Curriculum Guide on Neglected and Underutilized Species

Combating Hunger and Malnutrition with Novel Species

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Cover photos: Woman cutting amaranth leaves for cooking in Barotse, Zambia (front). Grain amaranth in the field, Barotse, Zambia (back). Credit: E.Hermanowicz/Bioversity International

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Dedication

This publication is dedicated to the Late Professor Kiarie Njoroge (pictured).

Professor Kiarie Njoroge of the University of Nairobi, Kenya, passed away in October 2015, barely three weeks after making very substantial contributions to the workshop on the development of this curriculum document, held 22-25 September 2015.

Prof. Njoroge taught at the Department of Plant Protection and Crop Production, University of Nairobi. Earlier, as a maize breeder and seed specialist at the Kenya Agricultural Research Institute, he coordinated the Kenya National Maize Research Programme for 15 years.

Prof. Njoroge dedicated part of his later career to promoting neglected and underutilized species (NUS) in Kenya and beyond. His contributions were significant. Since 2009, he was the focal person at the University of Nairobi for two consecutive projects under the Africa, Caribbean and the Pacific Group of States (ACP)—the European Union (EU) Science and Technology Programme, aiming at enhancing the capacity of scientists to conduct research on, and develop value chains of NUS in sub-Saharan Africa.

In 2010, he led a national study on 'The Potential to Enhance Conservation and Use of Neglected and Underutilized Crop Species in Kenya'. In the same year, he hosted a regional workshop to set priorities for the selection of NUS in Eastern and Southern Africa and to identify research needs. He served on the Scientific Committee of the 3rd International Conference on Neglected and Underutilized Species for a Food-Secure Africa, held in Accra, Ghana in 2013.

In Kenya, he organized a National Stakeholder Workshop in 2014 that analyzed constraints in the value chains of Bambara groundnut and amaranth and identified needs and opportunities for upgrading their value chains to develop nutritious NUS-based products for consumers. At the time of his demise, he was writing a National Action Plan to communicate the results of this work to stakeholders in Kenya.

Preface

In an increasingly globalized and interdependent world, eradicating hunger is a prerequisite for peace and world security. Achieving food and nutrition security for all while sustaining the environment will be particularly challenging in Africa, where the human population is projected to double to 2.5 billion by 2050. A sustainable intensification of smallholder production systems embracing a holistic, ecosystems approach to agriculture, will be needed. This changed paradigm will also use agricultural diversification in its 'tool box'.

Across the globe, consumers are showing a growing interest in their local food culture and a curiosity about exotic food that is readily available in many supermarkets and specialty stores. Ironically, while a rich diversity of local food is available virtually at our doorstep, mainstream agriculture programmes—and agricultural education—have for decades focused on increasing yield in just a few staple crops and high-value commodities. Due to this long neglect, the diversity of local or exotic food is not being used to its full potential, in spite of the nutritional, socio-economic and environmental benefits it might bring. Fortunately, consumer attitudes are slowly turning in favour of agricultural and dietary diversity.

The body of knowledge on neglected and underutilized species (NUS)—in particular of crop species—has steadily increased in the past two to three decades thanks to research and development efforts by organizations such as Bioversity International and Crops For the Future (including its predecessors, the International Centre for Underutilized Crops and the Global Facilitation Unit for Underutilized Species), as well as by universities in the North and South. However, investments in developing higher education courses and programmes that cover such species have been lagging behind. Indeed, the teaching of agricultural biodiversity is weak generally, both in agricultural and in natural resource conservation programmes. The resulting capacity gap is a constraint to both research and the scaling-up of innovations on NUS.

The project *'Strengthening capacities and informing policies for developing value chains of neglected and underutilized crops in Africa'* is supported by the ACP-EU Science & Technology Programme from 2014–2016, with co-financing

by the project partners[1]. The project's vision is that enhanced value chains of NUS in Africa will contribute to improved food and nutritional security, income of smallholder farmers and entrepreneurs and mitigation of, and adaptation to climatic, agronomic and economic risks. To this end, a key project output is '*strategies and tools for integrating NUS into higher agricultural education curricula agreed with universities and technical colleges, and shared through African educational networks*'. The curriculum presented here is a tool for achieving this goal.

The objective of this curriculum guide is to introduce NUS into higher education curricula—using the examples of fruits and nuts, vegetables, rodents and insects. We are convinced that students of agriculture and other related disciplines in both social and biophysical sciences would benefit from having a basic understanding of what these species are, how they are used and how they can make a difference in the fight against poverty, hunger and malnutrition. Students would learn how these species can form profitable value chains and be a business opportunity for graduates. The curriculum guide targets educational institutions from the vocational to the academic level. We invite teaching institutions to collaborate and also assist in further improvement of this curriculum.

1 The project is implemented by a partnership consisting of Bioversity International (Coordinator); Africa University, Zimbabwe; African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE), Kenya; International Foundation for Science (IFS), Sweden; Laboratory of Agricultural Biodiversity and Tropical Plant Breeding (LAAPT), Benin and University of Nairobi, Kenya.

Acknowledgement

The development of this curriculum was a collaborative effort led by the African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE) in close partnership with Bioversity International.

The two organizations co-organized a curriculum development workshop in Nairobi held 22-24 September 2015, followed by a curriculum 'write-shop' held 25-26 September 2015. The two events brought together various specialists and stakeholders who all contributed and made valuable inputs in the content of this curriculum guide.

The participants came from: Africa University, Zimbabwe; ANAFE, Kenya; AVRDC—World Vegetable Centre, Tanzania; Bioversity International, Italy; Egerton University, Kenya; Excel Hort Ltd., Uganda; Federal University of Technology, Akure, Nigeria; Global Horticulture Initiative, Germany; International Foundation for Science (IFS), Sweden; Kenyatta University, Kenya; Laboratory of Agricultural Biodiversity and Tropical Plant Breeding (LAAPT), Benin; Nyabyeya Forestry College, Uganda; Sokoine University, Tanzania; University Abomey-Calavi, Benin, and; University of Nairobi, Kenya (see list of participants).

The organizers sincerely thank all the above-mentioned contributors for their excellent input. We also express our gratitude to Prof. August B. Temu, former Deputy Director General of the World Agroforestry Centre (ICRAF), who facilitated the curriculum development process and assisted in the drafting of this curriculum.

Finally, we are grateful to Richard Hall, Ewa Hermanowizc, Thomas Dubois, Gennifer Meldrum, Stefano Padulosi and Tsvetelina Stoilova who reviewed draft versions of the curriculum guide and made valuable suggestions that made this a better curriculum guide.

Special thanks are directed to the ACP Science & Technology Programme and the European Union for the financial support provided.

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Introduction

1.1 What are neglected and underutilized species?

Neglected and underutilized species (NUS) are useful species of plants, animals, fungi, insects and fish, to which little attention is paid or which are largely overlooked by researchers, educators, breeders, extensionists and policy makers. Some of these species have been domesticated by local communities, others are gathered from the wild, but their cultivation and wider use are constrained by the lack of awareness, poor investment in their development, and insufficient human and institutional capacity, among other factors.

For plants, the improved conservation and use of NUS has been on the international agricultural agenda for over two decades. It was included in the first FAO Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture (FAO, 1996). Based on collaborative activities at national and international levels and a series of monographs on selected, underutilized plant species, a strategy on NUS was developed in 1999 by the International Plant Genetic Resources Institute—now Biodiversity International (Padulosi et al., 1999). In a similar fashion, the World Agroforestry Centre developed an approach to participatory domestication of tropical fruit tree species (Leakey and Tchoundjeu, 2001). While drawing extensively on these experiences from promoting underutilized crops and trees, this document also seeks to broaden the perspective to include other kinds of species, including animals and insects—many of the same principles apply.

NUS tend to be managed within traditional systems using informal seed or germplasm sources. Their processing can be laborious, grading and packaging primitive and the products marketed locally with limited or no involvement of

large enterprises or agricultural service providers. In most countries, agricultural statistics and research do not include NUS.

The potential of certain NUS can be realized and their value chains upgraded through concerted efforts by research, development, business and policy actors. Such is the case, for example, of quinoa, an Andean grain that was little known a decade ago but today is available in supermarkets globally, Baobab (*Adansonia digitata)* and moringa (*Moringa oleifera*) products from Africa have recently entered European and American markets thanks to efforts by researchers and the private sector to make known their food and nutritional values, overcome trade barriers and upgrade value chains. These have 'graduated' to become Nutritious Useful Species!

1.2 Why neglected and underutilized species are important

Our food system is increasingly dominated by a suite of truly global crop plants. Of these, various species and varieties of rice, maize and wheat contribute more than half of the world's food energy. Other crops are important locally, such as teff (*Eragrostis tef*) in Ethiopia. A broad study of food sources in 152 countries found that the top commodities contributing to 90% of total protein, fat, energy and weight supply in each of those countries belonged to a total of 94 species (Khoury et al., 2014). By comparison, a review of several global plant lists estimated that there are just over 4,000 edible food-plant species globally (Serban et al., 2008). Another estimate lists 7,000 wild or cultivated food plant species (Wilson, 1992).

While the national and international agriculture systems continue to focus on the truly global food species, there is also a parallel trend that brings agricultural diversity to the fore as tools for sustainable agriculture. Underutilized plants—crops as well as trees—animal species and breeds (Philipson, 2011), fish and insects are today receiving increasing recognition.

The role of NUS can be seen in five critical development areas, summarized below: i) conservation of biodiversity; ii) climate change adaptation and mitigation; iii) food and nutrition security; iv) job creation and income generation; and, v) culture, gender and women's empowerment. The extensive work done by Bioversity International and its partners documents these roles in greater detail (Padulosi et al., 2013; Padulosi et al., 2014).

Conservation of biodiversity

The NUS constitute a large gene pool of wild, semi-domesticated and domesticated species, including their wild relatives. This valuable part of the world's agricultural and forest biodiversity constitutes the subset of biodiversity of importance to food, medicine and for many other products and services for human utility and the environment. As such, this gene pool falls under the United Nations Convention on Biological Diversity (CBD). Knowledge of NUS diversity at ecosystem, species and within-species levels is highly relevant to agricultural and environmental conservation professions. Future agriculture is likely to benefit from enhanced gene pool and additional food and nutrition from NUS.

The conservation *in situ* and on farms of NUS is critical to species' and varieties' continued evolution and adaptation to changing conditions, and to the sustainability of agricultural ecosystems. Often, this requires conservation through use, which not only preserves the genetic resources but also the traditional knowledge about these species. The local food culture helps to conserve species and varieties *in situ* and on farms—conservation through use. This is particularly important because NUS are currently poorly represented in germplasm collections.

Climate change adaptation

Rural communities increasingly need to adapt their agricultural systems to climate change. The crops varieties and animal breeds they currently maintain are challenged by increasing temperature, changing rainfall patterns and shortening growing periods. The crop species and varieties farmers have access to today may not be fit for tomorrow's climate. Diversifying agriculture by promoting and expanding the use of NUS can contribute to adaptation strategies, and to increasing resilience of natural and socio-economic systems.

Many NUS are adapted to marginal growing conditions including poor soil, low water availability, intense drought, frost, and flood risk areas. For this reason, they can play a role in mitigating risks and enhancing resilience of agricultural production systems. Forest-based food sources also serve as a buffer at times of food shortage. NUS could improve harvest security in diversified production portfolios, or substitute for staple crops or major breeds that might not fit in hotter and dryer climate conditions.

Forests and forest biodiversity, including NUS, also provide carbon sequestration along with other environmental services such as clean water. Locally-adapted NUS also have greater water-use efficiency and lower requirement for inputs, which can also help mitigate climate change.

Food and nutrition security

Two diet-related problems—mal/under-nutrition and over-nutrition—affect the quality of life of more than two billion people globally. In many poor communities especially, women and children suffer from low caloric food intake and a deficiency in micro-nutrients and minerals. Simultaneously, there is a rapid transition from traditional diets based on local foods to a 'Western-style' diet, high in fats, salt and sugar but low in fibre and micro-nutrients. The dietary change is linked to raising rates of overweight and obesity and increased incidence of non-communicable diseases, such as diabetes, heart diseases and certain types of cancer.

A diverse diet that includes a healthy proportion of fruit and vegetables can help in addressing both problems. Many NUS have nutrition profiles that compare favourably to those of the major staples and can contribute to food and nutrition security at local and regional levels and to improving human health. Their ability to adapt to stressful growing conditions makes these crops particularly important assets for sustainable intensification of agriculture in marginal lands.

At the national level, NUS can strengthen a country's food and especially nutritional security, if they are promoted more broadly. Some NUS are high in carotenoids and minerals and therefore could play a role in helping to improve the micro-nutrient content in the diets of millions of people and animals around the world. Many of the species under consideration also have medicinal and plant protection benefits, which are valuable for health as well as environmental protection.

Job creation, income generation and value chains

Improving the production, quality and sales volume of NUS products, especially in high-value crops and trees such as fruits and vegetables, can increase the income of small-scale farmers and entrepreneurs. This opportunity to create

new jobs in the agricultural sector is one of the benefits of NUS. Given that many NUS are largely traded in local markets today, this requires upgrading of value chains to eliminate or reduce constraints and bottlenecks and identify new market opportunities.

Strategic interventions to that end could, for example, involve making NUS more commercially competitive by developing improved 'modern' varieties and breeds, by marketing local varieties in high-value niche markets for organic, fair trade food, or by developing new innovative products based on NUS. Markets can be developed through strategic placements of NUS in large commercial outlets, such as supermarkets catering for urban populations. Stimulating consumer demand for, and knowledge about NUS is important; this would contribute to changing a common perception of NUS as 'food for the poor'.

Culture and gender

Communities' knowledge of local ecosystems and food sources has evolved over generations, often with distinct gender roles. Traditional food systems are intertwined with the cultural identity of rural communities and NUS play a key role.

Today, the on-going rapid demographic and cultural change is often accompanied by a disappearance of NUS crops and loss of the cultural and traditional knowledge associated with the local food system. Indeed, NUS can suffer from a stigma as 'food for the poor'. But attitudes can change with the right kind of promotion and awareness. Efforts to conserve, promote and improve traditional food systems are a powerful way to safeguard local genetic resources while empowering women and men who are involved in the growing, processing and trade of the products they generate. The cultural link of NUS can sometimes add value through labels such as Geographic Indication or Fair Trade.

1.3 Examples of Underutilized Species

As indicated above, the number of NUS is very large. In Table 1, we share some examples of priority NUS of plants and animals.

Table 1: Examples of NUS food species

Fruits and nuts	Lychee (*Litchi chinensis*)
Baobab (*Adansonia digitata*)	Okari nut (*Terminalia kaernbac*hii)
Cashew nut (*Anacardium occidentale*)	Passion fruit (Passiflora edulis)
Cherimoya (*Annona cherimola*)	Persimmon (*Diospyros kaki*)
Guava (*Psidium guajava*)	Pistachio (*Pistacia lentiscus*)
Jackfruit (*Artocarpus heterophyllus*)	Soursop (*Annona muricata*)
Jujube (*Ziziphus mauritiana*)	Sugar plum (*Uapaca kirkiana*)
Loquat (*Eriobotrya japonica*)	Tamarind (*Tamarindus indica*)
Vegetables and pulses	Fluted gourd (*Telfairia occidentalis*)
African locust bean (*Parkia biglobosa)*	Indian poke **(***Phytolacca acinosa)*
African yam bean (*Sphenostylis stenocarpa*)	Kersting's groundnut (*Macrotyloma geocarpum*)
Amaranth (*Amaranthus sp.)*	Prickly pear (*Opuntia sp.)*
Bambara groundnut (*Vigna subterranea)*	Roselle (*Hibiscus sabdariffa)*
Black nightshade (*Solanum nigrum)*	Spider plant (*Cleome gynandra*)
Cowpea (*Vigna unguiculata*)	Tomatillo (*Physalis philadelphica)*
Drumstick tree (*Moringa oleifera)*	Velvet bean (*Mucuna sp.)*
Ethiopian kale (*Brassica carinata)*	Water spinach (*Ipomoea aquatica)*
	Yellowcress (*Roripa indica)*
Roots and tubers	Elephant ears/taro/cocoyam *(Colocasia esculenta)*
Aerial yams (*Dioscorea bulbifera)*	Livingstone potato (*Plectranthus sp*)
Arrow roots *(Colocasia spp.)*	*(Xanthosoma sp)*
Bitter yam (*Dioscorea dumetorum*)	

Cereals and pseudo-cereals

Buckwheat *(Fagopyrum esculentum)*

Finger millet *(Eleusine coracana)*

Fonio *(Digitaria exilis)*

Grain amaranth *(Amaranthus caudatus)*

Indian barnyard millet *(Echinochloa frumentacea)*

Proso millet *(Panicum miliaceum)*

Quinoa *(Chenopodium quinoa)*

Tef *(Eragrostis tef)*

Animals

Guinea pig *(Cavia porcellus)*

Giant African rat (*Cricetomys gambianus*)

Grasscutter or cane rat (*Thryonomys swinderianus*)

Insects

Agave worms (*Hypopta agavis)*

Mopane worms (*Gomimbrasia belina)*

2

Upgrading Value Chains of Neglected and Underutilized Species

The concept of value chain was coined by Michael Porter (1985) to analyze and evaluate how primary and secondary activities in an organization can maximize the value offered to customers, and add to the firm's profitability. A special consideration is the management of the links between key activities so as to achieve synergy in the system.

When applied to agriculture and natural resources, four key processes are involved in a generic value chain, as shown in Figure 1. These processes are supported by agricultural, technical or financial service providers. The value chain is operating within a business environment that involves policies, rules, regulations, etc., which may enable or hinder its effective functioning.

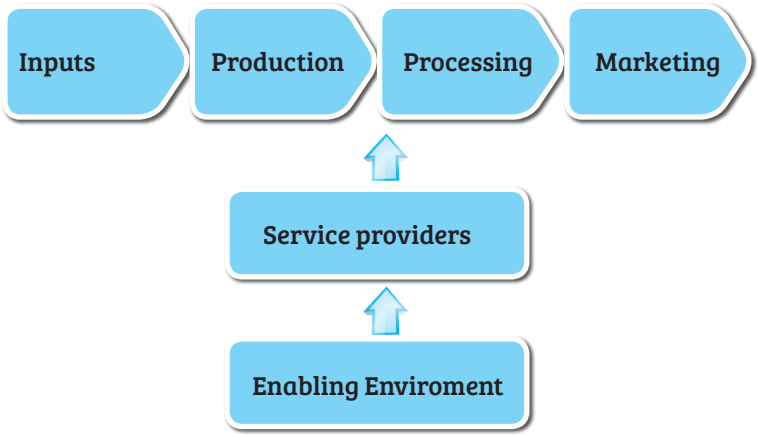

Figure 1: A typical agricultural value chain

The value chains of neglected and underutilized species differ in many ways from those of staple crops such as rice or maize, or commodities like tea or coffee. NUS value chains are often localized and informal and have low degree of sophistication or value addition. They lack dedicated organizations. Also, they usually receive no particular policy support (like, for example, the subsidies for main staples).

Common constraints to NUS value chain development are related to:

- Consumer awareness and demand: NUS are often viewed as 'food for the poor' and consumers may not be aware of their dietary benefits.
- Product quality and regular supply: Meeting quality demands at local, national and international levels, and meeting volume requirements (assurance of regular supplies of sufficient quantities) are common issues.
- Marketing and product development: The current status of a NUS market is often unclear and restricted to the local communities currently using them. Expanding these markets requires efforts to make the products attractive to urban consumers, and marketing and branding efforts to popularize them among local and international consumers.
- Seed/germplasm quality and access: The cultivation of NUS can often be constrained by poor access to quality seed or germplasm with desired traits, or by limited reach of the informal seed systems that many NUS rely upon. Private seed companies may stay away from NUS due to low volumes.
- Lacking or insufficient supportive infrastructure at all levels from production to processing and marketing: How can currently available structures for agricultural products be improved or adapted to cater for meeting NUS needs? Our analysis should range from physical infrastructure to institutional structures and cover as well as functionalities and human resources.

A typical example of research and development activities to upgrade a NUS value chain is shown in Figure 2. A key step in the process is to understand the available genetic diversity—a key input into the value chain. This involves work on germplasm collection, characterization, improvement, propagation and multiplication before investing in commercial production. At the tail end of the value chain is the final use—the consumers who use or buy the products generated. Understanding consumers' demands and behavior is a prerequisite for a value chain project.

Importantly, the whole value chain needs to be in focus, since only addressing one constraint may not suffice. Often, several bottlenecks need to be tackled simultaneously; coordinated solutions are the key for a good result. Each step in the value chain has its specific challenges, some of which require research solutions. Both technical and social processes need attention. To do all these, we need both human and institutional capacity regarding the species and the processes involved.

When upgrading a NUS value chain (which first may have been selected according to some priority setting criteria), one must understand the social, cultural and economic aspects involved. A stakeholder analysis is necessary to identify the key actors involved and their roles in the value chain. A multi-stakeholder 'innovation platform' of those stakeholders can then be created, which jointly analyses constraints and opportunities and agrees on an action plan for upgrading the value chain as a whole. The innovation platform—usually involving all stakeholders—would typically need to work together for a period of time (over several years) to monitor progress and continuously calibrate its approach. Developing capacity to facilitate such innovation platforms is hence a priority. Examples of questions that the innovation platform might tackle could be:

- How can NUS producers become more effective and capture new market opportunities? What do they need to change compared to current practice?
- What policies and actions are needed to create expanded opportunities for NUS products? How could such policies and programmes be supported?
- How to influence all stakeholders in the NUS value chain (e.g. producers, traders, processors, distributors and retailers, as well as researchers and trainers) and facilitate their collaboration.
- What capacity development actions will be needed and how could this be provided?

NUS value chain approach

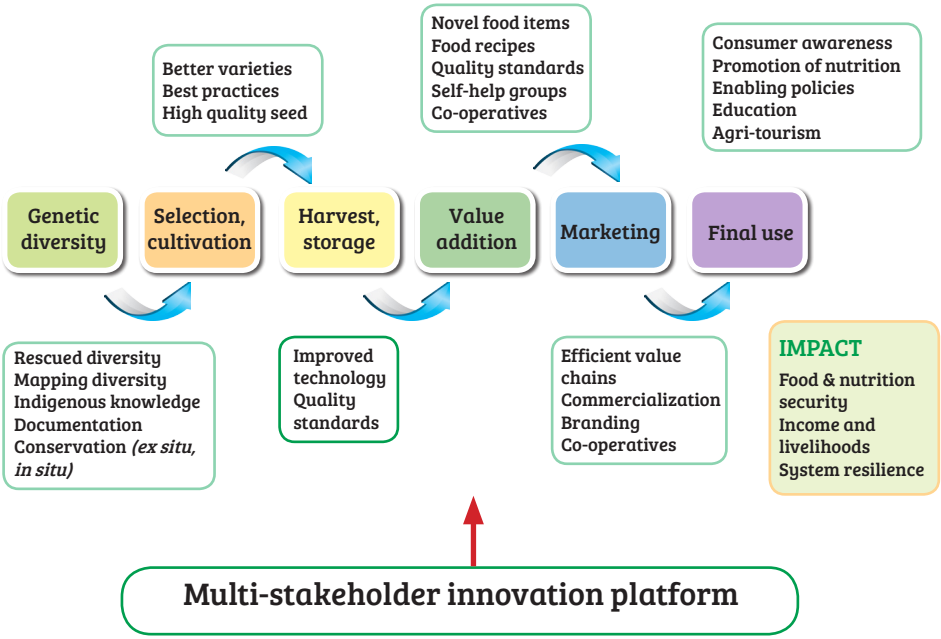

Figure 2: Activities to upgrade value chains of NUS (Source: (Padulosi et al., 2015)

The Necessity of Education on Neglected and Underutilized Species

3.1 Demand for human and institutional capacity

The major staple crops and commodities dominate agricultural education and are the mainstay of national agricultural and forestry research and development, and agribusiness. Currently, training on NUS receives very little attention in vocational, technical and professional training institutions. Thus, it is difficult to find experts to build the capacity for policy, research, development, private sector business and to advise farming communities on conserving and using NUS.

Education on NUS will enable the formation of scientists, development specialists and technicians needed to address the challenges related to NUS and to facilitate integration of these species into agriculture, natural resources management and agribusinesses practices. These challenges often require a systems perspective, due to their multi-disciplinary nature. Building capacity to facilitate such systems thinking is particularly important, but might require discipline-oriented educational programmes to change their teaching and learning approaches. Other issues can be more technical such as improved harvesting or processing machinery, upgrading post-harvest facilities, or improving seed storage and seed handling. Still, it is important that students learn that such efforts must take place in the light of upgrading the entire value chains of target NUS.

With regard to institutional capacity, it is recognized that there is a gap in both policy and practice when food security is interpreted as fulfilling specific levels of carbohydrates and proteins only. This view has driven agricultural development towards expansion of farming areas as well as genetic manipulation to increase

the productivity of specific high-yielding varieties of cereals and animals. It is important to also consider food species and varieties that can meet nutritional requirements, especially minerals and vitamins. The recent recognition of nutrition security as important and complementary to food security has changed the old perspective—and that brings NUS to the food and nutrition security debates.

The current structures of most research and education institutions lack entities to deal with such species specifically. There is therefore a need to develop policies and provide support (financial, personnel and facilities) that enable educational institutions to develop departments/sections that are capable of dealing with underutilized crops.

Financing institutions also do not understand or prioritize the development of such species. The world is coming to the realization that NUS are indeed important complements to the species that are currently intensively cultivated. However, financial mechanisms lag far behind; a very small proportion of agricultural investment goes to underutilized species. One way to stimulate further investment in this area is through education and research, to bring out the knowledge needed and provide evidence for the roles and values of NUS for food and nutrition security and for agricultural sustainability.

3.2 Education disciplines where NUS modules could be included

The teaching and learning of NUS is relevant to a wide range of educational disciplines, far beyond the ones covered by traditional agricultural curricula. They include, for example, agribusiness; agricultural economics; agricultural education and extension; agricultural engineering; agriculture; agroforestry; biodiversity conservation; climate change; crop science; development studies; food science and engineering; forestry; home science and management; horticulture; livestock; nutrition and dietetics; pharmacology; sociology; soil science and wildlife management.

There are many opportunities to introduce elements of NUS into a wide range of curricula, especially in agriculture, horticulture, veterinary science, forestry and related fields.

NUS can be taught as an area of specialization, meaning that all Modules presented in this Guide would be taught. Alternatively, the objective could be to just expose students in the above-mentioned fields to the basics of NUS, in which case only Module 1, “Introduction to Neglected and Underutilized

Species", perhaps would be selected. Of course, the use of the Guide is highly flexible and ultimately depends on the objectives of the educational programme in question. As an example, a student doing crop protection would be expected to do Module 1 and Module 4: "Neglected and Underutilized Insects for Food and Feed".

3.3 Role of education in strategic development of NUS

There is need for a strategy to stimulate education, research and practice (including business) on NUS. A three-pronged strategy for achieving this is captured in Figure 3. Creating awareness in educational institutions is considered to be a top priority and an entry point for the development of NUS human and institutional capacity.

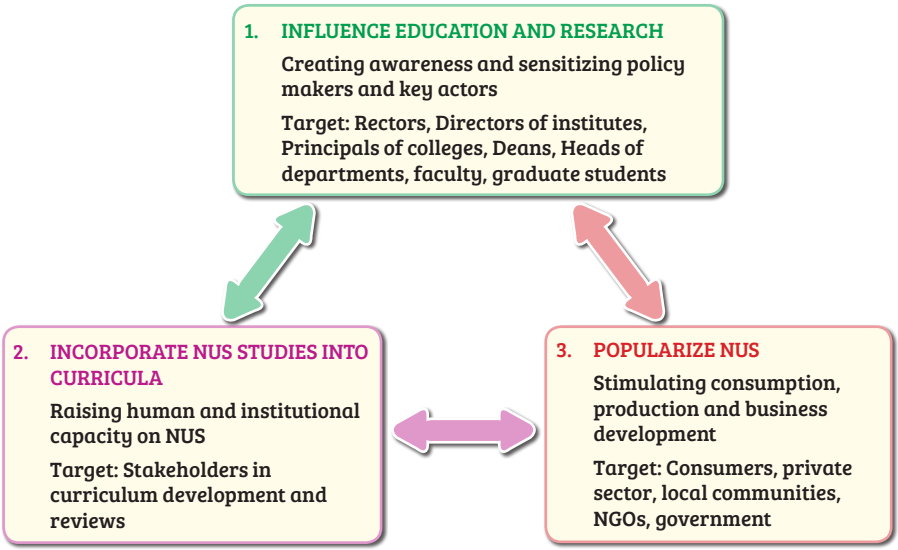

Figure 3: Stimulating education, research and practice on NUS

In Figure 3, Box 1 addresses the need to develop and share knowledge on NUS. Research and education institutions are prime movers in the development, organization and compilation of knowledge. Further, they drive the publication and sharing of knowledge and experiences. So our initial task is to convince the leaders of such institutions and especially in academia to include NUS in their work.

Box 2 is focused on producing the human capacity needed to develop the wide variety of NUS species and upgrade their value chains. The aim is to inject the learning about NUS into existing curricula and to develop the learning resources needed. Through these mechanisms, they will create the much needed human capacity to develop NUS. Box 3 takes the process to the public domain where the knowledge is applied and used to stimulate NUS production and use. Naturally, the experience feeds back into Box 1 where policy makers can incorporate the lessons learned.

The curriculum elaborated in this document is a response to Box 2 in Figure 3 (incorporate NUS studies into curricula). It is complementary and a logical follow-up of on-going efforts to inform policy makers to address hurdles in the development and teaching on NUS. It is important to note that capacity building for educators is an essential and key step in strengthening NUS education.

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Curriculum Structure and Guide

4.1 Structure

This curriculum guide presents five independent modules for teaching aspects of NUS in the context of food and nutrition security, and agricultural development and sustainability:

a) An introductory module on neglected and underutilized species as a common/prerequisite module. **Module 1: Introduction to Neglected and Underutilized Species** sets a foundation for deeper studies on species or groups of species that are targeted for upgrading of their value chains. It is recommended to make it compulsory for all students studying agriculture, forestry and related disciplines.

b) Four modules specially targeting groups of NUS species that appear to be convenient to handle together. Whereas this document only covers four such groups—fruit and nut trees, vegetables, insects and animals (rodents)—it is possible to develop many more modules to cover other groups of species such as fish, birds or fungi. Indeed, it is recommended that such modules are developed. The modules presented in this Guide are:

Module 2: Neglected and Underutilized Fruit and Nut Tree Species

Module 3. Neglected and Underutilized Vegetables

Module 4: Neglected and Underutilized Insects for Food and Feed

Module 5: Neglected and Underutilized Rodents

It is important to note that these modules do not cover the wide variety of neglected and underutilized species of plants and animals. Rather, they serve as examples and educators are expected to modify and expand the list taking into consideration local circumstances, as well as new knowledge from research.

4.2 Targeting of the Guide

This curriculum is primarily targeted at the undergraduate (first degree) level. For this reason, some indications of the weighting and methods of performance assessment are included. However, these modules can be enhanced and deepened for graduate studies or made lighter for technical and vocational training levels. For the latter, there would be greater emphasis on skills development and therefore practicum would be more dominant (not less than 60% of the indicated duration).

Modules for Learning Neglected and Underutilized Species

Module 1: Introduction to Neglected and Underutilized Species

Preamble

The promotion of neglected and underutilized species (NUS) is a recent idea developed primarily to bring out the hidden benefits from plant and animal species that are currently little known and/or poorly developed, to release their full potential for human development—food security, nutrition, health, income and environmental services. For the world's most common crops such as wheat, maize, rice and sorghum, huge amounts of knowledge have been accumulated from research and development practices. There are hundreds of varieties of these crops developed for different ecological conditions. To a lesser degree, the same is true for crops such as tea, coffee and cocoa. By contrast, NUS crops rely largely on informal seed systems. Nonetheless, with climate change, it is becoming clear that diversification of farming systems is not just desirable but imperative to reduce risks and expand future options. Already, there are environments where current crops are threatened. Some NUS crops are known to do better, and therefore learning about NUS should be encouraged if not compulsory for all students of agriculture and natural resources management programmes.

Learning objectives

On completion of this module, the student should be able to:

- Undertake a survey of neglected and underutilized species in a given location/community
- Explain the prevalence and importance of neglected and underutilized species
- Describe how a country's agricultural research and development system handles NUS, in comparison with major crops, and the challenges involved
- Make a convincing case for policy reform and decision making regarding NUS
- Apply principles and practices in the domestication of plant and animal species
- Develop a value chain analysis of a given species and its products

Indicative Module duration: 80 hrs; 32 hours of theory and 48 hours of practicum

Indicative Module weighting: 2 credit units

Practicum

Laboratory: General identification and classification of neglected and underutilized plant and animal species; applied food and nutrition analysis; testing food preservation technologies.

Fieldwork: Survey of NUS in local communities; survey of NUS products in rural and urban markets; studying natural ecosystems to identify niches for different underutilized species; discussions with local extension service/NGOs on NUS practices; discussions with policy makers and implementers on NUS development challenges; developing model value chain analyses.

Assessment methods: Continuous assessments, presentation of seminars according to topics assigned to each student, grading of practicum reports, final examination.

Module synopsis

The following topics are deemed to be basic and essential for all students undertaking studies on neglected and underutilized species.

1. **Introduction to neglected and underutilized species**
    - Global, regional and local perspectives on NUS
    - Understanding challenges involved in policy capacity and funding

2. **Typology, diversity and use of NUS**
    - Examples of NUS and their uses
    - Species for food and nutrition
    - Species for biodiversity and environment
    - Species useful for pharmaceutical products
    - Species that withstand droughts, floods and pests

3. **The challenges behind the underdevelopment of NUS**
    - Genetic characterization diversity
    - Genotype, phenotype, dominance relationships, multiple alleles, gene expression, environmental effects of gene expressions, polyploidy, species formation
    - Geographical distribution and ecological niches of species
    - Knowledge management
    - Fecundity issues
    - Policy dimensions
    - Institutional capacity needs
    - Human resource capacity needs
    - Health and dietary diversification

4. **Botany and zoology principles**
    - Taxonomy
    - Classification of crops/animals by use
    - Biological plant processes, respiration, the C3, C4 pathways, photoperiodism.
    - Ethnobotany

5. Principles in domestication and conservation of NUS of plants

- Wild and landrace varieties
- Participatory processes in selecting species for domestication
- Social, cultural and economic considerations (experiences and challenges)
- Technical aspects: seed/wildlings collection and management, vegetative propagation, nursery development and management
- Disease identification and management, pest management
- Product management

6. Principles in domestication of animal species

- Animal capturing techniques
- Reproductive systems and management
- Health and nutrition
- Basic disease management
- Product preservation

7. Value chain development methods

- Principles in value chain development
- Examples of commercializing new crops e.g. the baobab fruit (*Adansonia digitata*) and *Amaranthus cruentus* for Africa
- Building capacity at different levels in the value chain
- Marketing principles and challenges
- Local markets analysis

8. Special study

Each student is assigned a species that is used in the local area but requires promotion. The student will apply principles learned to study and provide advice on the way forward.

Useful References

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Padulosi S, Thompson J, and Rudebjer P. 2013. Fighting poverty, hunger and malnutrition with neglected and underutilized species (NUS): needs, challenges and the way forward. Bioversity International, Rome.

Porter ME. 1998. The Competitive Advantage: Creating and Sustaining Superior Performance. NY: Free Press, 1985. (Republished with a new introduction, 1998). 397p.

Ucko P, Dimbleby GW. 1969. Domestication and exploitation of plants and animals. Published by London: G. Duckworth & Co., London. 581p.

Useful Web Resources

Neglected and underutilized species community: http://nuscommunity.org/

Crops For the Future: http://www.cropsforthefuture.org/

FAO's Commission on Plant Genetic Resources for Food and Agriculture: http://www.fao.org/nr/cgrfa/cgrfa-home/en/

Convention on Biological Diversity/What is Agricultural Biodiversity: https://www.cbd.int/agro/whatis.shtml

Module 2: Neglected and Underutilized Fruit and Nut Tree Species

Preamble

The dioecious (and sometimes hermaphroditic) African pear (*Dacryodes edulis*), native to the rainforests of West and Central Africa, produces fruits that are rich in proteins, fats and vitamins. For hundreds of years, the local people have used these fruits for various food and nutrition products. Despite the huge interest in the local communities in this region to propagate the species and grow it in their farms, its nature (having female and male trees that are difficult to distinguish) was a complication that limited its cultivation. Recent research by ICRAF scientists has solved the challenges involved particularly in selecting suitable trees for cultivation, identifying varieties for different tastes and processing of the fruits to produce advanced products, including bread spreads. There are many other tree species with similar and even higher economic and food/nutrition security potentials but these potentials cannot be realized unless more studies are done to solve the problems. Examples include the bush mango (*Irvingia gabonensis*), the baobab (*Adansonia digitata*), *Uapaca kirkiana* and *Alanblackia stuhlmanii*. Some work is being undertaken by ICRAF and others on these and other species, but given the longevity of trees, a lot more investment is needed in research and education.

Learning objectives

On completion of this Module, the student should be able to:

- Understand the role and importance of fruits and nuts in livelihood and development
- Explain the different categories of fruit and nut trees
- Apply his/her knowledge in the domestication and propagation of these species

- Apply his/her knowledge in the harvesting, processing and preservation of fruits and nuts
- Understand and exploit market opportunities
- Contribute to policy and strategies for promoting NUS

Indicative Module duration: 80 hrs; 32 hours of theory and 48 hours of practicum

Indicative Module weighting: 2 credit units

Practicum

Laboratory: Tree identification (morphology, bark, leaves, flowers, fruits and nuts), dissections, fruit and nut typology and preservation techniques including solar drying and canning, fruit nutrition analyses.

Fieldwork: Local community involvement in fruit and nut development activities, fruit and nut collection techniques, values and culture relating to fruits and nuts, prioritization, nursery operations, propagation activities, value chain analysis, marketing exercises, industrial processing, visits to fruit and nut markets, market analysis.

Assessment methods: Continuous assessments, term papers, grading of practicum report, final examination.

Module synopsis

1. **Introduction**
    - Key concepts of fruit trees
    - Importance of fruit trees (food, nutrition, economic importance, conservation employment, medicines)
    - Types of fruit trees (nuts, berries and drupes)
    - Nomenclature and taxonomy
    - Examples of underutilized fruits and nuts
    - Challenges facing fruit and nut trees (knowledge of abundance and potential, land races and wild varieties, availability of germplasm, propagation problems)

2. **Ethnobotanical investigation**
    - Commonly used fruits and nuts by local communities
    - Cultures and beliefs associated with uses of fruits and nuts (e.g. Kola nut and *Garcinia kola*)
    - Participatory domestication practices (including retention on farms, cultivation, propagation)

3. **Germplasm management**
    - Phenology
    - Characterization and collection
    - Molecular characterization (gene sequencing)
    - Participatory varietal selection
    - Mapping trees and location, ecosystem analysis
    - Polyploidy and polypoid fruit & nuts
    - Developing fruit and nut tree database

4. **Fruit and nut tree conservation**
    - Types of reproduction systems
    - Seed storage behavior (orthodox, recalcitrant, intermediate)
    - Diversity indices
    - *In situ* conservation
    - *Ex situ* conservation approaches (*in vitro*, tissue culture, vegetative propagation)

5. **Fruit and nut tree cultivation**
    - Edaphic factors
    - Environmental factors (altitude, climatic factors)
    - Nursery development and management, including managing diversity in nursery populations
    - Field planting and management (weeding, pruning, fertilization)
    - Diseases and pests (nursery and field)

6. **Harvesting and post-harvest management**
   - Harvesting techniques
   - Processing techniques (sun drying, juice production, grinding)
   - Managing post-harvest losses
   - Storage/preservation and storage facilities
   - Common storage diseases and pests, and control methods

7. **Nutrition properties**
   - Nutritional and health benefits of fruits and nuts
   - Determination of nutritional values of fruits and nuts (proximate analysis, phytochemical analysis, vitamin assessment and anti-oxidant properties)
   - Organoleptic test (taste)
   - Quality management

8. **Marketing**
   - Local and urban markets: consumer profiles and preferences
   - Demand and supply management (agribusiness principles)
   - Branding (integrated marketing, communication, labelling)
   - Patenting (policy, laws, intellectual property rights)
   - Transportation (for product distribution)
   - Food safety

9. **Industrial production**
   - Different processing technologies and products
   - Packaging technologies (canning, bottling, tablet production)
   - Use of preservatives (health and shelf-life aspects)

10. **Term paper**

    Each student is required to select one fruit or nut tree species or one ecological landscape in one local community, study the current status and propose the way forward. Special attention will be paid to developing a strategy for an enterprise on NUS fruits/nuts. This paper will be marked and included in the overall assessment of performance.

Useful References

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Szolnoki TW. 1985. Food and fruit trees of The Gambia. Stiftung Walderhaltung in Afrika, Bundesforschungsanstalt Forst- und Holzwirtschaft BFH, Hamburg, German Federal Republic. 132p.

Wynberg R, van Niekerk J, Kozanayi W and Laird S. 2012 Formalisation and the non-timber forest product sector: Experiences from Southern Africa. Report. CIFOR, Bogor, Indonesia. 64p. http://www.cifor.org/fileadmin/subsites/proformal/PDF/RWynberg1207.pdf

Useful Websites

World Agroforestry Centre - http://worldagroforestry.org/

PhytoTrade Africa - http://phytotrade.com/

Module 3: Neglected and Underutilized Vegetables

Preamble

Good health requires sufficient vegetable consumption in addition to meeting the needs for calories (for energy) and protein for growth and repair. Vegetables bring in the much needed minerals and vitamins to balance the body development. Adequate consumption of vegetables can promote health by preventing major diseases, such as heart disease, cancer, diabetes and obesity, as well as alleviation of several micronutrient deficiencies.

Sufficient intake of fruit and vegetables is known to have positive effects on health. The World Health organization WHO recommends a minimum of 400g of fruit and vegetables per day (excluding potatoes and other starchy tubers) for the prevention of chronic diseases.

Diversifying the range of vegetables grown and increasing vegetable consumption is a strategy adopted by all African countries according to the Comprehensive Africa's Agriculture Development Programme (CAADP). To achieve this, many locally consumed vegetables need to be assessed, developed and disseminated across the continent. This requires technical as well as economic and social considerations.

Learning objectives

Upon completion of this module, the student should be able to:

- Collect and preserve NUS vegetable species and varieties
- Develop a protocol for identification of useful NUS vegetable species and varieties
- Apply principles and develop protocols for selection of suitable NUS vegetable varieties
- Prepare a complete cultivation process for specified NUS vegetables

- Prepare and defend an applicable seed system
- Develop a strategy for identification of useful products from selected NUS vegetables
- Identify the complete set of growth stages for specified NUS vegetables
- Prepare and defend a business proposal based on products from NUS vegetable species
- Characterize the nutritional status at the household level

This module is intended to provide a platform for students to familiarize and acquaint themselves with the principles and processes employed in the exploitation of NUS vegetables. It should be delivered through lectures and practicum sessions.

Indicative Module duration: 80 hours; 32 hours of theory and 48 hours of practicum.

Indicative Module weighting: 2 credit units

Practicum

Laboratory: Identification, characterization, food and nutritional analyses, chemical analyses.

Field: Visit to local communities, including surveys of production and use of traditional vegetables; assessment of optimal growing environments, nursery operations and propagation activities; value chain analysis, marketing exercises in both rural and urban markets; visits to processing industries; discussions/ interviews on gender role in NUS vegetable value chains.

Assessment methods: Continuous assessments, term papers, grading of practicum report, final examination.

Module synopsis

1. **Vegetable genetics**
    - Genotype, phenotype, dominance relationships
    - Multiple alleles, gene expression, environmental effects of gene expressions
    - Polyploidy, species formation

2. Common NUS vegetables in the local area

- Taxonomy
- Diversity of species and varieties of local vegetables
- Botanical classification of selected vegetables
- Basic biological plant processes, respiration, the C3 and C4 pathways, photoperiodism
- Productivity under current circumstances

3. Germplasm management and documentation

- Regulatory framework for germplasm collection: national/regional/international
- Documentation required for exchange of germplasm
- Genetic and morphological characterization
- Field germplasm identification, collection and documentation
- *In situ* and *ex situ* conservation of vegetable germplasm

4. Vegetable breeding

- The need for cultivar improvement
- Pollination systems for selected vegetables
- Breeding method for self- and cross-pollinated vegetables
- Developing hybrid cultivars
- Maintenance, multiplication and distribution of vegetable varieties
- Participatory vegetable breeding
- Field experimentation, statistical data analysis

5. Seed science and technology

- Production systems for selected NUS vegetables
- Seed collection and challenges involved
- Seed testing and quality management
- Seed multiplication and storage
- Packaging and distribution of seed
- Seed intellectual property
- Regulatory framework governing seed systems
- Prepare and defend a NUS seed multiplication system

6. Agronomic aspects

- Principles of cultivation and production of selected NUS vegetables
- Ecological needs of selected NUS vegetables
- Soil requirements of selected NUS vegetables
- Appropriate land preparation for production of selected NUS field vegetables
- Fertilizer requirements
- Preparation and implementation of a protocol for selected NUS vegetables
- Good agricultural practices (GAP) for selected NUS vegetables

7. Pest and disease management

- Pests and diseases of specified NUS vegetables
- Cultural, chemical and biological disease and pest control methods
- Traditional methods for controlling pests and diseases for the selected vegetables in the local area
- Health aspects related to the use of agrochemicals

8. Nutrition and dietetics

- Determination of nutritive values of selected NUS vegetables
- Nutrient management in harvesting, packaging and transportation
- Value addition to local and international food and nutrition needs
- Impact assessment on food and nutrition security for the local population

9. Harvest and post-harvest technologies

- Determine appropriate stages for harvesting selected NUS vegetables
- Maturity indexes for a specified NUS
- Techniques of harvesting
- Appropriate packaging, storage and distribution
- Preservation methods to maintain quality

10. Economics and business

- Develop and execute a market research plan for specified NUS vegetables
- Regulatory frameworks
- Pricing, marketing and market development
- Transport management
- Gender aspects in all aspects of vegetable production and use
- Extension and communication

11. Term paper

Each student is required to select one vegetable species or one ecological landscape in one local community, study the current status of its value chain and propose the way forward. Special attention will be paid to developing an enterprise on NUS vegetable/s. This paper will be marked and included in the overall assessment of performance.

Useful References

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Sukprakarn S, Juntakool S, Huang R, Kalb T. 2005. Saving your own vegetable seeds - a guide for farmers. The World Vegetable Center, Shanhua, Taiwan. AVRDC publication number 05-647. AVRD. 25p.

Thompson AK. 1996. Post-Harvest Technology of Fruits and Vegetables. Blackwell Science Ltd., Oxford. 410p.

Useful Websites

AVGRIS - AVRDC Vegetable Genetic Resources Information System - http://203.64.245.173/

AVRDC-World Vegetable Centre - http://avrdc.org/

Global Horticulture Initiative - http://www.globalhort.org/

Module 4: Neglected and Underutilized Insects for Food and Feed

Preamble

Globally, more than 1900 insect species are documented as edible, most of them in tropical countries. Surveys in Africa, Asia, Australia and Latin America show that insects are high in protein, energy, vitamins and minerals (Igwe et al 2011). While for some cultures, eating insects may sound quite disagreeable, there is nonetheless a surge of interest internationally and locally in research on the use of insects as food and feed. Furthermore, entomophagy (eating of insects) has gained prominence in recent years as a result of drought and poor economic conditions.

Many African countries have a cultural tradition of eating certain species of grasshoppers, caterpillars and termites. Many of these edible species are collected in the wilderness and on farms in specific seasons and are rarely cultivated. The whole value chain is limited to the local community markets. For example, Macrotermes nigeriensis is a termite that is widely known and harvested for food in Nigeria and several other west and Central African countries (Igwe et al 2011).

The interest in insects as feed is also raising fast. After all, in the wild, many fish and animal species eat larvae and insects. In fish farming, replacing fish meal with insect-based feed makes sense and has environmental benefits. Insects are already an important source of protein in poultry feed.

Learning more about the nutritional content, cultivation, and promoting the processing and marketing of edible insects can contribute significantly to food and nutrition security and the environment.

Learning objectives

Upon completion of this Module, the student should be able to:

- Explain the state of the art on the usefulness of insects including indigenous knowledge

- Collect and identify insects
- Investigate uses of insect species (e.g. for food and for other useful products/ services)
- Apply the principles of rearing of insects in healthy conditions
- Guide the processing and marketing of quality insect products
- Protect insects as a significant component of future food and nutrition security as well as for their contribution to other useful insect products
- Carry out field studies on insects

Indicative Module Duration: 60 contact hours; 20 lecture hours and 40 practicum hours

Indicative Module weighting: 2 credit units

Practicum

Laboratory: Identification, characterization and classification of insects, dissection, insect breeding exercises, preservation of insect specimens, insect parasites and disease detection, insect feeding and health management analyses.

Fieldwork: insect collection techniques using nets, lights and other trapping methods, butterfly management, pollination exercises, insect capture and recapture, community awareness on useful insects, establishing field insectaries, value chain analysis, edible insect marketing exercises, using statistical tools to assess insect populations, risk assessments/management.

Assessment methods: Term paper presentations, continuous assessments, grading of practicum, final examination

Module synopsis

1. **Biodiversity and identification of insects**
    - Insects useful as food and feed
    - Insects directly involved in food production (e.g. pollination)
    - Morphology and classification of selected insect species
    - Anatomy of target NUS insects

2. **Indigenous knowledge, socio-cultural traditions, gender practices**
    - Edible insects
    - Nutritive components and impact on health
    - Different methods used to prepare insect meals

3. **Biology of NUS insects & habitats**
    - Lifecycles, fecundity, population dynamics
    - Insect feeding systems and nutrition, digestive systems
    - Insect reproduction, circulation and gas exchange
    - Homeostasis
    - Adaptation to different environments
    - Ideal climatic and environmental conditions
    - Population dynamics, social behavior
    - Insect population management and impact on habitats
    - Insect pathology

4. **Selection & breeding**
    - Insect genetic makeup
    - Digestive systems, feeding and growth
    - Fertility, mating systems and parturition
    - Domestication: How it affects rearing and insect quality

5. **Analytical methods for nutrient composition and rearing of target NUS insects**
    - Local community practices in domestication and use of NUS insects
    - Laboratory rearing and maintenance
    - Mass rearing (artificial diets, plants)
    - Risks in rearing target insects

6. **Harvesting and processing of whole insects and insect products**
    - Household and industrial scales
    - Risk management
    - Market studies
    - Profitability

7. **Impact on human health and risk management**
    - Common diseases and parasites
    - Transmission of diseases
    - Control measures (prevention and treatment)

8. **Storage, shelf-life and safety issues**
    - Different methods of processing (drying, canning)
    - Quality management

9. **Marketing**
    - Packaging
    - Transport requirements
    - Branding and patenting

10. **Term paper**

    Each student is required to select one insect species or one ecological landscape in one local community, study the current status of NUS insect species and propose a strategy for the development of the species. This paper will be marked and included in the overall assessment of performance.

Useful References

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Useful websites

http://www.fao.org/forestry/edibleinsects/en/

Insects to feed the world conference 2014.
https://www.youtube.com/watch?v = Acxbx-DUkL4

Can Eating Insects Save the world? BBC.
https://www.youtube.com/watch?v = Acxbx-DUkL4

Videos

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Module 5: Neglected and Underutilized Rodents

Preamble

In Africa—as in Latin America and many countries in Asia—there are many species of rodents that are edible but their value chains are limited either to specific ethnic communities or geographic areas. The giant African rat (*Cricetomys gambianus*) and the grasscutter or cane rat (*Thryonomys swinderianus*), are well known as prime sources of meat in West Africa. Other examples include, guinea pigs, porcupines, rats, squirrels, mice and hamsters that are still wild or partially domesticated and used for human consumption in much of Africa. Their systematic identification, breeding and production can contribute enormously to addressing protein deficiency. However, the current level of knowledge on these rodents is quite low. Research is needed to enhance our knowledge and better development and utilization of these and other rodents.

Learning objectives

Upon completion of this Module, the student should be able to:

- Describe NUS rodents, their classification and genetic diversity
- Link different rodent species with their habitats, conservation of habitats and domestication methodologies
- Understand and apply local knowledge and practices in conservation, management, and utilization of NUS rodents and their products
- Analyze NUS rodent value chains for maximized production and productivity
- Construct suitable domestication and breeding cages for NUS rodents for sustainable productivity
- Manage the nutrition and health protocols for rodents and control zoonotic diseases

- Integrate and apply social, economic and cultural models in the management and utilization of NUS rodents
- Develop value chains for the different products of NUS rodents

Indicative Module duration: 60 contact hours; 20 lecture hours and 40 practicum hours

Indicative Module weighting: 1.5 credit units

Practicum

Laboratory: Identification, characterization and classification of useful rodent species, screening for zoonotic diseases; rodent breeding studies and behavior management.

Fieldwork: Rodent sample collections, studies on suitable habitats and feeding habits, local community approaches to domestication and management, linking with local communities to capture social, economic and cultural aspects, nutrition studies, market analysis for rodent species and their products; construction and management of rodent cages.

Assessment methods: Term paper presentations, continuous assessments, grading of practicum, final examination

Module synopsis

1. **Importance of NUS rodents**
    - Geographical distribution of rodents
    - Role of rodents in food diversity, food and nutrition security
    - Economic potential of NUS rodents by species
    - Products diversification along the value chains of rodent products
    - Local practices in domestication and use of rodents

2. **Rodent genetics and breeding**
    - Evolutionary classification
    - Recognition of species and varieties
    - Genetic characterization and sequencing
    - Genetic diversity of rodents, conservation and protection
    - Mating and breeding behavior

- Frequency of littering and litter sizes
- Parenting behavior
- Structure and construction of breeding cages

3. Rodent management

- Social behavior (diurnal, nocturnal, burrowing)
- Different types of structures for rodent keeping
- Feeding habits (herbivores and omnivores)
- Health management
- Diseases and pest control and links to human health

4. Rodent-human interactions and health

- Common rodent diseases and parasites
- Transmission systems for zoonotic diseases
- Control measures (prevention and treatment)
- Risk management

5. Rodent utilization

- Meat products, handling and safety considerations
- Other products (e.g. fur)
- Processing, storage and transportation of rodent products
- Harvesting tools/equipment for rodent products

6. Rodent business planning, management, utilization and regulatory factors

- Food and drug regulations and policies
- Laws and policies regulating management and use of animals
- Rodent products business planning, establishment, management and risk analysis
- Market assessment for NUS rodent products
- Quality and standards assurance
- Environmental impact assessment for sustainable NUS rodent management
- Rodent enterprise development strategies

7. Term paper

Each student is required to select one rodent species or one ecological landscape in one local community, study the current status of rodent utilization and develop a paper covering history, local practices, species involved, policy and regulatory frameworks, potential for rodent development and the way forward, with special attention to developing an enterprise on rodents. This paper will be marked and included in the overall assessment of performance.

Useful References

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Rodentia 1999 In The UFAW Handbook on the Care and Management of Laboratory Animals, 7th Edition Laboratory Animal Management: Rodents - online book from National Academies Press.

Useful Web Resources

Rodent breeding colony management: mice. Boston University. http://www.bu.edu/orccommittees/iacuc/policies-and-guidelines/rodent-breeding-colony-management-mice/

Appendix 1: List of Participants

NEGLECTED AND UNDERUTILISED SPECIES (NUS) CURRICULUM DEVELOPMENT WORKSHOP

Nairobi, 22–24 September, 2015

No.	Name and email	Organization	Full address
1.	Prof. A. B. Temu	Consultant	P.O. Box 13231 Arusha, Tanzania
2.	Per Rudebjer	Bioversity International	Via dei Tre Denari 472/a 00057 Maccarese, Italy
3	Wilson Kasolo	Nyabyeya Forestry College	Private Bag, Masindi, Uganda.
4	Amadji Guillaume Lucien	University of Abomey-Calavi	BP 49, Calavi, Rép. du Bénin
5	Everlyn Nambiri Chitechi Wemali	Kenyatta University	P.O. Box 43844, Nairobi
6	Dansi Anagonou Alexandre	Laboratory of Agricultural Biodiversity and Tropical Plant Breeding (LAAPT), University of Abomey-Calavi	BP 526, Cotonou, Benin
7	Raymond Vodouhe	Bioversity International	Bioversity International, Cotonou, Benin
8	Kiarie Njoroge	University of Nairobi	P. O. Box 30197 - 00100 GPO, Nairobi
9	Isaiah Masinde Tabu	Egerton University	P.O Box 536 -20115, Egerton, Kenya
10	R.C. Ishengoma	Sokoine University of Agriculture	P.O Box 3009, Morogoro Tanzania
11	Richard Hall	International Foundation for Science (IFS)	Karlavägen 108, 5th floor SE-115 26 Stockholm, Sweden

12	Thomas Dubois	AVRDC – The World Vegetable Center Eastern and Southern Africa	PO Box 10 Arusha, Tanzania
13	Tsvetelina Stoilova	AVRDC – The World Vegetable Center Eastern and Southern Africa	PO Box 10 Arusha, Tanzania
14	Albert Chiteka	Africa University	P. O Box 1320 Mutare, Zimbabwe
15	Adekunle, Victor Ajibola	Federal University of Technology, Akure, Nigeria.	PMB 704 340001 Akure, Ondo State, Nigeria
16	Detlef Virchow	Global Horticulture Initiative	c/o Center for Development Research Walter-Flex-Str. 3 53113 Bonn, Germany
17	Jeremiah Jonathan Atungwu	University of Agriculture, Abeokuta.	Alabata Road, Abeokuta 110124 Ogun State, Nigeria
18	Andrew Ainomugisha	Excel Hort	P.O. Box 16431 Wandegeya, Uganda
19	Aissetou Yaye	ANAFE	P.O. Box 30677-00100, Nairobi,
20	Oluwole Akinnagbe	ANAFE/Federal University of Technology, Akure	P.O. Box 30677-00100, Nairobi
21	Alfred Ochola	ANAFE	P.O. Box 30677-00100, Nairobi
22	Mipro Hein	ANAFE	P.O. Box 30677-00100, Nairobi
23	Sebastian Chakeredza	ANAFE	P.O. Box 30677-00100, Nairobi
24	Josephine Oyoo	ANAFE	P.O. Box 30677-00100, Nairobi
25	Peter Shitote	ANAFE	P.O. Box 30677-00100, Nairobi
26	Pius Mutinda	ANAFE	P.O. Box 30677-00100, Nairobi