, in Nepal, an enhanced local aromatic rice landrace (Jethobudho) was formally approved for release in 2006, after such a participatory process.

Community-based methods of assessing biodiversity, such as the four-cell analysis used in South and Southeast Asia, or 'seed fairs' and 'diversity field Fora' in the Sahel, can help improve seed systems and increase the use of local diversity. Such methods help scientists understand farmers' local knowledge of seeds and their rationale for using diversity, or they can help identify issues that need to be addressed. These methods can identify and re-introduce rare varieties and improve farmers' access to good-quality germplasm. The consumer's awareness of agrobiodiversity can also be enhanced this way.

Enhancing farmers' local seed systems will also be critical to adapting to climate change. Under a scenario of climate change and variability, the 'area suitability' of varieties and species might change dramatically. Seeds will need to be moved over larger distances – beyond today's social seed networks. Preparedness for such shifts is urgently needed, and might call for stronger linkages between formal and informal seed systems.

Main learning points

- To appreciate the strengths and weaknesses of the formal and informal seed systems
- To be familiar with the key features of farmers' traditional informal seed systems and to describe their strengths and weaknesses
- To be familiar with the methods and typology used for participatory plant breeding and varietal selection
- To know about key participatory methods for assessing and enhancing local agrobiodiversity
- To be able to discuss how climate change and variability might influence local seed systems and the links between formal and informal seed sources

Contents

- Formal seed systems
- Informal seed systems
- Custodian farmers and household-level selection and exchange between farmers
- Risk management versus high productivity
- Participatory plant breeding and varietal selection
- Methods for participatory biodiversity assessment and enhancement
- Climate change and seed systems

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- Bioversity International, Training materials, Seed handling in genebanks: self-learning module: www.bioversityinternational.org/training/training-materials/seed_handling_in_genebanks_self_learning_module.html
- Alliance for a Green Revolution in Africa (AGRA), Programme for Africa's Seeds Systems (PASS): www.agra-alliance.org/section/work/seeds
- Kew Royal Botanic Garden, Difficult Seeds Project: www.kew.org/science-research-data/kew-in-depth/difficult-seeds/index.htm

On-farm conservation and management of agrobiodiversity

Introduction

This topic aims to develop an understanding of how farmers conserve and manage agrobiodiversity on farms, the challenges they face in doing so and the opportunities that emerge for supporting such efforts.

As mentioned earlier in this Guide, over centuries, farmers have domesticated a rich diversity of landraces and local breeds. The centres of diversity that have emerged hold important parts of the genepools of agricultural species. On-farm conservation has been defined as "the continuous cultivation and management of a diverse set of populations by farmers in the agroecosystem where a crop has evolved" (Bellon et al. 1997). The continued evolution and adaptation of a species, including adaptation to climate change, thus depend on continuous on-farm conservation and management.

Local varieties are rapidly disappearing from farming systems globally as a result of the expansion of modern high-input agriculture, and other drivers. Efforts to

conserve disappearing landraces in genebanks are important but not sufficient. There are gaps in genebank collections, and genetic erosion can occur. Ecological processes can only be maintained in agroecosystems. *Ex situ* conservation must be complemented by both *in situ* and on-farm conservation, in managed agricultural production systems. The environmental services that farmers thus provide to the global community are important but might require specific incentives, rewards or compensations to be sustainable.

There are many reasons why farmers might prefer a diversity of landraces and NUS to modern varieties. This may be particularly so in rain-fed systems in marginal areas with highly variable environmental conditions. Here, managing risk by using a broad range of varieties and species can often be more important than high yields. Resource-poor farmers who can ill afford high inputs of seeds, fertilizers or irrigation might have no option but to use local seed sources. Culture and traditions can also be strong drivers for managing diversity on farms. Other processes, too, can contribute to the diversification of agriculture, such as promotion of the health and nutritional aspects of a more diverse diet.

Additionally, farmers' livelihood strategies include many products from wild species in adjacent ecosystems, including forests and woodlands. Because of the increasing pressure on natural ecosystems, many such species are now being moved from forests to farms. The expansion of agroforestry systems and the cultivation of medicinal plants previously collected from the wild are expressions of this trend.

Crop wild relatives are important for sustaining natural adaptation and evolutionary processes, and also as a source of traits that can be incorporated into breeding programmes. Often neglected in conservation strategies, crop wild relatives are elements of the agricultural landscapes farmers manage, but might not have any immediate value to them. Incentives and subsidies of various kinds, such as payments or rewards for environmental services, may be required for their *in situ* and on-farm conservation. Farmers thus play important roles in managing diversity not only in their fields, but also in adjacent 'wild' ecosystems. A landscape approach to conservation is required to cover interactions across fragmented agricultural landscapes.

In terms of improving on-farm management of agrobiodiversity, conventional methods such as crop improvement or seed-sector development may not suffice. A set of participatory tools has emerged that can be used to assess and enhance farmers' management of agrobiodiversity, such as the '4-cell analysis', which helps document unique, common and rare varieties or species cultivated in a community.

In conclusion, farmers are custodians of agrobiodiversity and the local knowledge about this diversity – a role that needs to be better recognized, nurtured and rewarded.

Main learning points

- To define the term 'on-farm conservation'
- To understand farmers' rationale for managing diversity on farms
- To explain how on-farm conservation complements *in situ* and *ex situ* conservation
- To understand the role of farmers in conserving crop wild relatives
- To understand why incentives and subsidies might be required to stimulate the conservation and management of genetic diversity in agroecosystems

Contents

- Domestication processes and the emergence of landraces in centres of crop diversity
  - Continued adaptation and evolution
  - Genetic erosion
- On farm conservation
  - Definition
  - Roles
  - Private and public benefits
- Wild species and crop wild relatives
  - *In situ* and on-farm conservation of crop wild relatives
- The role of farmers in conservation strategies
- Participatory tools for studying and enhancing community-based biodiversity management

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Internet resources

- Bioversity International, Training materials: www.bioversityinternational.org/training/training_materials.html
- Crop Wild Relatives Global Portal: www.cropwildrelatives.org
- Southeast Asia Regional Initiatives for Community Empowerment (SEARICE): www.searice.org.ph

Value chains of neglected and underutilized species

Introduction

This topic aims to explain how enhancing value chains, especially for neglected and underutilized species (NUS), could contribute to increased farmer income and agricultural diversification.

An effective value chain for an agricultural product depends on a large number of actors: seed producers, farmers, processors, traders, wholesale and retail dealers and others. The information flow among these actors is critical for decision making. Organizations such as farmers' associations, extension services and bodies that promote exports facilitate trade and commerce. Policies play a key role in creating incentives or removing disincentives.

The main commodities have well-developed value chains, often with specialized actors. In contrast, the commercialization of NUS is often hampered by weak value chains that constrain production, processing, marketing and consumption.

The potential for commercializing NUS is substantial, given the sheer number of plants used for food around the world. In tropical Africa alone, over 800 species of vegetables have been recorded. Recent successes in developing the value chains of NUS include leafy vegetables in Kenya, quinoa (an Andean grain), farro (an ancient wheat variety in Italy) and the participatory domestication of tropical fruits such as *Dacryodes edulis* in West Africa.

Reviving the interest in traditional, nutritious food among urban consumers in developing countries holds potential, but there is also a growing global market for exotic, organic and fair-trade products that provides opportunities, especially by extending well-developed national value chains. Uniform quality, regular supply, attractive packaging and attention to food safety are essential for accessing such markets and particularly for entering the supermarket's growing share of the food market.

The participation of small-scale farmers in markets for NUS requires that a number of constraints related to both the supply side and demand side of the value chain

be addressed. Supply-related constraints include a lack of varieties with defined characteristics, poor shelf life, narrow adaptation to growing environments, low yields and deficient agronomic practices. Demand-related constraints include the lack of processed convenience products, lack of consumer awareness of nutritional and other consumption benefits, and reputational problems ('the food of the poor' – a perception that has contributed to their abandonment in favour of exotic foods). Efforts to develop the value chain of NUS typically have to address many of these factors simultaneously, and bring down marketing costs by increasing efficiencies and facilitating the flow of information along the chain. Similar development of the value chains may also be important for the production and marketing of major crops by small-scale farmers.

The process of developing the value chain could have different starting points, but it commonly begins with an assessment of market opportunities, including consumer surveys. This can be compared with supply opportunities, such as an inventory at farmers' level of varieties with preferred taste and appearance, and an evaluation of agronomic aspects, such as seed quality, uniformity of production and management practices. Constraints are then addressed through a participatory process involving key stakeholders, for example, by variety selection and participatory breeding, and the improvement of the seeds and seed distribution. Post-harvest handling and processing might need attention, for example, by developing appropriate technologies that reduce losses or labour inputs. Attractive packaging might need to be developed. Storage facilities that improve the shelf life and serve as distribution hubs are required in order to provide a regular supply of sufficient quantities. Attention to hygienic aspects and food safety is essential throughout.

Wholesale and retail actors, supermarkets in particular, need to be involved in the process. In the case of leafy vegetables in Kenya, promotional campaigns to raise awareness among urban consumers of their health and nutritional benefits were part of their successful launch in supermarkets. Issues of market access might also need to be addressed, such as uniformity and food safety, or legal obstacles, such as food regulations in several countries, notably in the European Union.

Market information is critical for farmers' decisions. Schemes that use mobile phones for providing market information have become successful in some countries, a technology that is rapidly improving farmers' access to information. Finally, financing mechanisms, such as micro-credit and other approaches, might also need strengthening.

Enhancing value chains of NUS can contribute to increased income, awareness in society of the value of agrobiodiversity, and a diversification of both agricultural and food systems. Experience shows that such efforts can empower male and female farmers, processors and traders.

Main learning points

- To understand the processes, components and actors of the value chain for key NUS and how these differ from value chains of main staple crops
- To be aware of the potential for commercialization of NUS and familiar with recent examples of strengthening their value chains
- To be able to identify supply-side constraints to value-chain development and to identify opportunities to improve the functions of value chains of (target/key) NUS
- To be able to analyse demand-side constraints to value-chain development and to identify opportunities to improve the functions of value chains of (target/key) NUS
- To understand the social and cultural dimensions of value chains, including stigmas, and labour and gender aspects
- To understand the role of information, awareness and promotion for realizing the potential of agrobiodiversity value chains
- To understand the role of participatory, multi-stakeholder processes in enhancing value chains
- To be aware of policy, institutional and organizational aspects of value-chain enhancement

Contents

- Concepts of value chains for agrobiodiversity
  - Differences between staple crops and NUS value chains
- Agronomy of NUS
  - Seed systems and seed quality
  - Genetic variation
  - Production technologies (traditional/new)
- Post-harvest processing
  - Value addition, technologies
  - Packaging
  - Storage
  - Transport
- Marketing
  - Standards and labelling
  - Wholesale and retail
  - Role of consumer awareness
  - Role of partnerships with private sector, NGOs, etc.
- Policy and legal aspects
  - Food safety
  - EU food regulations
- Small-enterprise development

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- The World Vegetable Centre (AVRDC): www.avrdc.org

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