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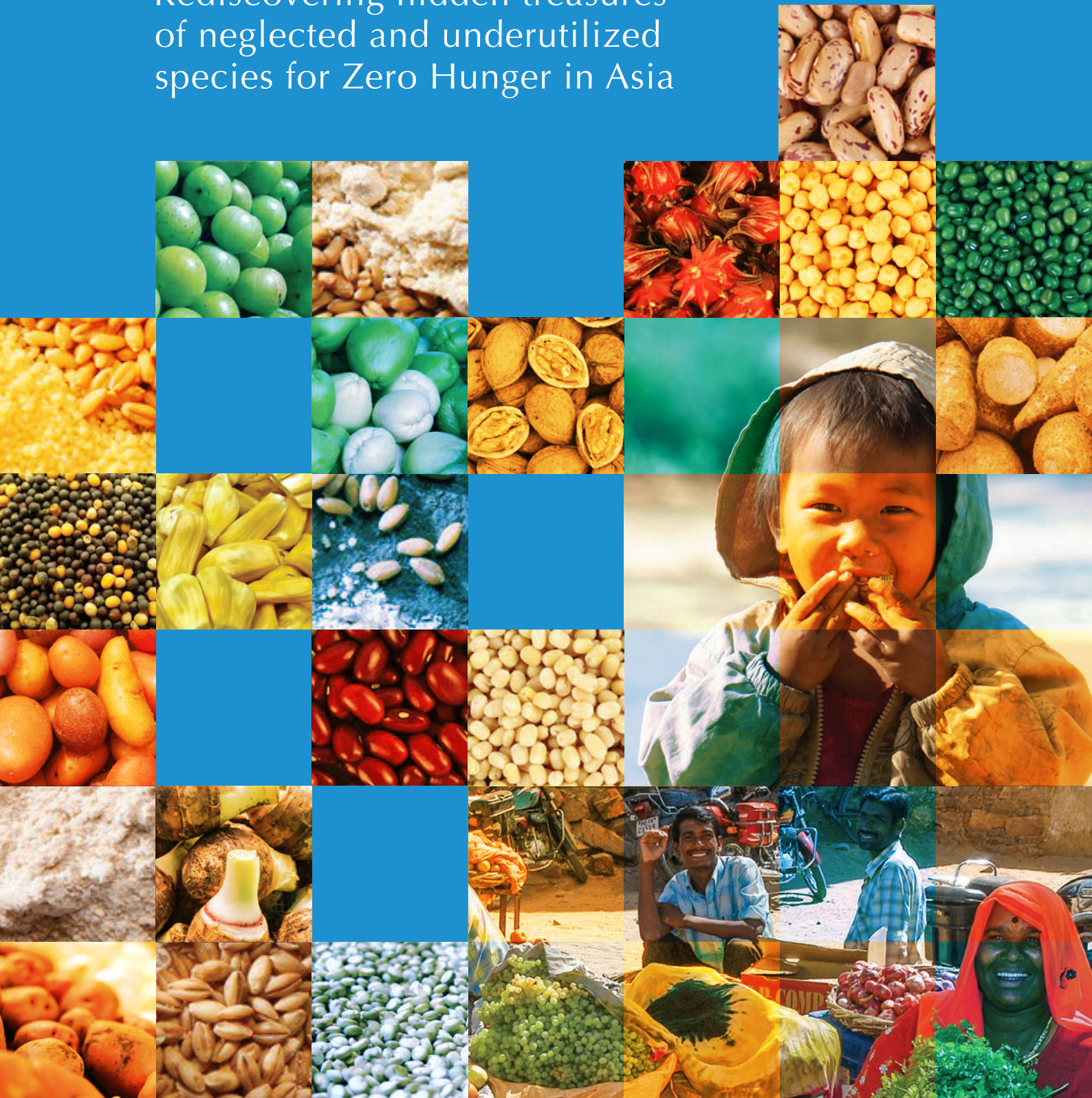
SUSTAINABLE  
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working for Zero Hunger

# FUTURE SMART FOOD

Rediscovering hidden treasures  
of neglected and underutilized  
species for Zero Hunger in Asia



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**Editors**  
Xuan Li and Kadambot H.M. Siddique

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# Foreword

Achieving the Sustainable Development Goals (SDGs) is at the heart of the work of the Food and Agriculture Organization (FAO), especially Sustainable Development Goal 2, which calls for the eradication of hunger and all forms of malnutrition. Delivering on this pledge requires that all people are able to access adequate and nutritious food, which will require a sustainable increase in the productivity and incomes of smallholder farmers. Furthermore, it will entail a transformation of food systems and an inclusive pro-poor boost to rural development to be pursued while sustaining our natural resource base and safeguarding biodiversity.

The purpose of this publication is: i) to demonstrate the multidimensional benefits of neglected and underutilized species (NUS) and their potential contribution to achieving Zero Hunger; ii) to identify promising NUS – sometimes called ‘orphan crops’ – that are nutrition-dense, climate-resilient, economically viable and locally available or adaptable as ‘Future Smart Food’ (FSF); iii) to highlight the challenges and opportunities for harnessing these less-mainstream food crops; and iv) to provide strategic recommendations to create an enabling environment for the promotion, production, marketing and consumption of FSF assuring healthy diets for the future.

FAO considers that NUS have a central role to play in the fight against hunger and malnutrition, and that they are currently being overlooked. Today, just 103 out of the nearly 30 000 edible plant species worldwide provide up to 90 percent of the calories in the human diet (and 60 percent of the world’s caloric intake comes from just a few staples such as maize, rice, wheat, soybean and potato. This percentage can reach up to 80 percent in some parts of the world).

Buoyed by the successes of the International Year of Quinoa (2013) and International Year of Pulses (2016), awareness of NUS as a valuable resource for sustainable agriculture and rural development has increased. Using sound scientific underpinnings to promote NUS can help diversify food production and diets in economically, socially and environmentally sustainable ways while contributing to the resilience of smallholder and rural populations.

The overarching global vision on NUS needs to be translated into concrete action on the ground. FAO’s Regional Office for Asia and the Pacific, as part of its Regional Initiative on the Zero Hunger Challenge, is taking a leading role in harnessing the hidden treasures embodied in NUS, which we like to call Future Smart Food. These foods are smart because they can bolster dietary diversification, improve micronutrient intake, enhance soil health, require fewer inputs such as chemical fertilizers, and often prove resilient to climate change and adverse farming conditions.

Turning the potential of FSF into real benefits is not an easy task. It requires a systems approach, multidisciplinary analysis, multi-stakeholder consultation and cross-sectoral coordination. To achieve Zero Hunger, more attention needs to be given to both production and consumption. Identifying which species are appropriate is just an initial step from a food-system perspective. How to create an enabling environment across value chains – to promote sustainable production, processing, marketing and consumption of FSF – is essential to achieving Zero Hunger.

It is also important to develop capacity and facilitate knowledge-sharing across regions on how to better harness the potential of FSF for Zero Hunger, and to build on the valuable experience gained in Asia on NUS.

It is now time to take advantage of the wealth of knowledge that we have accumulated on neglected and underutilized species so that we can develop more sustainable, nutrition-dense, climate-resilient and diversified food systems. The evidence is at hand. We need to act promptly and collectively.



**José Graziano da Silva**  
FAO Director-General





# Preface

For centuries, people in Asia and the Pacific have grown and consumed a wide variety of nutritious foods. Unfortunately, more recent generations have slowly but surely changed their diets and have moved away from many of these traditional foods. The Food and Agriculture Organization of the United Nations (FAO) is working with our Member Countries to reinvigorate both production and consumption of these crops – often referred to as neglected and underutilized species (NUS).

This work is consistent with FAO's role in providing support to countries to meet the targets of the Sustainable Development Goals (SDGs), primarily, but not limited to, SDG 2 which aims to achieve Zero Hunger, specifically to “end hunger, achieve food security and improved nutrition, and promote sustainable agriculture” by 2030. The Zero Hunger goal implies that no one should be left behind. The Asia-Pacific region is home to most of the world's undernourished people (490 million). Other forms of malnutrition remain challenging, including stunting and micronutrient deficiencies. While in some countries there are rising rates of overweight and obesity.

The issues are manifest in both the demand side and the supply side. On the demand side, there is population growth, urbanization, migration and the changing consumption associated with rising incomes. On the supply side, the combined effects of climate change, declining agricultural biodiversity, water scarcity, land scarcity and the degradation of natural resources are threatening world food security.

The demand and supply dilemma highlights two gaps in agriculture and food systems:

- 1 Production gap – FAO projections suggest that by 2050, agricultural production must increase by 50 percent globally to meet food demand. Increased production of traditional staple crops is unlikely to meet the increasing demand.
- 2 Nutrition gap – between what foods are grown and available, and what foods are needed for a healthy diet.

So what to do?

Increasing the availability of and access to nutritious foods necessary for a healthy diet will help to close both the production and nutrition gaps. But conventional staple foods do not supply all the nutrients needed for a balanced diet. Tackling the health problems caused by malnutrition requires a transformation of current agriculture and food systems towards more diversity on all levels.

FAO work has demonstrated that dependence on a few crops has negative consequences for ecosystems, food diversity and health. Food monotony increases the risk of micronutrient deficiency. In other words, we must make food and agriculture more nutrition-sensitive and climate-resilient. Over-reliance on a few staple crops coupled with low dietary diversity is a leading cause of persistent malnutrition. The dependency on rice, in particular, leads to insufficient intake of nutrient-rich foods, which increases the ‘nutrition gap.’ To achieve SDG 2, the agriculture and food system must be more sustainable – we have to ensure climate-smart agriculture and prioritize a paradigm shift: *save and grow*. Unsustainable high-input, intensive crop production and monocultures have led to environmental degradation. How to bridge the ‘production gap’ remains a huge challenge. Policymakers need to recognize that policy support for monocropping or cash crops has driven this unbalanced shift.

Diversification is an effective means of closing the production and nutrition gaps, and achieving Zero Hunger. Governments need to promote agricultural diversification from a dietary and production perspective. Dietary diversity is a cost-effective, affordable and sustainable means of eradicating hunger and malnutrition. Production diversity helps to address malnutrition and climate change simultaneously. NUS offer considerable potential to bridge both production and nutrition gaps, and are abundant in the region. NUS that are nutritionally dense, climate resilient, economically viable, and locally available or adaptable are considered Future Smart Food (FSF). Increasing the share of FSF in diets is the way forward to achieving Zero Hunger. FSF have received few incentives for production in the Asian region, which is mostly geared towards rice, and there is little consumer awareness of their nutritional and health benefits. Governments need to lessen their focus on staple and cash crops and tap into the vast potential of FSF. Creating an appropriate enabling environment for FSF is critical. It is time to rediscover these hidden treasures for achieving Zero Hunger.



**Kundhavi Kadiresan**

Assistant Director-General and Regional Representative  
FAO Regional Office for Asia and the Pacific

# Note from the editors

The FAO Regional Office for Asia and the Pacific (RAP)'s Future Smart Food Initiative (FSF Initiative), as endorsed by the FAO Director-General, is intended to promote agriculture diversification with sustainable intensification addressing Zero Hunger. This report moves forward with the outcomes of FAO RAP's regional priority-setting exercise on neglected and underutilized species (NUS), including the Regional Expert Consultation on Scoping, Prioritizing and Mapping of NUS in Asia (the Consultation).

The Consultation was co-organized by FAO and Australian Centre for International Agricultural Research (ACIAR) under FAO RAP's Regional Initiative on Zero Hunger Challenge (RI-ZHC), and took place from 3-5 December 2016 in Bangkok, Thailand. The purpose of the Consultation was to identify promising NUS crops that are nutritionally dense, climate resilient, economically viable, and locally available or adaptable, and to provide strategic advice to decision-makers. These promising NUS are referred to as Future Smart Food (FSF).

The Consultation was held in the context of hunger, food insecurity and malnutrition as major challenges in the twenty-first century for the Asia-Pacific region. To achieve the Zero Hunger goal, which is the aim of Sustainable Development Goal (SDG) 2, dietary patterns and food systems need to be improved urgently. Stakeholders in the agriculture and food value chain are affected by the disconnect between production, consumption and nutrition. Countries are facing challenges associated with population growth and climate change. Agricultural diversification offers enormous opportunities for addressing hunger and malnutrition, especially in the context of climate change. In this regard, NUS<sup>1</sup> offer diverse and nutritious food resources and agricultural resilience. NUS are important in specific agro-ecological niches and are often linked with traditions and cultural heritage in their places of origin. They are an essential source of protein and micronutrients, and can enhance climate resilience, improve agriculture sustainability and boost household incomes and livelihoods with considerable commercial potential. In this context, FAO, together with ACIAR, and in collaboration with national and international partners, organized the Consultation during the International Year of Pulses (2016). Thirty-five participants, representing eight countries,<sup>2</sup> including four governments represented by national focal points on the Zero Hunger Challenge (ZHC), as well as 21 national and international partners, attended the Consultation. Participants at the Consultation identified ten recommendations for policymakers.

The RI-ZHC of FAO RAP was formulated to assist its Member Countries following the launch of the global ZHC at the Rio+20 Conference in June 2012, and the Asia-Pacific regional ZHC in April 2013 by the United Nations and associated agencies, with participation by heads of governments, and other high-level and senior officials from across the region. Subsequently, the United Nations Regional Thematic Working Group on Poverty and Hunger, chaired by FAO, along with UNESCAP and UNDP, prepared the 'Regional Guiding Framework for Achieving Zero Hunger in Asia and the Pacific'. This Framework calls for all stakeholders to carry the momentum forward with concrete action at the country level.

<sup>1</sup> "Neglected and underutilized species are those to which little attention is paid or which are entirely ignored by agricultural researchers, plant breeders and policymakers. They are wild or semi-domesticated varieties and non-timber forest species that are not typically traded as commodities." Padulosi, Thompson and Rudebjer (2013).

<sup>2</sup> The Australian Centre for International Agricultural Research (ACIAR); Bangladesh Agriculture Research Institute (BARI); Bioversity International (BI); Cambodian Agricultural Research and Development Institute (CARDI); Chinese Academy of Tropical Agricultural Sciences-Tropical Crops Genetic Resources Institute (CATAS-TCGRI); Crops for the Future (CFF); Department of Agriculture, Ministry of Agriculture and Forests, Bhutan; Department of Agricultural Research (DAR), Myanmar; Food and Agriculture Organization of the United Nations (FAO); FAO Special Ambassador for International Year of Pulses 2016; International Centre for Agricultural Research in the Dry Areas (ICARDA); International Centre for Integrated Mountain Development (ICIMOD); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); International Tropical Fruits Network (TFNet); Mahidol University, Thailand; M S Swaminathan Research Foundation – Leveraging Agriculture for Nutrition in South Asia (MSSRF-LANSA); National Agriculture and Forestry Research Institute (NAFRI), Lao PDR; Nepal Agriculture Research Council (NARC); National Plant Resources Centre, Vietnam Academy of Agricultural Sciences, Viet Nam; The Akshaya Patra Foundation, India; The University of Western Australia (UWA); Uttar Banga Krishi Viswavidyalaya (UBKV), West Bengal, India.

Under this Framework, RI-ZHC established three major programmatic work areas in consultation with governments:

- 1 creating environments for food security and nutrition;
- 2 data collection, analysis, and monitoring on food security and nutrition; and
- 3 strengthening sustainable agriculture and food systems.

The FSF initiative is an integral component under RI-ZHC.

The initiative is implemented under the overall Strategic Programme of FAO to “contribute to the eradication of hunger, food insecurity and malnutrition,” in collaboration with various other strategic programmes.

Inspired by a request from Member Countries to identify alternative crops to address Zero Hunger in a changing climate, Kundhavi Kadiresan, Assistant Director-General and Regional Representative of FAO RAP, launched the FSF Initiative. The FSF Initiative is built on the strong foundation and the long-standing experience of FAO on NUS at global and regional levels, in particular, the International Year of Quinoa (2013), International Year of Pulses (2016), and the approach that the Director-General highlighted to address hunger and malnutrition from a food-system perspective. A concept note was developed, based on intensive consultation with strategic programme leaders of FAO; the technical departments responsible for agriculture, and economic and social development; the Office of the Director General, RAP; and FAO representatives in the Zero Hunger countries. Subsequently, the Consultation on NUS was organized. The results of the Consultation paved the way for implementation of FAO RAP’s Regional Technical Cooperation Project on Creating Enabling Environments for Nutrition-Sensitive Food and Agriculture to Address Malnutrition.

The development of the FSF Initiative started with a three-stage priority-setting exercise, which was the building block for achieving the goal of creating an enabling environment for promising NUS in the region. A special feature of the exercise was its applied methodology that covered a wide range of different disciplines, including nutrition, agricultural production, ecology and socio-economics. The first stage of the process involved preliminary scoping of the availability and use of NUS crops in eight countries in the region: Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, Nepal, Viet Nam and West Bengal in India, and the preparation of eight studies to serve as directions for governments to recognize the importance of NUS and to promote them at the national level. The preliminary scoping reports were reviewed and presented at the Consultation. The objectives of the review were to:

- 1 validate the preliminary scoping reports on crop-related NUS in selected countries,
- 2 rank and prioritize high-potential NUS based on established priority criteria,
- 3 identify five to six crop-related NUS per country, and
- 4 strategize to enhance production and utilization of the selected crops in local diets.

These studies were revised according to the outcomes and suggestions during the Consultation, and went through a peer review by FAO and the international partners whom had participated in the Consultation. The background, objectives, process, methodology and preliminary results for each country are presented in Chapter 1. Chapter 2 then presents details on the regional priority-setting exercise on FSF among NUS for Zero Hunger.

Partnerships are essential to the process of the FSF Initiative. The prioritization process is an interdisciplinary consultation with the governments of Lao PDR, Myanmar and Nepal (represented by National Focal Points of the Zero Hunger Challenge), national research institutes in Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, Nepal, Viet Nam and West Bengal, as well as leading international experts from agriculture, nutrition and socio-economic disciplines, including the FAO Special Ambassador for the International Year of Pulses, the University of Western Australia, ACIAR, the International Centre for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bioversity International, the MS Swaminathan Research Foundation – Leveraging Agriculture for Nutrition in South Asia (MSSRF-LANSA), Mahidol University in Thailand, the Chinese Academy of Tropical Agricultural Sciences – Tropical Crops Genetic Resources Institute (CATAS-TCGRI), the International Centre for Integrated Mountain Development (ICIMOD), Crops For the Future (CFF), the International Tropical Fruits Network (TFNet), and the Akshaya Patra Foundation (a non-government organization from India). The prioritization exercise

was led by FAO, and collectively conducted and owned by governments, and national and international partners. The prioritized lists of FSF are country specific, and have been reviewed by an international expert panel, and finalized by each country.

The main outputs of the prioritization exercise were two-fold. First, lists of prioritized FSF in Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, Nepal, Viet Nam and West Bengal in India were prepared by national researchers to provide context-specific crops that are nutritious, climate-smart and have economic potential. The studies, which are presented in Part II of this report, were peer-reviewed by FAO and leading international experts from agriculture, nutrition and socio-economic disciplines. Second, recommendations were made to policymakers on how to support FSF to address hunger and malnutrition in a changing climate through appropriate national policies. In the recommendations, presented in the Conclusion (Chapter 14), experts from the Consultation jointly proposed the term 'Future Smart Food' for promising NUS to change the negatively perceived attributes of these 'hidden treasures'. Subsequently, the leading international experts contributed thematic chapters, presented in Part I, which illustrate the justification, grounds and needs for an enabling environment to promote FSF production, marketing and consumption for Zero Hunger. The outputs of the exercise, including the Recommendations of the Consultation, were endorsed by the Minister of Agriculture in Lao PDR on behalf of Asia and the Pacific countries at the Zero Hunger Plenary Event during the 40th Session of the FAO Conference in Rome in 2017.

Chapter 1 of the report serves as a guiding chapter, outlining the context and justification of FSF to address Zero Hunger in the changing climate; the priority-setting exercise in terms of the objective, scope, principle, methodology and process; and the key recommendations on FSF for policymakers.

Part I comprises four chapters (Chapter 2 through Chapter 5) contributed by FAO and leading international experts. Chapter 2 highlights the challenges, opportunities and strategies to develop NUS into FSF. Chapter 3 analyses the potential of FSF for nutrition enhancement and climate resilience to address Zero Hunger. Chapter 4 presents experiences in South Asia of FSF crops in a paddy fallow agri-food system. Chapter 5 discusses how to mainstream FSF into national strategies and programmes on food security and nutrition.

Part II (Chapter 6 through Chapter 13) provides an overview of scoping and prioritizing FSF for eight countries: Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, Nepal, Viet Nam and West Bengal in India. For each country, high-potential crops were shortlisted after being prioritized on the basis of a set of multi-dimensional criteria. The studies include mapping of the availability of FSF, an assessment of their multiple benefits and the challenges they face, and feature lists of prioritized crops with potential in each country. Each study provides background on the country's agro-ecological environment, food composition, predominant cropping patterns and crops in the national farming system. A situation analysis identifies gaps and major challenges each country is facing with regard to hunger and malnutrition, climate change, and market and economic considerations, as well as cultural aspects. To link suitable FSF in each country to the identified challenges, potential FSF were assessed and prioritized according to their nutritional features, adaptation potential to local environments and climate change, economic potential, and sociocultural suitability. Each study also includes a set of recommendations and subsequent actions to further promote FSF in the respective country.

The Conclusion (Chapter 14) presents the policy recommendations made by the Panel of Experts.

**Xuan Li and Kadambot H.M. Siddique**



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# Acronyms and abbreviations

<b>ABPSD</b>	Agri-Business Promotion and Statistics Division, Nepal
<b>ACIAR</b>	Australian Centre for International Agricultural Research
<b>ADB</b>	Asia Development Bank
<b>ADS</b>	Agriculture Development Strategy, Nepal
<b>AEZ</b>	agro-ecological zone
<b>AFACI</b>	Asian Food and Agriculture Cooperation Initiative
<b>ASEAN</b>	Association of Southeast Asian Nations
<b>BARI</b>	Bangladesh Agriculture Research Institute
<b>BBS</b>	Bangladesh Bureau of Statistics
<b>BMI</b>	body mass index
<b>CARDI</b>	Cambodian Agricultural Research and Development Institute
<b>CATAS-TCGRI</b>	Chinese Academy of Tropical Agricultural Sciences – Tropical Crops Genetic Resources Institute
<b>CBD</b>	Convention on Biological Diversity
<b>CCAFS</b>	climate change, agriculture and food security
<b>CDHS</b>	Cambodia Demographic Health Survey
<b>CFF</b>	crops for the future
<b>CFS</b>	Global Committee for Food Security
<b>CGIAR</b>	Consultative Group on International Agricultural Research
<b>CSIR</b>	Council for Scientific and Industrial Research, India
<b>DAP</b>	Department of Agricultural Planning
<b>DAR</b>	Department of Agricultural Research, Myanmar
<b>DoAC&amp;FW</b>	Ministry of Agriculture and Farmers Welfare of India
<b>DOP</b>	Department of Planning, Myanmar
<b>ET</b>	evapotranspiration
<b>FAO</b>	Food and Agriculture Organization of the United Nations
<b>FAO PAR</b>	Food and Agriculture Organization and the Platform for Agrobiodiversity Research
<b>FAOSTAT</b>	Food and Agriculture Organization Corporate Statistical Database
<b>Fe</b>	iron
<b>FSF</b>	Future Smart Food
<b>FY</b>	farm yields
<b>GDP</b>	gross domestic product
<b>GEAS</b>	Global Environmental Alert Service
<b>GHI</b>	Global Hunger Index
<b>GI</b>	geoinformatics
<b>GIS</b>	geographic information system
<b>GM</b>	genetically modified
<b>HKI/IPHN</b>	Helen Keller International and the Institute of Public Health Nutrition of Government of Bangladesh
<b>HLPE</b>	High Level Panel of Experts for Food Security and Nutrition
<b>HRC</b>	Horticulture Research Center, BARI
<b>HRD</b>	Horticulture Research Division, Nepal

<b>HYV</b>	high-yielding variety in agroindustry
<b>ICAR</b>	Indian Council of Agricultural Research
<b>ICARDA</b>	International Center for Agricultural Research in Dry Areas
<b>ICIMOD</b>	International Centre for Integrated Mountain Development
<b>ICMR</b>	Indian Council of Medical Research
<b>ICRISAT</b>	International Crops Research Institute for the Semi-Arid Tropics
<b>ICUC</b>	International Centre for Underutilized Crops
<b>IFAD</b>	International Fund for Agricultural Development
<b>IFPRI</b>	International Food Policy Research Institute
<b>IGNRM</b>	Integrated Genetic and Natural Resource Management
<b>IMD</b>	India Meteorological Department
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IPGRI</b>	International Plant Genetic Resources Institute
<b>IRRI</b>	International Rice Research Institute
<b>ISI</b>	International Scientific Indexing
<b>IWMI</b>	International Water Management Institute
<b>IYP</b>	International Year of Pulses
<b>IYQ</b>	International Year of Quinoa
<b>JICA</b>	Japan International Cooperation Agency
<b>LANSA</b>	Leveraging Agriculture for Nutrition in South Asia
<b>LGP</b>	length of growing period
<b>MAFF</b>	Ministry of Agriculture, Forestry and Fisheries, Cambodia
<b>MAP</b>	medicinal and aromatic plants
<b>MARD</b>	Ministry of Agriculture and Rural Development, Viet Nam
<b>MDG</b>	Millennium Development Goals
<b>MI</b>	micro-irrigation
<b>MoAD</b>	Ministry of Agricultural Development, Nepal
<b>MoAF</b>	Ministry of Agriculture and Forestry, Lao PDR
<b>MoALI</b>	Ministry of Agriculture, Livestock and Irrigation, Myanmar
<b>MODIS</b>	moderate resolution imaging spectroradiometer
<b>MoF</b>	Ministry of Finance, Bhutan
<b>MoFSC</b>	Ministry of Forest and Soil Conservation, Nepal
<b>MoHP</b>	Ministry of Health and Population, Nepal
<b>MONRE</b>	Ministry of Natural Resources and Environment, Viet Nam
<b>MSSRF-LANSA</b>	M S Swaminathan Research Foundation – Leveraging Agriculture for Nutrition in South Asia
<b>NAFRI</b>	National Agriculture and Forestry Research Institute, Lao PDR
<b>NARC</b>	Nepal Agriculture Research Council
<b>NBSAP</b>	National Biodiversity Strategies and Action Plan
<b>NIPORT</b>	National Institute of Population Research and Training, Bangladesh
<b>NTFP</b>	non-timber forest products
<b>NUS</b>	neglected and underutilized species
<b>NWFP</b>	non-wood forest products
<b>PDR</b>	People's Democratic Republic [Lao PDR]
<b>PGR</b>	plant genetic resources

<b>PMKSY</b>	Pradhan Mantri Krishi Sinchai Yojana
<b>PRC</b>	Plant Resources Centre, Viet Nam
<b>PRC</b>	Potato Research Centre
<b>RAP</b>	Regional Office for Asia and the Pacific [FAO]
<b>RI-ZHC</b>	Regional Initiative on Zero Hunger Challenge
<b>SAARC</b>	South Asian Association for Regional Cooperation
<b>SAT</b>	semi-arid tropics
<b>SDGs</b>	Sustainable Development Goals
<b>SRDI</b>	Soil Resources Development Institute, Bangladesh
<b>TCGRI</b>	Tropical Crops Genetic Resources Institute
<b>TCRC</b>	Tuber Crops Research Centre
<b>TFNet</b>	International Tropical Fruits Network
<b>UBKV</b>	Uttar Banga Krishi Viswavidyalaya, West Bengal
<b>UNDP</b>	United Nations Development Programme
<b>UNESCAP</b>	United Nations Economic and Social Commission for Asia and the Pacific
<b>UNEP-GEF</b>	United Nations Environment Programme-Global Environment Facility
<b>UNFCC</b>	United Nations Framework Convention on Climate Change
<b>UNICEF</b>	United Nations Children's Fund
<b>USDA</b>	United States Department of Agriculture
<b>UWA</b>	The University of Western Australia, Australia
<b>VAAS</b>	Vietnam Academy of Agricultural Sciences
<b>WB</b>	World Bank
<b>WFP</b>	World Food Programme
<b>WHO</b>	World Health Organization
<b>WIC</b>	water impact calculator
<b>WUE</b>	water-use efficiency
<b>ZHC</b>	Zero Hunger Challenge



# Executive summary

**Chapter 1: Introduction: Setting the scene** by Xuan Li, Kadambot H.M. Siddique, Festus Akinnifesi, Karel Callens, Sumiter Broca, Arshiya Noorani, Günter Hemrich, Chikelu Mba and Nomindelger Bayasgalanbat provides the overall context of the Sustainable Development Goals (SDGs), highlights the main features of agriculture and food systems, and justifies neglected and underutilized species (NUS) as entry points for addressing hunger and malnutrition from a food system perspective. It also lays out the global policy frameworks and their integration of NUS, and describes the origin, criteria, process and outcome of the regional priority-setting exercise on NUS: Future Smart Food (FSF).

## 1 Context

SDG 2: Zero Hunger calls for the eradication of hunger and all forms of malnutrition, with targets for doubling agricultural productivity and incomes of small-scale food producers (SDG 2.3), ensuring sustainable food systems (SDG 2.4) and maintaining genetic diversity (SDG 2.5). Promoting NUS could be a powerful means of achieving the Zero Hunger goal while offering solutions to some worrying trends in agriculture.

From a demand perspective, the multiple challenges for global agriculture and food systems include population growth, increasing urbanization and the emergence of a larger middle-class, which has given rise to new food preferences and changing consumer attitudes that involve concerns about food quality and safety. Taken together, these trends will have a huge impact on Asia's future dietary patterns. From a supply perspective, there is concern about the slowing down of yield growth in staple crops to levels that are insufficient for meeting future food demands without the expansion of agricultural land, which is already scarce in Asia. The combined effects of climate change, declining agricultural biodiversity, water scarcity and degradation of natural resources are challenging world food security. Some studies predict that in South Asia, the climate change scenario would result in a 14 percent decline in rice production relative to the no-climate-change scenario, a 44-49 percent decline in wheat production, and a 9-19 percent fall in maize production (Nelson *et al.* 2009).

There are two significant gaps that exist, or will emerge, in our agriculture and food systems:

**1 Production gap.** A 30 percent increase in the global population by 2050 will require a 60-70 percent increase in food production, taking into account changing consumption patterns. Production increases of traditional staple crops are unlikely to meet the increasing demand; irrigated wheat, rice

and maize systems appear to be near 80 percent of the yield potential. Therefore, relying on these crops alone will not be enough to close the gap between food supply and demand.

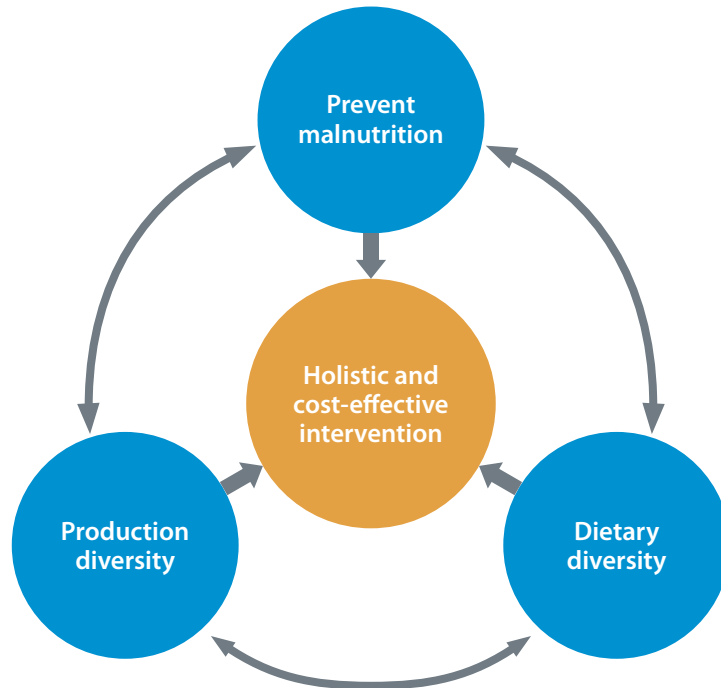
**2 Nutrition gap.** Even if traditional staple crops provide enough calories to prevent hunger, they do not provide all the nutrients necessary for a healthy diet. Current high levels of malnutrition are often due to unbalanced diets with insufficient nutrition diversity.

Closing the production and nutrition gaps requires a transformation of current agriculture and food systems towards greater diversity.

A holistic food system perspective can provide answers for tackling malnutrition, and addressing climate change and environmental threats in agricultural production. Nutrition-sensitive and climate-smart agriculture interventions can tap local potential to promote agricultural productivity that meets nutritional requirements. These interventions will go beyond the promotion of current staple crops and include crops previously considered of secondary importance. Characteristically, NUS are nutritious, climate resilient, economically viable (in the right setting) and adapt to local conditions, especially in marginal areas. In the past, NUS have been ignored by agricultural research, not included in agricultural extension curricula, and did not benefit from organized value chains. However, due to their adaptability and nutritional qualities, many NUS could make a major contribution to increased food availability, affordability and nutrition security.

Recognizing this potential, FAO RAP's Regional Initiative on Zero Hunger Challenge (RI-ZHC) has embarked on the promotion of NUS crops as a means to foster food and nutrition security, although the definition of NUS also includes livestock, fisheries and aquaculture species.



**FIGURE ES.1** Features of agriculture and food systems

## 2 Agriculture and food systems

There is a clear connection between the over-reliance on a few staple crops, low dietary diversity and malnutrition in agricultural and food systems at the country level.

A leading cause of persistent malnutrition is poor dietary diversity (poor quality and limited variety of food in the diet). Dietary diversity is low when a high consumption of cereals is accompanied by a low intake of vegetables, fruits and pulses, which could provide the necessary micronutrients and fibre. This dependency leads to a significant nutrition gap. Agricultural production in Asia focuses on a few staple crops, particularly rice. The pattern reflects a structural issue: too many people consume food with too few nutrients and too much food is being produced without offering enough nutrients. This is often the involuntary consequence of government policies that prioritize quantitative food production targets.

Figure ES.1 highlights that agricultural diversification is a powerful tool for achieving Zero Hunger. It outlines why we need diversity on two counts: dietary diversity, which is a cost-effective, affordable and sustainable way to prevent hunger and malnutrition; and product diversity, which makes it possible to supply nutritious and diversified food that provides better options for dealing with changing environments, especially the effects of climate change.

There are two major limiting factors in global agriculture and food systems, both of which are observed in Asia:

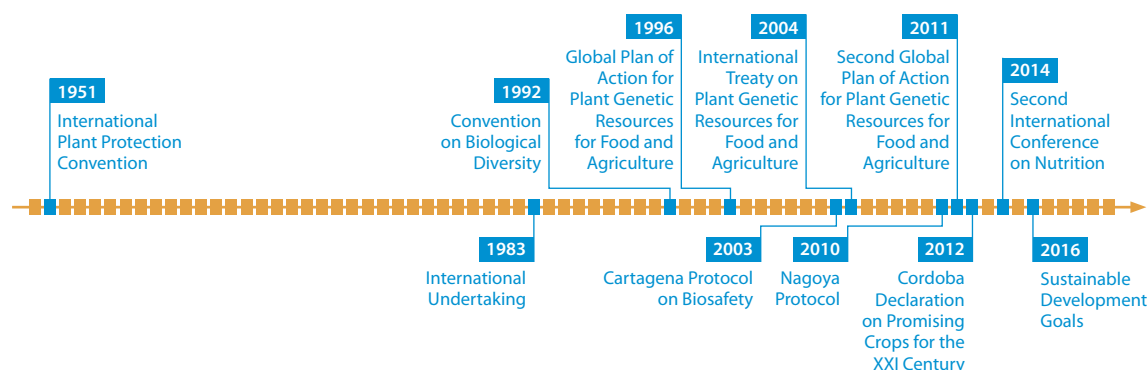
- 1 **Limited production diversity** with an emphasis on starchy crops can lead to unbalanced diets and ultimately malnutrition. An abundant supply of a few staple crops alone does not provide sufficient nutrition.
- 2 **Reliance on a few staple crops** with high input requirements leaves farming more vulnerable to environmental shocks, especially under a climate change scenario.

According to Graziano da Silva (FAO, 2012a), dependence on a few crops has negative consequences for ecosystems, food diversity and health. Food monotony increases the risk of micronutrient deficiency.

## 3 Neglected and underutilized species as entry points for addressing malnutrition from a food system perspective

From a food system perspective, dietary and production diversity need to improve to address malnutrition. NUS are underexplored and can be called 'hidden treasures' that offer tremendous opportunities for fighting poverty, hunger and malnutrition. As the FAO Director-General highlighted, NUS play a crucial role in the fight against hunger and are a key resource for agriculture and rural development (FAO, 2012a). Considering the wide coverage of NUS including crops, livestock, fisheries and aquaculture, and forests, this regional priority-setting

**FIGURE ES.2** Timeline showing the major relevant international policy frameworks for the conservation and sustainable use of plant diversity



exercise set crops as an entry point among NUS to address hunger and malnutrition. Historically, underutilized plants have been used for food and other uses on a large scale and, in some countries, are still common, especially among small or marginal farmers in rural areas where many are traded locally. A lucky few NUS have made their way to export niche markets around the world (Akinifesi *et al.*, 2008). NUS have high nutritional value and can be an essential source of micronutrients, protein, energy and fibre, which contribute to food and nutrition security. Apart from their superior nutritional qualities, many of these crops do not require high inputs, can be grown on marginal lands and easily intercropped or rotated with staple crops, as well as fit easily into integrated practices such as agro-ecology. Because they are frequently adapted to marginal conditions, and many have the unique ability to tolerate or withstand stresses, NUS can make production systems more sustainable and climate resilient.

#### 4 Global policy frameworks and the integration of neglected and underutilized species

The importance of NUS is widely recognized by the global scientific community (Joint FAO/IAEA 2004; Kahane *et al.*, 2013; Khoury *et al.*, 2014; Nyadanu *et al.*, 2016; Rutto *et al.*, 2016; Stamp *et al.*, 2012). The development and implementation of policies are often a key component in promoting NUS/FSF into agricultural production systems (Noorani *et al.*, 2015). This section provides an overview of the policy frameworks. It includes the first Global Plan of Action (GPA) for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture (PGRFA) (FAO, 1996) adopted by 150 countries in 1996; the International Treaty on Plant Genetic Resources for Food and Agriculture (the Treaty) that entered into force in 2004, which provides a legal framework whereby governments, farmers, research institutes and agro-industries can share and exchange PGRFA and benefits derived from their use (FAO, 2009); the Second

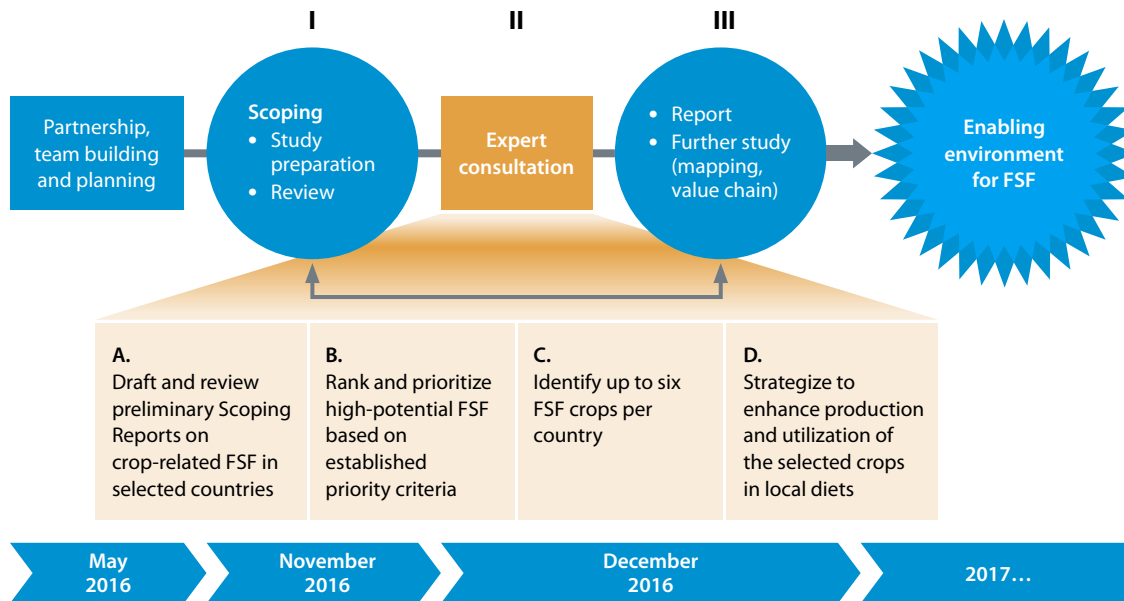
Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA) in 2011 (FAO, 2012b); the Cordoba Declaration (FAO, 2012c), which was elaborated upon at the international seminar on Crops for the XXI Century, and further emphasized the importance of underutilized and promising crops for the international arena; and the Second International Conference on Nutrition (ICN2) held in Rome in 2014, which showcased the profile of NUS and adopted the Rome Declaration on Nutrition. This high-level conference emphasized the importance of NUS through Recommendation 10: "Promote the diversification of crops including underutilized traditional crops, more production of fruits and vegetables, and appropriate production of animal-source products as needed, applying sustainable food production and natural resource management practices." (FAO, 2014a) All these policies reflect recent trends and calls for a global commitment to enhance the conservation and sustainable use of NUS/FSF, and for these frameworks to be translated into actions (see Figure ES.2 for a timeline of relevant international policy developments).

#### 5 Regional priority setting exercise on NUS: Future Smart Food

Given the wide range of NUS and their diverse characteristics and potential benefits, the Zero Hunger Initiative started by scoping, identifying and prioritizing promising NUS at the country level to create a list of NUS capable of helping to close production and nutrition gaps. Apart from their advantages for nutrition and production, the selected NUS also needed to be economically viable and socially acceptable.

The criteria for prioritizing NUS were established in four categories:

- 1 Nutrition (nutritional value and health benefits);
- 2 Production (local knowledge, availability, seasonality, productivity, intercropping and competition from other crops, and processing);

**FIGURE ES.3** Regional priority-setting exercise on scoping, prioritizing and mapping of NUS

- Ecology (agro-ecology, adaptability to potentially changing local climates and soil types), and
- Socio-economy (cultural acceptance and consumer preferences, access to markets and potential income generation).

Each participating country conducted assessments according to these criteria.

The regional priority-setting exercise focused on the following groups:

- cereals,
- horticultural species,
- nuts and pulses,
- roots and tubers, and
- others.

Scoping of NUS was limited to the available species in the national gene bank. Prioritization followed the principles of country ownership and country specificity.

As such, the NUS scoping and prioritization results are owned by the participating countries. International partners offered technical assistance through multidisciplinary reviews and verifications to support each country. The status of NUS is country specific, which means that a species recognized as NUS in one country may not be considered as NUS in another country. Following these principles and criteria, FAO – in collaboration with FAO's Special Ambassador on International Year of Pulses, the University of Western Australia, ICARDA, ICRISAT, MSSRF-LANSA, CATAS-TCGRI,

Mahidol University, ACIAR, ICIMOD, CFF, as well as national governments and research institutes – conducted an interdisciplinary priority-setting exercise (Figure ES.3).

Based on the national scoping studies and international interdisciplinary review, each country prioritized up to six promising NUS as candidates for FSF. The initial results of the FSF selection process in eight countries in South and Southeast Asia (Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, Nepal, Viet Nam and West Bengal in India) are presented in Table ES.1.

**Part I** of the publication contains four thematic chapters (Chapter 2 through Chapter 5) on the features, challenges, opportunities and strategies related to enabling environments required to promote the production, marketing and consumption of FSF.

#### **Chapter 2: Challenges, opportunities and strategies for Neglected and Underutilized Species as Future Smart Food for Zero Hunger**

by Mahmoud Solh argues that the projected 50 percent increase in demand for agricultural production from 2013 to 2050 (FAO, 2017) has to be achieved despite the ongoing degradation of natural resources and the serious implications of climate change on agriculture. Despite impressive progress, more than 800 000 people are still facing hunger globally (FAO, 2017), and many Asian countries are categorized as 'serious' in the Global Hunger Index (GHI) because 20 percent to 34 percent of their populations are undernourished. NUS have important advantages over widely grown commercial crops. They often link with the cultural heritage of their places of origin; are

**TABLE ES.1** Potential Future Smart Food in eight countries in South and Southeast Asia

Cereals	Roots and tubers	Pulses	Fruits and vegetables	Nuts, seeds and spices
Amaranth	Elephant foot yam	Black gram	Chayote	Linseed
Buckwheat	Fancy yam	Cow pea	Drumstick	Nepali butter tree
Finger millet	Purple yam	Faba bean	Fenugreek	Nepali pepper
Foxtail millet	Swamp taro	Grass pea	Indian gooseberry	Perilla
Grain amaranth	Sweet potato	Horse gram	Jackfruit	Walnut
Proso millet	Taro	Lentil	Pumpkin	
Quinoa		Mung bean	Roselle	
Sorghum		Rice bean	Snake gourd	
Specialty rice		Soybean	Wood apple	
Tartary buckwheat				

well adapted to specific agro-ecological niches, harsh environments and marginal lands; and perform well in traditional production systems with little or no external inputs. However, NUS have been given little attention by national research, extension services, policy and decision makers, donors, technology providers and consumers. NUS crops are scarcely represented in *ex-situ* collections and, despite having nutritious and/or medicinal properties or other multiple uses, are often not attractive to the public and private sectors due to social, economic, environmental (e.g. genetic erosion of NUS gene pools), agronomic (e.g. lack of seed supply systems) or political reasons.

There are several examples of NUS that have become important commercial crops. Quinoa and lentil are two NUS crops that attracted global interest despite being important mainly in subsistence agriculture locally or regionally. Quinoa used to be a subsistence crop in the Lake Titicaca basin of Peru and Bolivia, but with rising consumer appreciation, its production in Bolivia, Peru and Ecuador almost tripled from 1992 to 2010. Quinoa cultivation has spread to more than 70 countries, including Denmark, England, France, Holland, India, Italy, Kenya, Sweden and even Australia. The reasons for the fast evolution of quinoa as a commercially important food are its high nutritional value, good taste and quick cooking properties. Quinoa was promoted globally, with 2013 being the International Year of Quinoa; but to reach this stage, quinoa underwent numerous phases:

- Perception change among farmers, processors, policymakers and the public in general
- Improved capacity of researchers, educators, policymakers, farming communities and the private sector
- Better documentation of indigenous knowledge and use, propagation, growth characteristics, nutritional aspects, adaptation to harsh environment, resistant traits and variability

- Improved *ex-situ* and *in-situ* conservation
- Breeding programmes to enhance productivity and quality traits
- Development of seed production systems
- Involvement of stakeholders at all stages in the value chain
- Development of the value chain and exploration of markets at local, national and international levels
- Modernization of agricultural production including mechanization
- Development of post-harvest technology and conservation
- Creation of supportive policy environments including legal frameworks at both national and international levels (incentives such as subsidies to promote targeted species)
- Increased cooperation at national, regional and international levels

Lentil, along with other pulses, is known as 'poor man's meat' in the Middle East, North Africa and South Asia due to its relatively high protein content. In addition to this important nutritional advantage, lentil is well adapted to low input agriculture and its ability to fix atmospheric nitrogen enriches soil fertility and ensures agricultural sustainability.

In Ethiopia, India and Turkey, lentils and other pulses are becoming cash crops, as demand has been rising for local production due to government interventions and investments in research and technology transfer with national and international partners. International agricultural research centres, such as ICARDA, in collaboration with national agricultural research systems, worked, in particular, on better crop management and improved varieties, improved crop genetics, horizontal

expansion of lentil production in rice–fallow replacement, reduction of post-harvest losses, and improved plant architecture and mechanical harvesting.

Particularly in South Asia, lentil development has bridged yield gaps by 65 percent to 75 percent in farmers' fields as a result of improved production packages in rainfed agriculture. Lentil cultivars with high concentrations of iron and zinc have been released in Bangladesh, Ethiopia, India, Nepal, Portugal, Syria and Turkey. In Bangladesh, five bio-fortified varieties covered 90 000 ha or 43 percent of the total lentil cultivated area in 2014.

These examples show that NUS are important for conserving and enhancing biological diversity and protecting fragile ecosystems. However, the potential of NUS goes beyond local niches: they have become globally important both as a means to achieving greater food and nutrition security, and as a response to dealing with the implications of climate change.

### Chapter 3: Future Smart Food: Hidden treasures to address Zero Hunger in a changing climate

by Kadambot H.M. Siddique and Xuan Li highlights the potential of FSF for nutrition enhancement and climate resilience, and points out the compelling need to rethink agricultural strategies in a climate-change context. Production and nutrition gaps will widen if conventional production patterns continue. Finding solutions to bridge the production and nutrition gaps cannot be achieved without a fundamental transformation of the current agricultural and food system. Agricultural diversification with sustainable intensification is a promising strategy for achieving Zero Hunger in a climate-change context, where NUS have a significant role to play.

Most NUS do not require high inputs and can be grown on marginal and degraded lands while contributing to increased agricultural production, crop diversification and a better environment. In turn, food and nutrition security are improved. Pulses, in particular, are a potential health food, reducing risks of chronic diseases, obesity and other conditions. The current over-reliance on a handful of major staple crops (rice, wheat, maize and potato) has inherent agronomic, ecological, nutritional and economic risks. National and international research bodies, non-government organizations, community-based organizations and commercial entities interacting with farmers have not paid enough attention to NUS. However, not all NUS will effectively foster food and nutrition security. NUS have to be assessed and prioritized following established criteria. NUS will be labelled FSF if they are:

- 1 Nutritionally dense,
- 2 Climate resilient,
- 3 Economically viable, and
- 4 Locally available or adaptable.

Pulses are an excellent example of an FSF that exhibits all four criteria.

The chapter shows that the promotion of FSF will:

- contribute to closing nutrition gaps and offer food security and nutrition;
- reduce the risk of over-reliance on limited numbers of staple crops and increase the sustainability of agriculture by reducing inputs;
- provide focused effort to help marginalized and indigenous people improve their livelihoods and income; and
- contribute to the preservation and celebration of cultural diversity.

These characteristics amply justify investments in NUS, as they have enormous potential for bridging the dual production and nutrition gaps. In light of the multi-functionality of NUS, it is time to rediscover these 'hidden treasures'.

### Chapter 4: Future Smart Crops for paddy fallow agri-food systems in Southeast Asia

by Suhas P. Wani and Gajanan L. Sawargaonkar argues that since 1950 the global availability of water and land per capita has declined significantly. In the case of India, per capita water availability declined from 5 177 m<sup>3</sup> in 1951 to 1 820 m<sup>3</sup> in 2001, and is expected to decrease further to 1 341 m<sup>3</sup> in 2025 and 1 140 m<sup>3</sup> by 2050. Water is the primary limiting factor in dryland agriculture. Productivity enhancement studies from Africa and Asia demonstrate an enormous potential for enhancing water-use efficiency as well as increasing the availability of green water. Tapping into this potential is important, as many of the 1 338 million poor people in the world live in dryland/rainfed areas and poverty is strongly linked to variations in rainfall and to the ability of farmers to bridge intra-seasonal dry spells. The adoption of land and water conservation practices, together with crop diversification, improved seed varieties, and integrated nutrient and pest management practices, offers the opportunity for vertical integration of existing cropping systems in South and Southeast Asian countries to meet the increasing food demand. In particular, increased use of paddy fallows could intensify cropping systems and enhance agricultural productivity per unit area.

Paddy remains the most important crop in Southeast Asia, with much of it grown in rainfed conditions. In rainfed paddy, much of the acreage remains fallow in the post-rainy season due to several limitations, primarily due to the limited soil moisture availability in the topsoil layer for crop establishment. Since paddy is grown on some of the most productive lands, there is substantial scope for increasing cropping intensity by introducing a short-duration legume crop with simple seed priming and micronutrient amendments using appropriate technologies. Fallow cultivation also avoids the ecological disadvantages of continuous cereal cropping, while water-efficient short-season grain legumes, which also improve soil health via nitrogen fixation, constitute an ideal secondary crop. However, there are production constraints, including narrow windows for planting, lack of short-duration and high-yielding varieties, poor plant stands due to poor soil-seed contact, and traditional grazing practices, as well as low volumes of crop production and limited markets, non-availability of critical inputs, and scarcity of labour after paddy harvest due to migration.

Potential climate and FSF crops for paddy fallow cultivation include a variety of both warm-season legumes (such as black gram, groundnut, mung bean, pigeon pea, soybean) and cool-season legumes (such as chickpea, faba bean, khesari, lentil, pea), along with nutrient-rich cereals and millet (such as finger millet, pearl millet and sorghum). The inclusion of climate/FSF crops into paddy-based cropping systems can contribute to improved soil structure and nutrition and, as they require less water, they offer better options for safe additional income. Pulses help to improve soil health by fixing nitrogen and increasing soil microbial diversity; leaf droppings provide green manure and, in severely eroded soils, these crops help to conserve topsoil and rejuvenate degraded land. Similarly, pulses are the main source of dietary protein, and the high dietary fibre content in pulses lowers the risk of diabetes, heart ailments and gastrointestinal diseases. To ensure successful cropping system intensification in paddy fallows, efforts need to focus on systemic management of the entire paddy-based cropping system and the promotion of technological interventions for utilization of paddy fallows.

On-farm trials and other studies demonstrate the importance of balanced nutrient management inclusive of secondary and micronutrients. Similarly, the availability of sufficient seed, particularly short-duration varieties, is an important success factor. Therefore, the establishment of decentralized quality seed banks is a possible solution to increase availability of seed, together

with approaches to ensure better crop establishment and the promotion of conservation agriculture. Initiatives, in which these approaches were trialed improved per unit productivity, and increased crop yields in a range from 40 percent to 200 percent and incomes up to 100 percent. Paddy fallows thus offer a promising niche for legume cultivation in Southeast Asia, if promoted in a holistic way, including early sowing, minimal tillage and seed priming. Pulses can bring additional income, improve family nutrition, and enhance the capacity of people to cope with the effects of climate change or other natural disasters.

### **Chapter 5: Promoting and mainstreaming promising NUS as Future Smart Food for Improving food security and nutrition** by S.B. Dandin and Krishna N.K.

Kumar specifies that mainstreaming of biodiversity for food and nutrition security, and climate resilience has been on the international agenda since 1992 with the signing of the Convention on Biological Diversity (CDB). Biodiversity promotion, in general, includes promotion of NUS for their environmental benefits as well as their potential to overcome the challenges of undernutrition and malnutrition. Many NUS – minor cereals, vegetables, legumes, fruit species, root and tuber crops, etc. – form major components of underutilized biodiversity and provide immense support to ecosystem services. More recently, several international consultations and initiatives have highlighted the need for mainstreaming NUS, given their potential to improve dietary diversity.

Minor crops are widely distributed in both hemispheres, covering tropical, subtropical and, to some extent, semi-temperate regions of the world. NUS have remained ignored often for reasons of poor commercial performance, restricted distribution, consumption by small population groups, inadequate research, absence of modern processing and post-harvest methods, and lack of organized value chains and policy support for popularization.

Despite these drawbacks, there has been research in the last two decades covering the importance of underutilized tropical fruits of Asia, the role of underutilized plant species in poverty alleviation, and the relevance of nutritious minor millets in addressing food security challenges. Various authors and institutions have documented initiatives promoting NUS, and a growing list of institutions is active in the research and development of NUS.

Bioversity International has initiated programmes in temperate regions of Central Asia on tropical fruit tree conservation in South and Southeast Asia and Latin

America, and has been involved in, among other activities, various UNEP-GEF and IFAD collaborative programmes and projects. Various bilateral donors, including China, Germany, India, Korea and Malaysia, have supported initiatives on better conservation of germplasm, and promotion of NUS to address food insecurity, poverty and climate change through on-farm conservation of local agrobiodiversity. Bioversity International has initiated a special programme, “Moving from orphan to high potential crops,” aimed at mainstreaming certain NUS and making them more popular to substitute or supplement major food crops in Africa, Asia and Latin America.

FSF have high potential to address malnutrition, climate change and economic constraints in South and Southeast Asia. Understanding the context of the agriculture and food system in each country is of paramount importance when starting any new FSF intervention.

**Part II** (Chapter 6 through Chapter 13) **includes eight country scoping and prioritization studies on FSF**, prepared by national experts from Bangladesh, Bhutan, Cambodia, Lao PDR, Myanmar, Nepal, Viet Nam and West Bengal in India, which provide a comprehensive overview on the status and availability of FSF in the region. Each report has an introductory section with an overview on the country, agro-ecological zones, and status of the current food basket including staple crops, as well as major cropping patterns and crop diversity within these systems. The second section of each study comprises a situation and gap analysis to identify the major challenges each country is facing with regard to hunger and malnutrition, and climate change, as well as economic and cultural aspects. Nutrition challenges are the component with the highest priority and refer to undernourishment; stunting; wasting; underweight; micronutrient deficiencies such as anaemia; vitamin A, zinc or iodine deficiency; and overweight and obesity. Challenges associated with climate change are climate variability (e.g. drought, flood, heat waves) and seasonality that can negatively affect agricultural production systems. In the economic environment, the main risk factors are price fluctuations and commercial potential, distance, access to transportation, and infrastructure. Other challenges are the existing gap between informal and formal markets, unfavourable value-chain arrangements, subsistence farming and local diets, including traditional food habits, food taboos and religious restrictions.

Following the section on addressing the identified major challenges, a detailed scoping and prioritization of the availability and use of FSF in each country was undertaken based on nutritional value, adaptation to local environments and climate change, as well as economic, social and cultural potential. The results of this prioritization process led to a list of up to six proposed crops in each country. These crops can meet some of the prominent malnutrition challenges, as they complement existing cropping systems, and are deemed to be economically feasible and culturally acceptable.

**Bangladesh** (by Md. Amjad Hossain, Md. Tariqul Islam, Rozina Afroz and Taslima Jahan) has made progress towards the elimination of hunger and malnutrition, but still has a high prevalence of stunting and underweight among children, as well as high prevalence of other indicators of malnutrition. Some important crops grown in Bangladesh (potato, pulses and oilseed) require temperatures from 18-25°C. In a climate change scenario, these crops are highly sensitive to fog, cloud and changes in humidity, and are predicted to suffer with rising temperatures.

Cultivation of minor cereals in Bangladesh is limited to stress-prone areas that receive only minimal care. Their share in area and production is negligible; among the minor cereals and pseudo-cereals, foxtail millet (*Setaria italica*) is the only crop cultivated in different areas of the country and can be considered the fourth cereal crop after rice, wheat and maize. Other minor cereals and pseudo-cereals (such as barley, barnyard millet, buckwheat, finger millet and proso millet) are so neglected that they are often considered lost crops. Among the pulses, the same fate has met faba bean, horse gram and winged bean. In the last two decades (1994-2014), pulse production has had a 62 percent decline in area, but an increase in yield has, to some degree, offset this decrease.

Minor and underutilized crops received little attention in the past due to the emphasis on major cereals like rice and wheat. High crop competition during the winter (*rabi*) season makes the scope of horizontal expansion for FSF crops limited to stress-prone areas, and the summer and rainy (*kharif*) season. Improvements in the collection and conservation of germplasm of prioritized FSF crops, coordinated research and development, political commitment, as well as organized seed production and marketing systems are preconditions for successful FSF promotion.

Following the prioritization exercise, Bangladesh selected the following FSF:

- 1 cereal – foxtail millet;
- 2 roots and tubers – taro;
- 3 pulses – mung bean;
- 4 horticultural crops – pumpkin;
- 5 horticultural crops – snake gourd; and
- 6 others – bael (*Aegle marmelos*, a tree species native to Bangladesh and India).

**Bhutan** (by Kailash Pradhan and Ganesh B. Chettri) has made remarkable progress in achieving national as well as regional and international goals and targets. Bhutan is on track to achieve some of the nutrition indicators including reducing wasting in children under five years old, reducing stunting and increasing exclusive breastfeeding. However, due to poor food diversity and accessibility, the prevalence of hidden hunger or malnutrition is quite high in Bhutan. About 21.2 percent of children under five years old are stunted and 9 percent are underweight; and 44 percent of children under five years old and 35 percent of non-pregnant women (aged 15-49 years) are suffering from anaemia. Overall, 68 percent of the dietary energy requirement comes from cereals, mainly rice, and 17 percent from oil. Livestock products, vegetables, fruits and pulses contribute only 25 percent of the energy balance. It is evident from the energy contribution that nutrient intake is limited and diversity of food composition is very poor.

Increasing temperatures and erratic rainfall induced by climate change have negatively impacted food production in Bhutan. The production of major crops is decreasing owing to a decline in soil fertility, inadequate irrigation water, and increasing incidence of pests and diseases.

A major constraint affecting the agriculture sector is the inability to address all the issues along the value chain, even for mainstream crops. Available data show that FSF such as barley, buckwheat, millet and soybean contribute only a small portion to the national food basket but are more important for the household food and nutrition security of small and marginal farmers in rural areas. With the increasing awareness of health and nutrition, consumption and demand are increasing among the urban population, but production technologies are limited, and investment in research and development is negligible.

Six prioritized FSF have a demonstrated potential to improve nutrition and incomes. Their promotion as FSF can address the food and nutritional security of the poor and rural section of the population:

- 1 grains – sweet buckwheat;
- 2 grains – quinoa;
- 3 pulses – soybean;
- 4 pulses – lentil;
- 5 nuts – walnut; and
- 6 others – drumstick/moringa.

In **Cambodia** (by Chhourn Orn and Kynet Kong) the main crop is rice, which is cultivated on approximately 3 million hectares. Cambodian people are the third highest rice consumers in the world (172 kg per person per year). Cambodia has been an important rice exporter since 2005. Cassava is the second major crop, mainly cultivated for starch and bioenergy production. Other crops, including maize and mung bean, are important food crops in upland areas. In some marginal areas, root crops, such as sweet potato and local cassava, are planted to generate income, food security and nutrition.

Cambodia has made some progress concerning child malnutrition, but diets remain dominated by rice. Cambodia is one of the most vulnerable countries to climate change. Scientists predict that climate change will profoundly affect Cambodia's coastal residents, ecosystems and economy. For example, rainfall in Cambodia is expected to increase from 3 percent to 35 percent, exacerbating the already high damage from flooding.

NUS are mostly grown in small quantities for local use only. Local people often do not have sufficient facility or knowledge to process their agricultural products to meet market standards, and public awareness of the benefit of NUS, such as the nutritive value, is limited. As a result, some traditional underutilized crops are being displaced due to pressure from imported species, and demography and household structure changes. In contrast, where markets are available, underutilized crops play an important role in the lives of the rural poor because they contribute to livelihoods, poverty alleviation and sustainable environments. NUS have been rapidly replaced by introduced varieties. Promotional efforts would require germplasm collection of endangered species, documentation of collected materials, development of diversified cropping systems that include NUS, improved public awareness of the importance of NUS for nutritional value and health



benefits, and research on sustainable management practices for underutilized species and improved marketing.

From the shortlist of 16 crops, six were prioritized as FSF in Cambodia:

- 1 pulses – wild vigna (*Vigna umbellata*);
- 2 roots and tubers – sweet potato (*Ipomoea batatas*);
- 3 roots and tubers – taro (*Colocasia esculenta*);
- 4 nuts – peanut (*Arachis hypogaea*);
- 5 others – Sleuk Bah/ivy gourd (*Coccinia grandis*); and
- 6 others – drumstick (*Moringa oleifera*).

In **Lao PDR** (by Sivienkhek Phommalth), rice is the key crop for national food and livelihood security. Lao people consume on average 165.5 kg of milled rice per head per year. Seventy-three percent of the population is employed in the rice sector, which accounts for 25 percent of the GDP. The total agricultural sector accounts for 30.8 percent of the national GDP. The main threats to agricultural diversity stem from deforestation, over-exploitation, clearing for infrastructure development, the extension of farming systems into frontier zones, mechanization of agriculture and adoption of new, high-yielding varieties. The change from a subsistence to an open-market economy, and the availability of fertilizers and other inputs, are contributing to genetic erosion in several crops such as legumes, local vegetables and rice.

In Lao PDR, chronic malnutrition affects 378 388 or 44 percent of the children under five years old, one of the highest rates in Southeast Asia. Micronutrient deficiency rates are also high with 41 percent of children under five years old and 59 percent of children under two years old suffering from anaemia, the latter figure being especially high. Although the underweight malnutrition rate among children under five years old fell from 32 percent in 2006 to 27 percent in 2012, the sudden malnutrition (wasting) rate stood still at 6 percent. Moreover, the chronic and underweight malnutrition rates of the 6-24 month age group are markedly higher than those of other age groups. Scientists predict that in Lao PDR, climate change will lead to rising temperatures, longer dry seasons and more erratic rainfall. The marketing of agricultural products in Lao PDR tends to be regionally confined, resulting in significant variation in market prices from region to region. Also, limited human resource capacity, poor agricultural support and delivery services, and the lack of medium-term and short-term credit and other financial services hamper agricultural development.

For Lao PDR's prioritized FSF, most information is based on indigenous knowledge passed on from generation to generation. This information is scattered and not systematic and there is also a lack of human resources for FSF research and development. However, the Government will consider and invest more in research and development of FSF because of the national strategy to promote food and nutrition security.

The following FSF crops in Lao PDR have been prioritized:

- 1 roots and tubers – taro;
- 2 roots and tubers – purple yam;
- 3 roots and tubers – fancy yam;
- 4 pulses – mung bean;
- 5 pulses – rice bean; and
- 6 pulses – cowpea.

**Myanmar** (by Min San Thein and Khin Mar Oo) is a surplus producer of rice. Other important food crops are food legumes, fruits, maize, oilseeds, sugarcane, vegetables and wheat. Myanmar is one of the major pulse exporting countries in the world. However, there is still a gap between production and demand that accounts for hidden hunger in the country. Dietary quality in Myanmar is considered poor, being low in protein and vitamins, and high in carbohydrates. Cereals remain the most important source of food energy (50 percent), but their contribution to overall daily energy supply has decreased since 1990. Products from animal origins, such as eggs, milk and meat, have increased notably. Anaemia in Myanmar is a severe public health issue, and is extremely high among pregnant women (71 percent), children under five years old (75 percent) and non-pregnant women (45 percent). Stunting and underweight are more than twice as common in the poorest quintile as in the wealthiest quintile. Severely high rates of vitamin A deficiency (37 percent of pre-schoolers) co-exist with iron deficiency, especially among children and women.

Agriculture value chains are not very advanced; farmers generally sell their produce at the primary market due to constraints such as the lack of a credit system, high transport costs, no storage facilities, lack of market information, and price instability.

Among Myanmar's selected FSF, sorghum has been identified as an important crop for climate adaptation, both for food and feed in the dry zones of Myanmar, but research on outstanding varieties is needed. Among roots and tubers, elephant foot yam has been selected

as a rich source of starch, vitamins and minerals. Over-exploitation may endanger the genetic base; and domestication and identification of elite genotypes for cultivation as FSF will become crucial.

The following FSF crops in Myanmar have been prioritized:

- 1 cereals – specialty rice/Namathalay (*Oryza sativa* L.);
- 2 cereals – sorghum;
- 3 roots and tubers – elephant foot yam;
- 4 horticultural crops – roselle;
- 5 horticultural crops – drumstick; and
- 6 others – amla (*Embllica officinalis*).

**Nepal** (by Bal K. Joshi and Renuka Shrestha) has diverse agro-ecological zones, ranging from tropical to arctic. Agriculture, including forestry and fishery, is the principal economic activity in Nepal, employing about 66 percent of the population and providing 32.7 percent of the GDP and 60 percent of export earnings (ABPSD, 2015). The total cultivated area of agricultural land is 3 091 000 ha while the uncultivated area is 1 030 000 ha. Agriculture is basically subsistence, with crops, livestock and forests as the three major components of the complex farming system; cereal crops (maize, rice and wheat) are the main crops, followed by lentil and potato. In the lowlands, rice is the major staple crop followed by wheat, and in the hills, maize is the most important food crop. In high hills, potato is the main food crop, followed by maize, buckwheat and barley. Rice is the major source of energy for most Nepali people.

Nepal ranks 157th of 187 countries on UNDP's Human Development Index. The distribution of malnutrition varies geographically by ecological zone and rural/urban residence. The Nepal Demographic and Health Survey (2011) reported that the prevalence of stunting and severe stunting in children under five years old was 41 percent and 16 percent, respectively. Micronutrient deficiencies are widespread, with almost half of pregnant women and children under five years old and 35 percent of women of reproductive age being anaemic.

Nepal is ranked the fourth most-vulnerable country in the world; and its natural-resource-based livelihoods and economy, political conflicts, and low adaptation potential make it vulnerable to climate change. The impact of climate change in Nepal is evident in the increased melting of glaciers, warmer days and nights, erratic monsoons (drought and flood), increased number of rainy days with more than 100 mm per day, and extreme foggy and cold periods.

Agricultural constraints include low-volume production in scattered areas, lack of processing facilities, lack of knowledge of processing and product diversification, and consumer ignorance of nutritional values. Most of the potential FSF in Nepal are considered socio-culturally inferior (e.g. colocasia, grass pea and millet), despite being nutritionally rich. Most FSF are localized and produced and consumed by poor people and the lower caste (e.g. *dalit*, *damai*, *kami*). At the local level, there is much diversity in FSF, but they are not grown widely by many households.

In Nepal the following six FSF crops have been prioritized:

- 1 cereals – tartary buckwheat (*Fagopyrum tataricum* L.);
- 2 pulses – grass pea (*Vicia sativa* L.);
- 3 roots and tubers – taro (*Colocasia esculenta* L.);
- 4 horticultural crops – drumstick (*Moringa oleifera* Lam.);
- 5 fruits – jackfruit (*Artocarpus heterophyllus* Lam.); and
- 6 oilseeds – Nepal butter tree (*Bassia latifolia* Roxb.).

**Viet Nam** (by Pham Hung Cuong) can be divided into eight eco-agricultural zones. Its traditional farming base is an integrated system of rice and other crops. Viet Nam's agricultural share of economic output declined from about 25 percent in 2000 to 17 percent in 2016. Cereals are the main source of energy in the Vietnamese diet providing 78 percent of total energy. The main food is rice, with an average daily consumption of 400 g per person in all regions of the country. Other staple foods such as corn and cassava are grown in the mountainous and plateau regions, sweet potatoes are grown in the plain regions, and roots and tubers are grown in the midland and mountainous regions.

In addition to rice and other staple foods, vegetables, tubers, fruits, oily nuts, beans, soya beans and soya products (tofu, soy sauce and soymilk) play an important role in the Vietnamese diet. The diversity of vegetables includes amaranth, bottle gourd, broccoli, cabbage, celery, chayote, Indian spinach, jute, kohlrabi, lettuce, luffa, pumpkins, radish, squash, star-gooseberry, vegetable beans and water spinach. The daily diet also includes diverse fruits depending on the region. Popular fruits are banana, grapefruit, guava, jackfruit, mango, oranges, papaya and tangerines. In the daily diet, along with plentiful seafood, the amount of meat and animal products has increased significantly.

Viet Nam has made good progress in reducing stunting, which declined from 23 percent in 2011 to 19 percent

in 2015. However, overweight and obesity have become a national concern affecting 5 percent of children and 8 percent of women, while at the same time, twice as many women are underweight. Iodine deficiency has resurfaced as a significant public health concern; anaemia continues to affect children under five years old and non-pregnant women. According to a report of the National Institute of Nutrition, the rate of anaemia among women of childbearing age (not pregnant) is 29 percent and among pregnant women is 36.5 percent, reaching its highest percentage in the northern mountainous domain and Central Highlands with nearly 60 percent.

Crop yields in Viet Nam are above the mean level for Asia due to high applications of agricultural inputs and the conversion of marginal lands previously regarded as unsuitable for agriculture. However, over-intensive land utilization is increasing soil erosion and reducing soil fertility. High-intensity rainfall, suboptimal irrigation techniques, and a lack of incentives for farmers to adopt sustainable natural-resource management has led to high levels of soil loss, as well as pesticide and fertilizer runoff, which reduces productivity and causes groundwater and surface water contamination. In economic terms, rural value-chain stakeholders generally only receive a meager share of the value of the final agro-product, usually due to the small scale of production, non-homogenous product quality, poor market information and knowledge, high transaction cost per unit of marketed product, cash shortage, and perishability of product. NUS are grown primarily by native farmers in their place of origin, where they are still important for the livelihood of local communities, or were once more widely grown but are today falling into disuse for a variety of agronomic, genetic, economic and cultural factors.

The following FSF crops in Viet Nam have been prioritized:

- 1 cereals – buckwheat/*mạch ba góc*;
- 2 roots and tubers – taro/*khoai môn sọ*;
- 3 roots and tubers – greater yam/*củ mỡ*;
- 4) pulses – cowpea/*Đậu các loại*;
- 4 pulses – mung bean/*Đậu xanh*; and
- 5 horticultural crops – pumpkin/*bí ngô*.

**West Bengal in India** (by Apurba Kumar Chowdhury) has a rice-based agricultural system, but other cereals play an important role, and the production and consumption of vegetables is high. The cropping pattern is dominated by rice, followed by cereals (all combined), oilseeds, jute and potato. Since the late 1990s,

horticultural crops such as vegetables and fruits have been gaining ground, probably due to the higher relative return to cultivators. India is facing a huge challenge related to the poor nutritional status of the population, and West Bengal is marginally better than the country overall. The main causes of malnutrition in the state are deficiencies in childcare and poor feeding practices.

Many underutilized nutritious crops exist in West Bengal but only benefit those who live in areas where these plants grow, as technologies to preserve and store NUS have not been developed. Local foods are rarely a subject of research; however, the Indian Council of Agricultural Research (ICAR) has made efforts to develop superior varieties of indigenous and underutilized crops.

West Bengal has prioritized the following FSF for intervention:

- 1 cereals – aromatic rice/*Kalo Nunia*,
- 2 root crops – swamp taro, sweet potato and elephant foot yam,
- 3 pulses – lentil, black gram and green gram; and
- 4 horticultural crops – jackfruit, drumstick, amaranthus and fenugreek.

**Chapter 14: Conclusion: Way forward** (by Kadambot H.M. Siddique, Mahmoud Solh and Xuan Li) states that hunger, food insecurity and malnutrition are major challenges in the twenty-first century for Asia and the Pacific. To achieve Zero Hunger, which stands at the core of the SDGs, food systems need to be improved urgently, and dietary patterns have to change. There are disconnects in the value chain between production, consumption and nutrition. Current agricultural production patterns are not sustainable, are unlikely to achieve necessary growth rates, and do not offer the right mix of nutrients needed for a healthy diet. Consumers are often unaware of their potential food choices and stick to dietary patterns that do not agree with an urbanized lifestyle. Poor people's diets are still over-dependent on a few staple crops that lack important nutrients and minerals. At the same time, the newly affluent strata of society have begun to suffer from obesity and related health issues.

Agricultural diversification and resilience offer enormous opportunities for addressing hunger and malnutrition, especially in the context of climate change. In this regard, NUS offer diverse and nutritious food resources. NUS are important in specific agro-ecological niches, often linked with tradition and cultural heritage in their places of origin. They are an essential source of protein and

micronutrients, they enhance climate resilience, improve agriculture sustainability, and boost household income and livelihoods with considerable commercial potential.

The report expands on the message formulated by a Regional Expert Consultation on Scoping, Prioritizing and Mapping of NUS, organized by FAO in collaboration with national and international partners, which was held in Bangkok from 3-5 December 2016. The panel of experts, representing eight countries, as well as 22 national and international partners, attended the Consultation and developed ten key recommendations:

- 1 Urgent call for decision makers to raise awareness of the nutrition-sensitive and climate-resilient benefits of NUS to address hunger, malnutrition and climate change.
- 2 Recognize, identify and promote complementarities of NUS with existing staple crops for nutrition enhancement, climate-change resilience and diversification of cropping systems, and reliable NUS as Future Smart Food (FSF) to popularize these species.
- 3 Establish a National Coordinating Committee on FSF involving concerned ministries and appoint a Strategic Coordinator at the inter-ministerial level.
- 4 Create an enabling environment by strengthening national institutional support for mainstreaming FSF into national policies and programmes, using appropriate incentives, procurement of FSF for food programmes (e.g. mid-day meal/school-meal schemes) to enhance national consumption, local production and facilitate marketing.
- 5 Establish nationally coordinated research for development programmes targeting FSF with high potential, and expand coverage of national agriculture statistics and national food composition data on FSF for evidence-based decision making.
- 6 Document and validate best-bet FSF case studies, compile indigenous knowledge related to FSF, undertake clinical and field studies to demonstrate the health benefits and climate resilience of FSF, and assemble quantitative data for public dissemination.
- 7 Enhance public awareness of the importance of FSF by developing nutrition and climate-change education materials and curricula on the importance of FSF for consumers, traders, producers, health professionals, researchers, teachers (e.g. school curricula), farmers, women and youth.
- 8 Identify key entry points in the value chain and encourage value-chain development for specific FSF, including innovative and targeted interventions for promotion (e.g. ready-to-use food products) and increase funds for research, development and extension capacities on FSF production and processing technologies.
- 9 Strengthen multidisciplinary and multi-sectoral collaboration through existing coordination mechanisms and build partnerships at national and regional levels, including academia, civil society and the private sector, to enhance research and consumption and to attract the private sector to boost production, processing, value addition, product development and marketing of FSF.
- 10 Establish a regionally coordinated network on FSF to facilitate the exchange of information, policy, technologies and genetic resources, as well as FSF promotion, in target countries.

Addressing hunger and malnutrition in a changing climate is considered a top priority by most countries in Asia. Within an agricultural diversification and sustainable intensification strategy, promoting FSF through a food systems approach is a cost-effective intervention to address the dual challenge of malnutrition and climate change. An enabling environment for promoting FSF is essential. This requires a long-term vision and holistic approach that integrates political, economic and environmental aspects, multi-stakeholder cooperation, and forward-looking institutions covering production, marketing and consumption stages.



# 1 Introduction: Setting the scene

Xuan Li, Kadambot H.M. Siddique, Festus Akinnifesi, Karel Callens, Sumiter Broca, Arshiya Noorani, Günter Henrich, Mba Chikelu and Nomindelger Bayasgalanbat

## 1.1 Context

The eradication of hunger and all forms of malnutrition is central to the Sustainable Development Goals (SDGs). SDG 2 focuses specifically on ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture by 2030. Attaining Zero Hunger implies leaving no-one behind regarding hunger and all forms of malnutrition. Achieving the Zero Hunger vision under Agenda 2030 requires food systems that are economically efficient, socially inclusive and environmentally sustainable. To ensure that everyone has access to sufficient nutritious food today and tomorrow, requires widespread promotion of sustainable agriculture and conservation of biodiversity; enhanced livelihoods of smallholder farmers, including fishers, foresters and pastoralists; and increased investment in agriculture, markets, agribusinesses and related infrastructures.<sup>3</sup>

In the Asia and Pacific region a number of challenges lie ahead. First, the absolute number of hungry and malnourished people in the region remains high and may have already begun to rise again.<sup>4</sup> In fact, Asia is the continent with the most undernourished people (515 million), of whom 272 million are in the Southern Asia sub-region (FAO, SOFI, 2017). While Southeast Asia has achieved the many of the Millennium Development Goals (MDGs) and the World Food Summit (WFS) hunger target – a more demanding target of halving the absolute number of undernourished people by 2015 – it is estimated that 64.8 million people remain undernourished (FAO, SOFI, 2017). Furthermore, micronutrient deficiencies are widespread in many countries of Southeast Asia and South Asia. The incidence of undernutrition is costing countries in the form of lost productivity and increased pressure on health systems. It is estimated that annual costs can be as much as USD 700 million for Bangladesh (World Bank, 2013), USD 134 million for Cambodia

(World Bank, 2011a) and USD 544 million for Viet Nam (World Bank, 2011b).

Second, on the production side, yield growth in major staple crops is slowing down and appears to have reached a plateau. In addition, climate-change projections indicate a worsening environment for agriculture, with Asia being hit especially hard. From 1989-2008, global yield increase rates averaged only 1.6 percent for maize, 1.0 percent for rice, and 0.9 percent for wheat (Ray *et al.*, 2013). It is expected that weather, and agricultural seasons will become more extreme and farming will be negatively affected by climate change. For Asia, some studies predict that while climate change will reduce yields of the most important crops in developing countries, South Asia will be particularly hard hit. Climate change will have varying effects on irrigated yields across regions, but irrigated yields for all crops in South Asia will experience large declines (Nelson *et al.*, 2009).

In light of the above, the case can be made for better links between production, consumption and nutrition to tackle malnutrition and its causes, especially in terms of diversifying agricultural and food systems. Diversified agricultural systems would reduce over-reliance on a few staple crops that are close to their intrinsic yield levels. Moreover, agricultural diversification also gives farmers a better chance to cope with the effects of climate change. Further still, dietary diversification is a cost-effective, affordable and sustainable means of strengthening local food systems and reducing hunger and malnutrition. Recognizing the complex range of factors that contribute to hunger and malnutrition, recent reviews highlight the need to focus on multi-sectoral approaches to ensure that agricultural production utilizes the potential of crops with better nutritional qualities for improved and diversified diets.

<sup>3</sup> 2017 HLPF Thematic review of SDG2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. (also available at [https://sustainabledevelopment.un.org/content/documents/14371SDG2\\_format.revised\\_FINAL\\_28\\_04.pdf](https://sustainabledevelopment.un.org/content/documents/14371SDG2_format.revised_FINAL_28_04.pdf)).

<sup>4</sup> FAO. 2017. Asia and the Pacific Regional Overview of Food Security and Nutrition. (also available at [www.fao.org/3/a-i7930e.pdf](http://www.fao.org/3/a-i7930e.pdf)).

This introductory chapter highlights some of the key challenges, features and gaps, and implications of the current food systems in Asia. It also establishes a link between theory and practice on diversification by presenting case studies from a regional priority-setting exercise on neglected and underutilized species (NUS) in selected Asian countries. Considering the wide coverage of NUS, including crops, livestock, fisheries and aquaculture, and forests, this regional priority-setting exercise set crops as an entry point among NUS to address hunger and malnutrition.

### 1.2 Agriculture and food systems

From a food system perspective, how do we address hunger and malnutrition? Food is consumed by individuals according to their energy requirements, which are conditioned by age, sex, body weight, physical activity, health and temperature, among others factors. Consuming less food than the daily dietary energy requirement leads to chronic undernourishment while consuming more than the daily dietary energy requirement results in overweight and obesity. In addition to providing energy, a balanced diet needs to provide macro- and micronutrients, vitamins and minerals. Without them, the body's immune functions, work capacity and cognitive development faculties, including learning capacity in children, will be impaired. Scientific evidence suggests that micronutrients, vitamins, and minerals play an important role in preventing diet-related chronic diseases, one of modern society's major causes of morbidity and mortality. The objective of this section is to present a broad picture of the main features of agriculture and food systems, and the main challenges and their implications for agriculture and food systems.

#### 1.2.1 Main features of agriculture and food systems

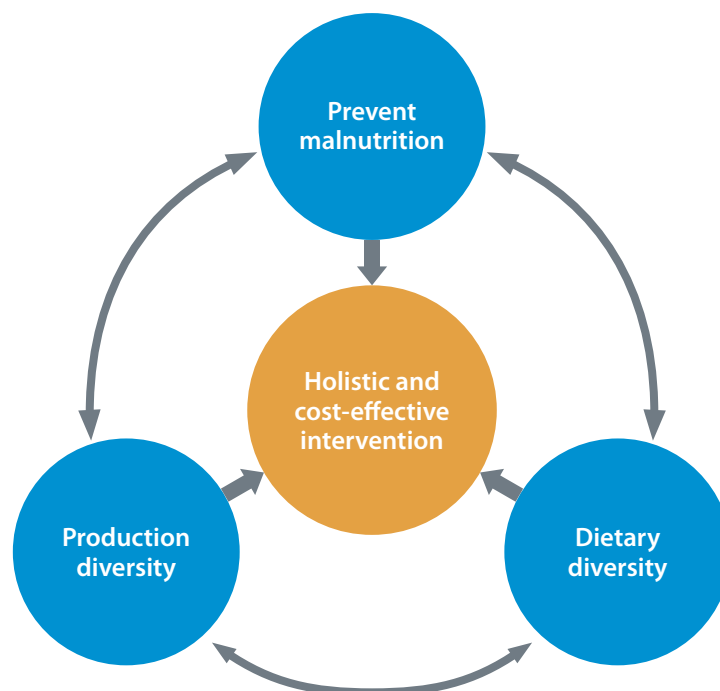
While most policies aim to increase food production to meet the dietary energy requirement of the growing population, malnutrition is still predominant in the

region. One of the basic causes of malnutrition is an inadequate diet lacking the sufficient nutrients, minerals and vitamins in terms of quantity and quality for healthy body growth and maintenance. Inadequate diets affect the health of individuals leading to diseases and sometimes death, and have a direct negative effect on the socio-economic development of a country. Malnutrition affects mostly children and women, particularly those of reproductive age. While stunting, underweight and wasting are the most common outcome indicators among children under 5 years old. Anaemia and vitamin A deficiency are those indicators assessing the health status of both women and children.

What has gone wrong? There is a clear relationship between malnutrition, low dietary diversity and limited diversity in agricultural production (see Figure 1.1). From a consumption perspective, many people are consuming too little nutritious food, which would be good for health, and too much food is being produced that doesn't offer enough nutrients – often because of the policies that governments pursue. Stakeholders along the agriculture and food value chain are affected by a disconnect between production and consumption patterns and knowledge about nutrition, which results in a poor overall nutritional status among too many people. So, in order to achieve Zero Hunger, which is at the core of the SDGs, it is crucial to improve dietary patterns and production systems.

From a production perspective, one of the key factors is a lack of diversification and over-concentration on a few staple crops, especially rice in Asia. This over-reliance on one staple crop is a leading cause of persistent malnutrition and low dietary diversity. While rice fills the stomach, a rice-dominated diet provides only low to zero amounts of protein, amino acids and essential micronutrients, which can be found, for example, in pulses, fruits, nuts, tubers, vegetables, fish, meat and edible insects. The dependency on rice leads to insufficient intake of nutrient-rich foods, which in turn leads to a significant 'nutrition gap'.

FIGURE 1.1 Features of agriculture and food systems



A leading cause of persistent malnutrition is poor dietary diversity (poor quality and variety of food in the diet) as well as low production diversity. Dietary diversity is low when there is high consumption of cereals, mainly rice, but relatively low intakes of vegetables, fruits and pulses which are known to be rich in micronutrients and fibre. The majority of agricultural households in Asia grow rice and there is a correlation between the human intake of rice and the areas that produce rice. In Lao PDR, for example, 81 percent of the daily food supply consists of cereals.

Two key features of agriculture and food systems in South and Southeast Asia are:

- Limited production diversity leads to unbalanced diets, and ultimately to malnutrition. Agriculture has concentrated on a few staple crops, which in turn make up the bulk of people's diets. Without diversity, these crops do not provide wholesome nutrition.
- Mainstream agricultural production that relies on a few staple crops with high input requirements make farming more vulnerable to environmental shocks. According to Graziano da Silva (FAO, 2012a), dependence on a few crops has adverse consequences for ecosystems, food diversity and health. Food monotony also increases the risk of micronutrient deficiency.

### 1.2.2 Challenges: Implications for agriculture and food systems

From a demand perspective, world food security over the next decades will be threatened by numerous challenges. The world population is around 7 billion and is expected to increase to 9.7 billion by 2050 (UN, World Population Prospects, 2015). Population growth will increase the demand for food, which will, in turn, exert pressure on the agriculture sector to increase productivity. This situation will be further exacerbated by changing consumption and dietary patterns with increasing preference for quality, food safety and convenience foods. Asian countries will experience increasing urbanization and rising middle-class incomes, which will have a huge impact on the region's future food consumption patterns. Currently, about 45 percent of the world population lives in urban areas; by 2050, the population in urban areas is expected to increase to 66 percent (UN, World Urbanization Prospect, 2014). Rising incomes will lead to changing dietary patterns: consumers will reduce their intake of traditional staples such as rice, and spend more on other cereals, pulses, fruits and vegetables; they are also likely to eat more meat and dairy products.

Looking at food security from the supply side, the levels of yield growth of staple crops, as illustrated earlier, including maize (1.6 percent), rice (1.6 percent) and wheat (0.9 percent), are insufficient to meet future food demands without resorting to agricultural land expansion. The population in the Asia Pacific region is projected to rise from around 4.5 billion to 5.2 billion by



2050 (UN ESCAP, 2016),(UN DESA, 2015). Asia has little arable land available for expansion. For example, ASEAN's arable land makes up just 15.6 percent of its total land area, and little space is available for expansion (Desker *et al.*, 2013). Without an expansion of agricultural area, farmers in ASEAN countries would need to achieve annual yield increase rates of more than 1.7 percent to feed the growing population. In addition, some studies predict that in South Asia, the climate-change scenario would result in a 14 percent decline in rice production relative to the no-climate-change scenario, a 44-49 percent decline in wheat production, and a 9-19 percent fall in maize production (IFPRI, 2009). So, how to bridge the food security gaps remains an enormous challenge, which can only be met with a fundamental transformation of current food and agricultural systems.

Given that conventional staple crop production is unlikely to yield enough food under the above-mentioned circumstances, it is critical to develop alternative strategies. Commercial crop production, based on the monoculture model, has led to the loss of biodiversity and ecological imbalance. An estimated 75 percent of crop genetic diversity has been lost since the 1900s (FAO, SOFI, 2017). Currently, only three crop species (wheat, rice, and maize) represent virtually half of the average daily calories consumed by the world population (FAO, SOFI, 2017). This dependence poses a threat to food security in the context of climate change. In particular, changes in temperature and rainfall patterns will disturb conventional agriculture and disrupt the performance of traditional staple crops, undermining food security and, especially, the livelihoods and food security of vulnerable groups such as smallholder farmers, children, women, and indigenous people who have come to depend on these crops.

### 1.2.3 Production and nutrition gaps in meeting the challenges of food systems

In an era of rapid change and growing uncertainty, our food systems are encountering two key challenges that may limit their long-term sustainability and capacity to meet hunger and nutrition goals. The first is the production gap. Will the growing global population have enough food to meet its nutritional needs? To feed an additional two billion people by 2050, food production will need to increase by half globally (FAO, SOFI, 2017). Increasing the production of traditional staple crops is unlikely to meet the increasing demand; in major irrigated wheat, rice and maize systems, yields appear to be near 80 percent of the yield potential. Relying on these crops alone will develop a major gap between

food supply and demand. The second challenge is the nutrition gap between what foods are grown and available, and what foods are needed for good health. This requires increasing the availability and access to the nutritious foods necessary for a healthy diet. Increasing the production of staple crops is not enough to accelerate reductions in malnutrition due to the insufficient supply of nutrient-rich foods. Conventional staple foods do not supply all the nutrients needed for a balanced diet. Tackling the health problems caused by malnutrition requires a transformation of current agriculture and food systems towards more diversity at all levels. In sum, the ramifications of the global challenges facing agriculture and food systems require a paradigm shift that emphasizes sustainable production and the consumption of nutritious food.

### 1.3 Neglected and Underutilized Species as entry points for addressing malnutrition from a food system perspective

This report asks a number of important questions. How do we address the high prevalence of malnutrition from a food system perspective? What is the appropriate entry point to tackle the nutritional gap? How do we tap local agro-biodiversity potential to meet nutritional requirements? NUS are those that have received little attention or have been entirely ignored by agricultural researchers, plant breeders and policymakers. They include wild or semi-domesticated varieties and non-timber forest species that are not typically traded as commodities (Padulosi *et al.*, 2013). Among NUS, those that are nutrition dense, climate resilient, economically viable, and locally available or adaptable offer the potential to address hunger and malnutrition.

Dietary diversity is a cost-effective, affordable and sustainable means of eradicating hunger and malnutrition. From a food system perspective, dietary and production diversity need to improve to address malnutrition. Dietary diversification needs to take advantage of the opportunities offered by NUS, which could contribute to increasing food availability, affordability and stability.

Agro-biodiversity is essential to sustainable agriculture, and NUS are key elements. According to Garn and Leonard, between 300 000 and 500 000 plant species exist, of which 30 000 are identified as edible plant species. Of these, more than 7 000 crop species have been either cultivated and domesticated for food, or collected from the wild throughout the history of

humanity (Garn and Leonard, 1989). Of greater concern is the fact that no more than 150 crop species are cultivated commercially and, of these, only 103 provide up to 90 percent of the calories in the human diet. Only three main crops, namely rice, maize and wheat, provide 60 percent of the world's food energy intake (FAO, 1995). Thus, tens of thousands of edible plant species remain relatively 'underutilized', with respect to their ability to contribute to the world's increasing food requirements (Chivenge and Mabhaudhi, 2015).

Broadly, crops can be divided into two main categories: staple crops and underutilized crops. Underutilized crops (sometimes called 'neglected', 'minor', 'orphan', 'promising', or 'little-used') usually belong – but are not limited to – the non-staple foods. They are mostly wild or semi-domesticated species adapted to local environments. These traditional foods have often been in use for centuries, but have become increasingly neglected in modern times as more productive, profitable and improved crops replaced them in farming systems. As a result of agricultural modernization and widespread promotion of technology in support of high-yielding varieties, some NUS have even been forced into extinction due to genetic erosion. This increasing oversimplification of agriculture and food systems has led to NUS playing a marginal role in current farming and food systems. Worse still, their perception as 'food of the poor' often stigmatizes them, creating a disincentive for their production and consumption.

Although NUS are underexplored, they offer tremendous opportunities for fighting poverty, hunger and malnutrition. As the FAO Director-General highlighted, NUS play a crucial role in the fight against hunger and are a key resource for agriculture and rural development (FAO, 2012a). Historically, underutilized plants have been used for food and other uses on a large scale, and in some countries are still common especially among small or marginal farmers in rural areas. Many are traded locally and a few have been lucky to make their way to export niche markets around the world (Akinnifesi *et al.*, 2008). NUS have high nutritional value and can be an essential source of micronutrients, protein, energy and fibre, which may contribute to food and nutrition security. As well as their superior nutritional qualities, many of these crops do not require high farming inputs. Some can be grown in marginal lands and easily intercropped or rotated with staple crops, and can easily fit integrated practices such as agro-ecology. Because they are frequently adapted to marginal conditions, many NUS have the unique ability to tolerate or withstand stresses, and they can make production systems more sustainable and climate-resilient.

Wider use of today's underutilized crops will provide more options for building temporal and spatial diversity into cropping systems, which may enhance the resilience of production systems exposed to both biotic and abiotic stresses. Some NUS have considerable commercial value, such as vegetables and fruits, and therefore contribute to increasing household income. By virtue of being locally available or adaptable, NUS are easily accessible and affordable to the local population, therefore contributing to food security, nutrition and cultural dietary diversity.

### Combating food insecurity and building resilience

From the perspective of sustaining long-term food security, the world's current food system is vulnerable as it relies on a very narrow range of food items. Current farming systems favour monocultures and standardized approaches; this is faster and more convenient for producers but may undermine food security, nutrition and biodiversity. Relying on a very small fraction of staple crops for our diet has dire implications for both food security and nutrition. The lack of genetic diversity within the gene pools of the dominant cultivated crops, leaves agricultural systems vulnerable to pests, diseases and other abiotic stresses.

Rediscovering neglected crops is one way to reduce over-reliance on a few major crops. Agricultural sustainability relies on a healthy interaction between agriculture and nature. This web of organic interactions operates at three hierarchical levels of genetic diversity: agro-ecosystems, diversity among species (inter-specific diversity), and within species (intra-specific diversity). Intra-specific diversity is the simplest form of diversity that would prevent a devastating scenario such as the Irish potato famine, which saw over a million people die of starvation almost 200 years ago. Marginalizing neglected plants endangers agro-biodiversity and threatens the sustainability of our food systems. Often, NUS can increase agricultural sustainability by reducing the need for external inputs, such as inorganic fertilizers and pesticides. Integrating promising NUS in farming systems can reduce the build-up of pests and diseases when they are grown in rotation with the main crops. Depending on their characteristics, NUS can also increase soil fertility, prevent soil erosion, reduce evaporation and suppress weed growth.

NUS are often less demanding of their environment, and so offer stronger resilience to climate change. They can be more resistant to biotic stresses and provide dependable harvests under unfavourable climatic conditions or depleted soils. For instance, DeFries *et al.* (2016) found in Central India that small millets were more resilient to climate variability compared to rice,

which was more sensitive to rainfall variability. Canahua (*Chenopodium pallidicaule*), an underutilized Andean plant that is part of the spinach family and closely related to quinoa, with more than 200 varieties. It is remarkably frost-tolerant and has high nutritional value in terms of protein content and dietary fibre levels close to quinoa. (*Chenopodium quinoa*) (Giuliani, *et al*, 2012). This adaptive capacity is one of the key traits of many NUS. They can be grown in areas where major staples requiring high inputs fail, and they to be more resistant to local pests and diseases. In addition, several NUS in Asia are perennial crops, such as jackfruit, bread fruit and bread nut (*Artocarpus* spp.), mangosteen (*Garcinia mangostana*), durian (*Durio zibethinus*) and rambutan (*Nephelium lappaceum*). Thus, NUS provide a safety net when the weather conditions are unfavourable, or when external inputs become unavailable, unaffordable or harmful to the environment.

### It is time to make a dent in malnutrition

Despite decades of economic growth in Asia, the double burden of undernutrition and obesity is still prevalent among children. The 'hidden hunger', defined as the insufficiency of vitamins and minerals even if energy intake is met, affects both developed and developing countries. Of the world's estimated seven billion people, 500 million suffer from protein-energy malnutrition. More than 1 600 million suffer from iron deficiency, and Over 200 million are affected by vitamin A insufficiency. It has been estimated that more than 400 000 children die every year from effects related directly to zinc deficiency. The estimated costs for interventions to address undernutrition is relatively small compared with the expected benefits. In Bangladesh, interventions are estimated to cost USD 65 million (World Bank, 2013). However, this is seen as worth the investment given the USD 700 million of estimated annual costs of vitamin and mineral deficiencies to the GDP. Why then does malnutrition persist in the region? One reason is that there is insufficient effort to take advantage of the vast abundant diversity to increase nutrition. Second, inadequate attention is given to making agriculture more nutrition sensitive, including effective policy interventions to combat malnutrition. It is evident that economic growth is insufficient to eliminate malnutrition. Direct nutrition intervention is key to FSF solutions. Sustainable agriculture can impact nutrition by reducing the cost of nutrient-rich crops, bringing rich new sources of nutrients to people's diets and by increasing available micronutrients in staple foods.

Malnutrition is also partly due to the reliance on only a few staple crops for consumption. Since the Green Revolution in the 1960s – initiated to fight hunger by increasing crop yields to provide enough food for the

world's growing population – staple crops such as wheat, corn and rice have been the main focus of modern agriculture, largely driven by monoculture, uniformity and profit. Diversity and variety were compromised, with severe declines in fruit, vegetable, and legume production and consumption (Welch, 2002), and complete neglect of indigenous under-cultivated, wild and semi-wild food sources. This loss of diversity in the diet is one of the greatest factors contributing to malnutrition, especially micronutrient deficiency (Welch and Combs, 1997). The quality of nutrition was of less concern when many people were suffering from hunger. However, while people's living conditions have improved, the effects of diets deficient in essential vitamins and minerals have become obvious in many parts of the world.

What nutritional and health values can NUS bring? NUS are often richer in nutrients when compared to more popular staple crops. They often contain high levels of essential minerals, vitamins, phytochemicals such as flavonoids, and they can have a good macronutrient profile of fat, protein and carbohydrates. With regard to nutritional and health superiority, NUS such as pulses can be counted as a promising food group. Chickpeas, for example, are three times richer in protein, four times richer in dietary fibre, four times richer in iron, and 70 times richer in folate than white rice. Mung beans too are three times richer in protein, four times richer in iron, and 78 times richer in folate than white rice. Lupins are five times richer in protein, eight times richer in dietary fibre, four times richer in iron, and 44 times richer in folate than white rice (Sathe, 1996).

In terms of health benefits, pulses have outstanding value. For example, lentils are typically rich in micronutrients and have the potential to provide adequate dietary amounts of iron, zinc, and selenium (Megan *et al.*, 2015). As anaemia is typically high in many Asian countries, a clinical nutrition study was initiated to investigate the impact of an iron-rich lentil diet on anaemic children in Sri Lanka. The pilot study involved 33 mildly anaemic children (haemoglobin levels =  $11 \pm 0.8$  g/dL) and findings showed that the group fed 50 g of red lentils per day for two months had significantly improved their iron status (Wijesuriya *et al.*, 2013) (Table 1.1). These preliminary results show that the short-term introduction of lentils into children's meals can contribute to the reduction of anaemia prevalence by improving the iron nutritional status, and so show the potential for other populations (Megan *et al.*, 2015). In India, lower rates of anaemia were observed in areas that grow lentils. The Indian Government has recognized the key role of dietary diversification for the prevention of nutritional anaemia and applied food-based approaches

**TABLE 1.1** Improvement in mildly anaemic children after a 60-day red lentil feeding trial in Sri Lanka (n = 33)

Indicator	0 day	60 days	% Improvement
Hemoglobin (g/dL)	11.1	11.8	6.3
Serum Fe (µg/dL)	51.5	89.8	74.4
Total Fe binding capacity (µg/dL)	405.3	377.6	-6.8
Trans ferritin saturation (%)	12.8	24.3	89.8
Serum ferritin (ng/dL)	29.5	41.2	39.7

to achieve dietary adequacy of iron (Government of India, 2013). To promote dietary diversification, the Indian Government encourages the consumption of micronutrient-rich foods, such as dark green leafy vegetables, lentils and vitamin-C-rich NUS fruits, which are often available but are underutilized by the population (Government of India, 2013).

Drumstick or *Moringa oleifera* is another example of an NUS with superior nutritional and health benefits. Its leaves and seed pods are excellent botanical sources of protein. The fresh leaves are an outstanding source of vitamin C, while the dried leaf powder offers a more concentrated version of the same nutrients, especially vitamin A. Other vitamins and minerals present in plant leaves and seed pods include high concentrations of calcium, iron, potassium, magnesium and B vitamins. An empirical study confirmed that daily use of the leaves and seeds of the Moringa plant could provide the recommended dietary allowance for vitamins C and A, and minerals, such as calcium and potassium (Asghari *et al.*, 2015).

So, underutilized crops offer superior nutritional value for improving protein and micronutrient contents in diets, as well as help prevent non-communicable diseases in millions of people around the world. Their resistance to climate change means that they can provide food when other crops fail. This is why we observe a new global trend, particularly in Western and newly affluent societies with many NUS, including quinoa, chia, moringa and açai, now returning to the dining table.

#### Income generation and improved livelihoods through NUS

Many studies show that NUS can generate income in both domestic and international markets. For example, it is estimated that 275 million people in India rely on non-timber forest products (NTFP) for part of their subsistence and livelihood (Pandey, Tripathi, and Kumar, 2016). The FAO estimated that 80 percent of the populations of developing countries use NTFP – also known as minor forest products, non-wood, minor,

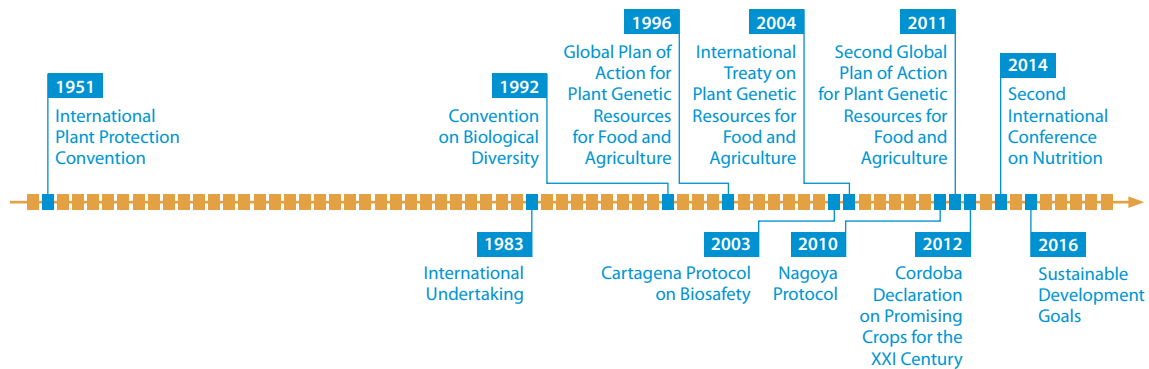
alternative and secondary forest products – to meet their health and nutrition needs (FAO, 1997). In India, adding value to little millet enhanced farmer incomes three-fold and generated employment in villages, particularly for women, so improving their social status and self-esteem (Vijayalakshmi *et al.*, 2010). Globally, there is a rising interest in promoting healthy diets, which NUS, with their multiple benefits, can contribute to in novel ways. The growing demand, through proper awareness-raising, promotion and facilitation, can be exploited to develop markets for promising NUS from which local communities and indigenous groups can benefit (Padulosi *et al.*, 2013). Promoting niche markets through denomination of origin, eco-labelling, fair trade, organic and slow food initiatives, geographic indication, globally important agricultural heritage systems, and one-village-one-product initiatives may be particularly useful.

### 1.4 Global policy frameworks and the integration of neglected and underutilized species

Plant genetic resources for food and agriculture (PGRFA) are any material of plant origin, including reproductive and vegetative propagating material, containing functional units of heredity of actual or potential value for food and agriculture (FAO, 2009). Therefore, PGRFA include both farmers' varieties/landraces and modern cultivars of staple crops as well as NUS. The development and implementation of policies are a key component in promoting NUS/FSF into agricultural production systems (FAO, 2015a).

The international community has consistently underscored the importance of the conservation and sustainable use of the widest possible spectrum of PGRFA as a means of sustaining global food security and nutrition for current and future generations. Over the years, the following instruments have been used to safeguard PGRFA, enhance access to them in a sustainable manner and foster the fair and equitable sharing of benefits arising from their exploitation (Figure 1.2):

**FIGURE 1.2** Timeline showing the major relevant international policy frameworks for the conservation and sustainable use of plant diversity



- International Plant Protection Convention (IPPC) (FAO, 2011);
- International Undertaking on Plant Genetic Resources (FAO, 1983);
- Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity, 1992);
- Global Plan of Action (GPA) for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture (FAO, 1996);
- Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA) (FAO, 2012b)
- International Treaty on Plant Genetic Resources for Food and Agriculture (FAO, 2009);
- Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (Secretariat of the Convention on biological Diversity, 2011);
- Cartagena Protocol on Biosafety to the Convention on Biological Diversity: text and annexes (Secretariat of the Convention on Biological Diversity, 2000); and
- Sustainable Development Goals (United Nations, 2017).
- Improving education and awareness to ensure that the values of a much wider range of crops are recognized by all society;
- Increasing recognition and support for small-scale and family farmers, women and men in maintaining diversified and resilient agricultural systems;
- Facilitating the conservation, access, availability, use and exchange of seeds by farmers;
- Promoting formal and informal research, and plant breeding to realize the full potential of these crops; and
- Improving access to markets and stimulating demand for a wider range of crops, while ensuring that benefits are shared fairly.

Most recently, Priority Activity 11 of the Second GPA explicitly calls for “Promoting development and commercialization of all varieties, primarily farmers’ varieties/landraces and underutilized species” by countries.

In particular, significant investments of efforts and resources have been dedicated to the conservation and sustainable use of NUS (Joint FAO/IAEA, 2004; Kahane *et al.*, 2013; Khoury *et al.*, 2014; Nyadanu *et al.*, 2016; Rutto *et al.*, 2016; Stamp *et al.*, 2012). In 2012, the Cordoba Declaration on Promising Crops for the XXI Century (FAO, 2012c) identified the actions for securing NUS as including the following:

A year later, the Accra Statement for a Food Secure Africa further validated these priority activities (Bioversity International, 2014). Following this, the Rome Declaration on Nutrition included the call to “Promote the diversification of crops including underutilized traditional crops, more production of fruits and vegetables, and appropriate production of animal-source products as needed, applying sustainable food production and natural resource management practices” (FAO, 2014a).

All these recent developments underscore a global commitment to enhance the conservation and sustainable use of NUS/FSF, and for these frameworks to be translated into action on the ground. These commitments have become even more compelling with the imperative of achieving the SDGs by 2030. In order to eradicate hunger and malnutrition, significantly more nutritious food – over current levels – must be produced sustainably, i.e. without further damage to the environment, for an ever-growing population, despite climate change and other challenges. An enhanced deployment of NUS must be an integral part of any envisaged interventions – both in

**TABLE 1.2** The four prioritization criteria on NUS for FSF

Nutrition	<ul style="list-style-type: none"> <li>• Nutritional value and health benefits</li> </ul>
Agricultural production practices	<ul style="list-style-type: none"> <li>• Local knowledge, availability and seasonality</li> <li>• Productivity, intercropping and competing with other crops</li> <li>• Processing</li> </ul>
Ecological sustainability	<ul style="list-style-type: none"> <li>• Agro-ecology</li> <li>• Adaptation to local climate and soil types</li> </ul>
Socioeconomic sustainability	<ul style="list-style-type: none"> <li>• Cultural acceptance and consumer preferences</li> <li>• Access to markets and potential income generation</li> </ul>

order to safeguard the resilience of production systems and for improved nutrition.

### National action

In order to maintain a sustainable food system, farmers must have access to quality seeds and planting materials of well-adapted varieties of their choice, including NUS, in a timely manner and at an affordable cost. In general, in developing countries, the attainment of this objective even for staple crops, and more so for NUS, remains a seemingly intractable problem. To address this shortcoming, especially as indicated in the Second GPA, countries must conserve their PGRFA so that they are used to grow well-adapted crop varieties, which, in turn, must have effective seed delivery mechanisms in order to reach farmers. The need to address these three imperatives of the management of PGRFA is even more critical for NUS – which usually are not accorded meaningful priorities in countries. The *Voluntary guide for national seed policy formulation and the Guidelines for developing a national strategy for plant genetic resources for food and agriculture* (FAO, 2015b; FAO, 2015c; Mba *et al.*, 2012) are two resources that can aid countries in these endeavours.

In order for policies and actions to be effective, policymakers have to be able to assess progress towards set objectives, which in turn requires an appropriate monitoring mechanism. This entails the establishment of a systematic and coordinated national approach, supporting the sustainable management of PGRFA, including NUS/FSF. Continuous assessments of the state of PGRFA are required for establishing on-going activities, identifying gaps and defining priorities (Diulgheroff, 2006; Diulgheroff and Leskien, 2016).

Further, there are a number of different approaches that can raise the profile and sustainable use of nutrition-sensitive programmes and food biodiversity from local or traditional food systems (Toledo and Burlingame, 2006; Pinstrup-Andersen, 2009). These include:

- Integration of NUS/FSF into national school meal programmes;
- Promotion of NUS/FSF in home gardens to highlight the need for locally available resources;
- Improvement of low-yielding but climate-resilient NUS/FSF;
- Adoption of marketing mechanisms to increase production of NUS/FSF; and
- Awareness-raising and information campaigns to promote the nutritional value of these foods.

Promoting NUS/FSF will require close cooperation between policy-makers and national agricultural research systems, as well as the support of international centres and non-governmental organizations, breeder and farmer organizations, seed producers, indigenous and local communities and the private seed sector. The overall conservation and sustainable use of PGRFA are crucial for the survival and development of human society; therefore, the range of agricultural biodiversity present must be maintained to ensure that food security and nutritional needs are met.

## 1.5 Priority-setting Exercise on NUS: Future Smart Food

NUS offer not only potential but also real solutions to achieving nutrition-sensitive, climate-resilient and economically sustainable agriculture. They also play an important role in closing production and nutritional gaps. However, not all NUS are nutritious or climate-resilient. So, how to identify the promising NUS that are available at country level? To support countries to better address Zero Hunger in a changing climate, the FAO Regional Office for the Asia Pacific and the Australian Centre for International Agricultural Research (ACIAR), in collaboration with a number of national and international partners, conducted a regional priority-setting exercise on scoping and

prioritizing NUS in 2016. Overall, the regional priority-setting exercise on NUS involved four steps.

### Step 1: Conceptualization

Given the vast repository of NUS and multiple benefits of various NUS, the question was how to prioritize them for application, further research and to contribute to healthy diets. Which criteria should be used? In consultation with concerned parties in the FAO, calling on both internal and external expertise, the objective of the priority-setting exercise was to identify NUS grounded on sustainable agriculture that are climate-smart, nutrition-sensitive, economically viable and socially acceptable. The selections should also be functional to contribute to closing production and nutrition gaps for Zero Hunger.

For this regional priority-setting exercise, the target food crops focused on the following groups:

- 1 cereals,
- 2 roots and tubers,
- 3 nuts and pulses,
- 4 horticulture, and
- 5 others.

The scope of NUS is limited to the available plant genetic resources in the national gene banks. *In-situ* collections of NUS in different agro-ecological zones need to be carried out separately. This limited the exercise, and many fruits, vegetables and medicinal NUS were not captured.

To conduct a priority-setting exercise on NUS, four prioritization criteria were established to address the multi-dimensional challenges that sustainable agriculture faces: nutrition density, agricultural production practices, ecological sustainability and socioeconomic sustainability. Each criteria is elaborated upon in Table 1.2.

The exercise also established the principle of country ownership of the scoping and prioritization results. The prioritization of NUS is contingent on the local context of each country, therefore a species which is considered an NUS in one country may not be considered so in another country.

### Step 2: Partnership building

To conduct this comprehensive and interdisciplinary analysis, FAO built strong partnerships with some national and international partners and experts who made significant contributions to the priority-setting exercise.

Initially, the priority-setting exercise, under the Regional Initiative on Zero Hunger Challenge, focused on four countries: Cambodia, Lao PDR, Myanmar and Nepal. It then expanded to four additional countries: Bangladesh, Bhutan, Viet Nam, and West Bengal in India. The exercise built on suggestions and strong support from the International Centre for Agricultural Research in the Dry Areas (ICARDA), which committed to contributing to this important exercise under FAO RI-ZHC, among other partner organizations.

In terms of national partners, the government and national agricultural research councils or institutes are the main stakeholders in the priority-setting exercise on NUS. In the four focus countries under RI-ZHC, the government played a pivotal role in organizing and facilitating the preparation of the country study on NUS at the national level, coordinated by the National Focal Point of the Zero Hunger Challenge, including the nomination of a competent national institution and expertise to undertake and finalize the country study on NUS.

The national agricultural research council or institute took the lead in undertaking and finalizing the priority-setting study on NUS in each of the eight countries:

- Bangladesh Agriculture Research Institute (BARI);
- Department of Agriculture, Ministry of Agriculture and Forests, Bhutan;
- Cambodian Agricultural Research and Development Institute (CARDI);
- National Agriculture and Forestry Research Institute (NAFRI), Lao PDR;
- Department of Agricultural Research (DAR), Myanmar;
- Nepal Agriculture Research Council (NARC);
- Plant Resources Centre (PRC), Viet Nam; and
- Uttar Banga Krishi Viswavidyalaya (UBKV), West Bengal, India.

International partners, organizations with expertise in agriculture, ecology, socioeconomic disciplines and experiences on NUS were also stakeholders in the priority-setting exercise on NUS. Nominated international experts were grouped by discipline to offer technical assistance to support the country on prioritization through interdisciplinary reviews. Specifically, from a nutrition dimension, MS Swaminathan Research Foundation – Leveraging Agriculture for Nutrition in South Asia (MSSRF-LANSA) and the Mahidol University of Thailand joined as partners

**TABLE 1.3** Potential Future Smart Food in eight countries in South and Southeast Asia

Cereals	Roots and tubers	Pulses	Fruits and vegetables	Nuts, seeds and spices
Amaranth	Elephant foot yam	Black gram	Chayote	Linseed
Buckwheat	Fancy yam	Cow pea	Drumstick	Nepali butter tree
Finger millet	Purple yam	Faba bean	Fenugreek	Nepali pepper
Foxtail millet	Swamp taro	Grass pea	Indian gooseberry	Perilla
Grain amaranth	Sweet potato	Horse gram	Jackfruit	Walnut
Proso millet	Taro	Lentil	Pumpkin	
Quinoa		Mung bean	Roselle	
Sorghum		Rice bean	Snake gourd	
Specialty rice		Soybean	Wood apple	
Tartary buckwheat				

to support an international review on the nutrient value of NUS. From an agricultural production and ecological perspective, the FAO Special Ambassador in the International Year of Pulses 2016, ICARDA; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Bioversity International (BI), the University of Western Australia (UWA), and the Chinese Academy of Tropical Agricultural Sciences-Tropical Crops Genetic Resources Institute (CATAS-TCGRI) joined as partners to support the international review on agricultural traits and climate-resilience of NUS. From a socioeconomic perspective, the International Centre for Integrated Mountain Development (ICIMOD), Crops for the Future (CFF), and the International Tropical Fruits Network (TFNet) served as partners to support the international review. ACIAR co-organized the Regional Expert Consultation with FAO.

### Step 3: National scoping and prioritizing study on NUS

The national study on NUS focused on scoping, identifying and prioritizing the promising NUS at the country level. Of the eight participating countries, each conducted an assessment according to the established four-dimensional criteria.

During this stage, following the overall guidelines, each country in the NUS priority-setting exercise prepared a preliminary national scoping report on the availability of NUS at the national level according to the four-dimensional criteria, and the selection was made in sequence at the country level. Guidelines on how to prepare the country study are in Annex 1. Guidelines on the provision of aggregated and disaggregated data are in Annex 2.

The preliminary country reports were subsequently reviewed and shared by FAO with an international

panel of experts specializing in agriculture, ecology and the socioeconomic aspects of crops. The international experts conducted a review of the preliminary national scoping report from the respective disciplines prior to the Regional Expert Consultation.

### Step 4: Regional Expert Consultation on scoping and prioritizing NUS

A Regional Expert Consultation was organized under FAO RAP's Regional Initiative on Zero Hunger Challenge in Bangkok from 3-5 December 2016, led by FAO and ACIAR, in collaboration with international and national partners. Thirty-five participants, representing eight countries, as well as 22 national and international partners attended.

The objectives of the Regional Expert Consultation were to:

- review and validate the preliminary scoping report on crop-related NUS in the selected countries;
- rank and prioritize high-potential NUS based on the established priority criteria;
- identify up to six crop-related NUS per country; and
- strategize to enhance production and utilization of the selected crops in local diets.

During the Consultation, the country teams presented the results of the preliminary country reports on NUS. This was followed by a multi-dimensional review by international experts from each participating country.

Based on the country studies, through the multidisciplinary review, promising NUS were discussed and identified at the country level. Strategic suggestions were made by leading experts, the details of which are presented in Chapter 14 Conclusion: Way Forward.



As per the international expert recommendations, NUS that are nutrition-dense, climate-resilient, economically viable and locally available or adaptable were referred to as Future Smart Food (FSF) to overcome the negative stigma of being labelled neglected and underutilized.

Based on the national studies and international expert reviews, an interdisciplinary review further considered and finalized a few promising NUS as prioritized candidates for FSF among NUS for Zero Hunger. A combined list of the NUS suggested as FSF from the national studies for the eight countries is presented in Table 1.3. A detailed analysis of each country's results is illustrated in Part II.

### 1.6 Conclusion

FSF have high potential to contribute to the Zero Hunger challenge, reducing all forms of malnutrition and enhancing sustainable agriculture. They have an important role to play in sustainable agriculture due to their agility and adaptability to low-input systems, climate resilience and high nutritional values. Several of these FSF are fruits, cereals, pulses, roots and tubers, and vegetables. FSF may be in the form of trees, palms, woody and non-woody perennials, or herbaceous species. There is a need for increased investment and concerted efforts to develop and improve FSF along the value chain, using sustainable agriculture and food system approaches (FAO, 2014b).

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## ANNEX 1 Guidelines for the Preparation of a Preliminary Scoping Study on Crop-related Neglected and Underutilized Species (NUS)

### Background

Malnutrition still prevails in the Asia Pacific region. To tackle its underlying causes, it is important to address the problem from different angles, and link production, consumption and nutrition perspectives within a holistic food system approach. In this regard, the study focus will be on crops within the abundance of Neglected neglected and Underutilized Species (NUS), based on available plant genetic resources at the national level, excluding mainstream cash and staple crops such as rice, maize, and wheat. Crop-related NUS have multiple benefits and offer potential to diversify both agricultural production and dietary consumption, as well as strengthen natural environments. In the future, NUS will play a pivotal role in addressing malnutrition.

### Objective

The objective of this preliminary scoping study is to assess the availability of high-potential NUS crops in selected countries in South and Southeast Asia, and evaluate their potential from nutrition, agriculture, ecological and socioeconomic perspectives at the national level (see Annex 2 table with priority criteria). The outputs will be compiled in a comprehensive report that facilitates the validation of an overall picture on crop-related NUS that will help to identify and prioritize their promotion for each country in the region.

### Requirements

- 1 Available crop-related NUS in each country will be listed in the Annex table (Annex 2) and sorted into the assigned food groups: cereals, roots and tubers, nuts and pulses, horticulture, and others (fruit trees, etc.). Where the number of identified NUS exceeds the rows displayed, please insert additional space for your findings.
- 2 After the available target crops have been listed, national experts will assess the listed NUS based on the information available in their field and their national experience (e.g. nutrition expert in Cambodia assesses NUS in Cambodia from nutrition perspective). Please note that for each priority criterion, a separate Excel sheet is provided.
- 3 Each ministry/expert/institute may fill in additional information according to their knowledge.
- 4 Ensure that all relevant sources are tapped and that an integrated set of information is available after the scoping. Make as much use as possible of available data, studies and reports, and fill information gaps by using informants and other methods to gather empirical data.
- 5 To ensure traceability of your findings and the aggregated information on crop-related NUS, please list your sources in the last Excel sheet 'Documentation'.
- 6 The listed NUS will be ranked within each food group, and **up to six priority crops per food group** are to be highlighted according to national judgment. The judgment can be based on the given parameters (e.g. drought tolerance, area under cultivation) within each priority criterion, but you may also choose high-potential crops that are characterized by parameters beyond the set priority criteria. Also, if you wish to prioritize more than six crops, please proceed and substantiate why.
- 7 Please provide high-resolution photographs of the prioritized NUS to be presented at the Expert Consultation, if available.
- 8 Please share your ideas, suggestions, and comments about the set criteria, parameters, food groups and table setup, e.g. what is still missing? Did you face any problems/limitations?
- 9 In case of any queries or uncertainties, please seek direct contact with Ms. Xuan Li on Skype (lixuan6182) or via e-mail (xuan.li@fao.org).
- 10 After completion, Annex 1 will be shared with international experts and research institutes for review and comments, and then resent to each country for preparation of a national preliminary scoping study based on the following provisional outline:

## Provisional outline

### Preliminary National Scoping Study on Neglected and Underutilized Crops

- 1 Introduction: Importance of crop-related NUS in the country, national policy environment, challenges
- 2 Scoping the availability and potential of crop-related NUS at the national level and provide information related to four priority criteria: nutrition, agriculture, ecological, socioeconomic parameters – see Annex 2
  - 2.1 Cereals (excluding rice, wheat, maize)
  - 2.2 Roots and tubers
  - 2.3 Nuts and pulses
  - 2.4 Horticulture
  - 2.5 Others
- 3 Preliminary prioritization of ten high-potential crop-related NUS per food group according to priority criteria – see Annex 2
  - 3.1 Cereals
  - 3.2 Roots and tubers
  - 3.3 Nuts and pulses
  - 3.4 Horticulture
  - 3.5 Others
- 4 Conclusion and recommendations from a country perspective

## Follow-up

The national preliminary scoping studies are expected to be submitted by 31 October 2016. They will be subject to subsequent review and validation by international research institutes and experts and serve the basis for further validation and discussion at the Regional Expert Consultation from 3-5 December 2016 in Bangkok and finalized after the Consultation.

ANNEX 2 Aggregated Data on Crop-related Neglected and Underutilized Species (NUS)

Crop-related Neglected and Underutilized Species (NUS)		Priority Criteria									
		Nutrition		Production Practices			Ecology		Socio-Economic		
Food group	English/Local Name	Scientific Name	Accessions	Nutritional value and health benefits	Local Availability/Seasonality	Productivity	Processing	Climate tolerance	Agroecology	Access to Market/Income Generation	Cultural acceptance/Consumer preference
				Nutrient content, bioavailability	Dispersion and propagation, harvest season	Agronomic issues and yield	Infrastructure, machinery	Drought/flood/heat tolerance, salinity	Ecological impact and benefits e.g. irrigation, waste, soil fertility	Price, distance to market	Food taboos, religious restrictions, traditional uses
1 Cereals	Finger millet	<i>Eleusine coracana</i>	10,334								
2 Roots and Tubers											
3 Nuts and Oulses											
4 Horticulture											
5 Others											

PART I  
ENABLING ENVIRONMENT  
REQUIRED TO PROMOTE FUTURE  
SMART FOOD PRODUCTION,  
MARKETING AND CONSUMPTION





# 2 Challenges, opportunities and strategies for Neglected and Underutilized Species as Future Smart Food for Zero Hunger

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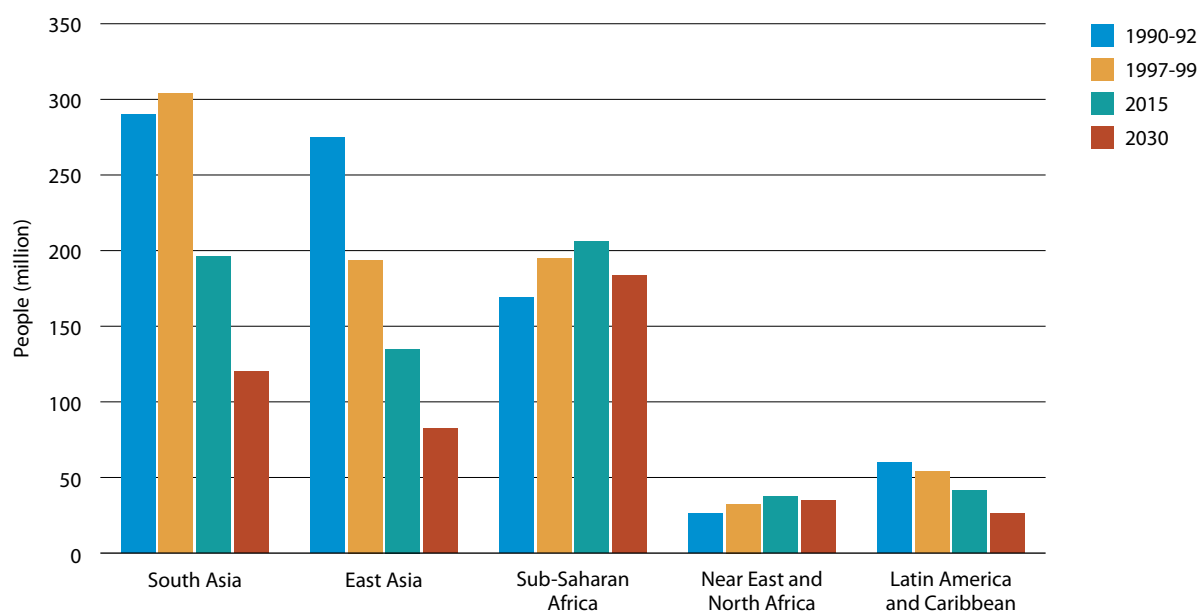
## 2.1 Introduction

The growing world population poses many challenges for agriculture. An estimated global population of more than 9 billion by 2050 will cause serious food, energy and water shortages. Demand for food and energy will increase between 70 and 100 percent, if we maintain our current production levels. There will be a 30 percent increase in demand for fresh water while the per capita availability of water is projected to decrease by 25 percent (Hoff, 2011, Al-Riffai *et al.*, 2017). Considering the United Nations revised figures for population growth and the increase in agricultural production by 15 percent between 2005/06 and 2012, the projected increase in demand for agricultural production is estimated to rise by approximately 50 percent from 2013 to 2050 (FAO, 2017). Population growth, the current degradation of natural resources and the serious

implications of climate change will have major consequences on agricultural production. Despite efforts to increase food production to reduce both hunger and poverty, there are still more than 800 000 people facing hunger globally (Al-Riffai *et al.*, 2017; FAO, 2017). Many Asian countries, including India, are categorized as 'serious' in the Global Hunger Index (GHI) with 20-34 percent of their populations undernourished.

Around 30 crop species provide 95 percent of the world's food energy despite more than 7 000 known species that have been used for food and are either partly or fully domesticated (FAO, 1996; Wilson, 1992). Only 15 cultivated crops provide 90 percent of the world's food energy intake – exclusive of animal protein (FAO, 1995). Currently, only about 12 crops are targeted by scientific interventions to cope and adapt better to various challenges. Widening the number of crops and

**FIGURE 2.1** Projection of undernourished people in various regions, 1990 to 2030



Source: FAO data and projections, 2006

the genetic base are important to food and nutritional security. However, despite considerable investments in the improvement of major food and industrial crops, annual increases in yields of rice, maize and wheat at global levels have only reached slightly more than 1 percent. Yields of soybean and sugar beet have improved less than 1 percent since the 1990s, which is much lower than the increases seen in 1960s (FAO, 2017). This suggests that the yield potential of these crops has been fully exploited. Therefore, we need to consider a broader range of crops and management options and to explore their potential; ensure adaptation to enhance food and nutrition security in various agro-ecologies, including harsh environments; and cope with climate change implications. More attention should be given to NUS, particularly since they have high potential, are adaptable to harsh environments, and are likely to contribute to food and nutritional security.

Underutilized crops are defined as those that “were once grown more widely or intensively but are falling into disuse for a variety of agronomic, genetic, economic and cultural reasons. Farmers and consumers are using these crops less because they are in some way not competitive with other species in the same agricultural environment. The decline of these crops may erode the genetic base and prevent distinctive and valuable traits being used in crop adaptation and improvement” (Padulosi *et al.*, 2006).

Underutilized is commonly referred to species whose potential has not been fully realized, but represent an important component of farming systems and diets in different parts of the world. The term ‘underutilized’ therefore needs to be defined in terms of the geographical (where?), social (by whom?) and economic (to what degree?) dimensions (Padulosi *et al.*, 2006).

Lentil is a prime example of a globally underutilized crop that is well utilized in certain regions and underutilized in others: lentils are an essential ingredient in traditional food in the Middle East and South Asia, but are less commonly used in other parts of the world.

Neglected crops are those that “are grown primarily in their centres of origin or centres of diversity by traditional farmers, where they are still important for the subsistence of local communities. Some species may be globally distributed, but tend to occupy special niches in the local ecology and production and consumption systems. While these crops continue to be maintained by socio-cultural preferences and use practices, they remain inadequately characterized and neglected by research and conservation” (Padulosi *et al.*, 2006).

NUS include a wide range of crops, fruit trees and industrial crops as indicated by Williams and Haq (2002):

- Cereal and pseudo-cereal crops (13 species).
- Fruits and nuts species (33 species).
- Vegetable and pulse crops (33 species).
- Root and tuber crops (17 species).
- Industrial underutilized crops (34 species).
- Oil crops (16 species).
- Latex/rubber/gums (two species).
- Fibre crops (one species).
- Starch/sugar crops (two species).
- Dye crops (three species).

### 2.2 Importance and main features of NUS

NUS have important features that include the following:

- Links with the cultural heritage of their places of origin.
- Local and traditional crops cultivated with indigenous knowledge for which distribution, biology, cultivation and uses are poorly documented.
- Adaptation to specific agro-ecological niches, harsh environments and marginal land.
- Weak or no formal seed supply and multiplication systems.
- Locally important associations with traditional uses and traditional food.
- Produced in traditional production systems with little or no external inputs.
- Little attention given by national research, extension services, policy and decision makers, donors, technology providers and consumers.
- Scarcely represented in *ex situ* collections.
- Despite having nutritious and medicinal properties or other multiple uses, are not generally attractive to the public and private sectors.

**FIGURE 2.2** Examples of NUS: *Amaranthus* and an opened *Bixa* fruit

© FAO

*Amaranthus caudatus*  
*Bixa orallana* fruit opened

© FAO

NUS provide an opportunity for the future fight against hunger, malnutrition and poverty. They are also well adapted to low-input agriculture and harsh agro-ecosystems as well as resilient to climate change implications. There is a growing realization that NUS can play an important role in widening the food base to enhance food and nutritional security. However, more effort is needed to increase farmer, producer, consumer and policymaker awareness of the many benefits of neglected and underutilized crops.

**Global interest in NUS:** There has been a gradual change in attitudes toward biodiversity and plant genetic resources in many countries. The 1992 Convention on Biological Diversity and the 1996 FAO International Technical Conference on Plant Genetic Resources for Food and Agriculture officially recognized NUS. Several new organizations and initiatives, including the International Centre for Underutilized Crops (ICUC), the Global Facilitation Unit for Underutilized Species, and the International Plant Genetic Resources Institute (IPGRI, now Bioversity International), and bilateral programmes, such as the GIZ Programme on Underutilized Crops, have directed international attention to NUS.

While plant genetic resources work of the twentieth century focused on the systematic collection and conservation of genetic resources of staple crops (Pistorius, 1997), twenty-first century efforts have been increasingly directed toward the need to rescue and improve those crops left behind by research, technology and marketing systems, and conservation efforts (Padulosi *et al.*, 2006, 2008, 2011). As a result, some NUS are now included in worldwide plans of action, such as the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 2011).

More recently, as part of the FAO Regional Programme for the Asia Pacific, a Regional Expert Consultation on Scoping, Prioritizing and Mapping of Neglected and Underutilized Crop Species was held under the Regional Initiative on Zero Hunger Challenge from 3-5 December

2016 in Bangkok, Thailand. NUS were emphasized as Future Smart Food (FSF). In addition, an FAO Conference held in Rome, Italy, from 3-7 July 2017 on Zero Hunger, which involved FAO, the World Food Programme and IFAD to support the Zero Hunger/SDG2 at the global level, also emphasized the potential of NUS.

### 2.3 Challenges facing NUS

Despite growing awareness of their potential role, NUS face major challenges to become widely utilized beyond their traditional niches (Padulosi, 1999b; IPGRI, 2002; Padulosi *et al.*, 2013). The reasons for this include:

- Low competitiveness.
- Limited germplasm available, particularly at the national level.
- Lack of research and well-documented technical information on genetic diversity, growth stages and life cycle of NUS, including agronomy and breeding systems, specifically self vs. cross-pollinated species.
- Lack of information on their susceptibility to diseases, insect pests and parasitic weeds of economic importance.
- Lack of national policy for supporting research and development for improving production.
- Loss of indigenous knowledge and documentation of national recipes.
- Lack of interest from producers.
- Lack of interest in the private sector.
- Lack of markets and commercialization.
- Insufficient demand of consumers outside traditional niche markets.

NUS face many social, economic, environmental, agronomic and policy challenges, which are listed in Table 2.1 (Padulosi *et al.*, 2013).

TABLE 2.1 Challenges to NUS by category

<b>Social</b>	<ul style="list-style-type: none"> <li>• Decisions by farmers to replace traditional, local crops with new varieties and improved crops</li> <li>• Changes in diet that accompany urbanization</li> <li>• Loss of indigenous knowledge of traditional and local crops</li> <li>• Inadequate awareness of the nutritional value of local varieties</li> <li>• Perceived low status of some local and traditional foods</li> <li>• Migration of farm labour to urban areas</li> <li>• Overexploitation of wild resources</li> </ul>
<b>Economic</b>	<ul style="list-style-type: none"> <li>• Changes in land use</li> <li>• Low commercial value of NUS</li> <li>• Lack of competitiveness of NUS with other crops</li> <li>• Lack of market infrastructure</li> <li>• Lack of market niches for NUS</li> <li>• Lack of incentives for farmers to continue to maintain NUS in their fields and gardens</li> </ul>
<b>Environmental</b>	<ul style="list-style-type: none"> <li>• Genetic erosion of NUS gene pools through the effects of drought, fire, pests, diseases, overexploitation, overgrazing, land clearing and deforestation</li> <li>• Effects of climate change</li> <li>• Environmental pollution</li> <li>• Ecosystem degradation</li> </ul>
<b>Agronomic</b>	<ul style="list-style-type: none"> <li>• Insufficient propagation material and seed</li> <li>• Lack of seed supply systems</li> <li>• Insufficiently trained human resources</li> <li>• Overuse of pesticides, fertilizers and other agrochemicals</li> </ul>
<b>Political</b>	<ul style="list-style-type: none"> <li>• Failure of national and local governments to prioritize the conservation and use of NUS</li> <li>• Lack of funds for <i>ex situ</i> conservation</li> <li>• Lack of adequate facilities and electricity supplies to maintain <i>ex situ</i> collections</li> <li>• Failure of governments to support scientific research on NUS</li> <li>• Lack of characterization, breeding and evaluation information</li> <li>• Absence of legal frameworks, policies, projects, national programmes and strategies</li> <li>• Lack of integration between conservation and use programmes</li> </ul>

Source: Country reports for the Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture (FAO, 2010).

The future development of NUS requires significant efforts to address these challenges. As a first step, NUS crops could be prioritized based on their potential value in food and nutritional security as well as their adaptability to harsh environments and the effects of climate change.

## 2.4 Opportunities and potential

NUS can render farming systems more sustainable and improve human well-being by contributing to:

- Agrobiodiversity in agricultural development and new tools for using and conserving biodiversity.
- Increased food security and better nutrition.
- Better use of the vast marginal lands.
- Coping with environmental stress and climate change effects.

- Ecosystem stability.
- Increased attention to indigenous knowledge and cultural diversity.
- Increased income for the rural poor due to increased market opportunities including eco-tourism.

Considering the potential of the contributions listed above, the global and national interest in NUS originates from three major areas (Padulosi *et al.*, 1999):

- **Development of new markets and new uses:** With modern technologies, including breeding and processing tools, NUS can become important new food and plant products.

- **Concerns about environmental change and ecosystem stability:** With the degradation of land and water resources in many parts of the world and the serious implications of climate change, NUS provide genetic material that can adapt to various stresses and harsh environments. Their development will contribute to enriching plant biodiversity and ecosystem stability.
- **Concern over food and nutritional security:** Many NUS are nutritionally rich and suitable for low-input agriculture, two important factors for enhancing food and nutritional security. Furthermore, the development of NUS that are traditionally important in certain rural communities will not only enhance food and nutritional security nationwide but also boost the incomes of these rural communities.
- Promote national, regional and global campaigns on the comparative benefits of the improved NUS to enhance their production, marketing and consumption.

Due to the large numbers of NUS globally, IPGRI developed a specific approach to guide the prioritization process of NUS (Padulosi *et al.* 1999). Accordingly, the selected species will serve as a model to work with various stakeholders for the conservation and genetic improvement to become commercially important and improve livelihoods of traditional communities. In 1998, IPGRI (Bioiversity International) organized a conference focusing on setting priorities for NUS in the Central and West Asia, and North Africa region. Several presentations focused on identifying the limiting factors to full exploitation of NUS, along with a list of priority actions needed for their sustainable promotion commercially (Padulosi *et al.*, 1999a).

## 2.5 Strategies and actions for turning NUS into important commercial crops

Development of NUS is essential considering the global challenges of hunger, malnutrition and poverty. It is also important for improving livelihoods of resource-poor farmers throughout the world where NUS are important. Considering the desirable traits of certain NUS in contributing to food and nutritional security, focus on the improvement of NUS with the potential to become commercially important crops is needed. It is important to set a strategy to turn selected NUS into commercially viable crops by identifying development priorities to be addressed through research. Strategically, the approach to achieve this objective requires the following steps:

- Identify NUS crops/species with high potential based on their nutritional value, and adaptation to harsh environments and climate change, and focus research on developing these species into important commercial crops.
- Develop priority-setting approaches to help stakeholders involved in the value chain to prioritize research areas with development and conservation actions plans for the selected NUS (Padulosi, 1999b).
- Enhance the conservation and use of plant genetic resources of the selected (targeted) NUS to be promoted as nutritious food, feed and fibre from production to consumption.
- Strengthen the efforts of others working on the documentation, evaluation, improvement, processing and marketing of the identified NUS.

NUS are divided into nine categories:

- medicinal and aromatic species,
- forest species,
- fruit trees and nuts,
- vegetable species,
- forages,
- industrial species,
- ornamental species,
- pulses, and
- cereals.

These categories were evaluated at the conference. Each category was awarded a score (from 1 to 5) based on the constraints they were facing in the Central and West Asia and North Africa region, which were used to set the priorities (Padulosi *et al.*, 1999). The constraints included low competitiveness, lack of knowledge on use, lack of research on genetic diversity assessment and use, policy and legislation, lack of market/commercialization value, low income, lack of propagation technique, scarce knowledge about cultural practices, and lack of attractive traits. These constraints along with nutritional value and adaptation to harsh environments and climate change can be used to identify priority-specific species within each category to develop as commercial commodities. IPGRI (Bioiversity International) developed a series of monographs on 25 NUS that have commercial potential (Padulosi *et al.*, 1999, 2013).

**What needs to be done to promote priority NUS as important commercial crops:** Once specific NUS are identified, several steps are needed to develop the targeted species as important commercial crops (Padulosi *et al.*, 2013):

- Develop improved varieties
- Improve cultivation and management practices
- Enhance value-adding technologies
- Help farmers or producers to get better access to markets
- Provide clear evidence and promote nutritional value of the targeted NUS
- Develop and maintain genetic diversity
- Build stakeholder capacity at different stages of the value chain of targeted species
- Develop national and international policies to support sustainable conservation and use

To address these issues, the following actions are needed to ensure that the priority/targeted NUS are both economically and commercially important (adapted from Padulosi *et al.*, 2013):

- a Change the perception** of the targeted NUS by making farmers, producers, policymakers, and the public aware of their benefits for food and nutritional security as well as their importance for coping with harsh environments and climate change. Furthermore, emphasize the importance of NUS to broaden narrow food bases.
- b Develop the capacity of researchers, educators, policymakers, farming communities and the private sector** to acquire the skills needed to improve and promote NUS.
- c Investment in research on NUS** to document indigenous knowledge and use, propagation, growth characteristics, nutritional aspects, adaptation to harsh environments, resistant traits, and variation for genetic improvement.
- d Improve both *ex situ* and *in situ* conservation to protect and characterize biodiversity.** This is important for genetic improvement to promote priority NUS.
- e Involve stakeholders to address challenges at all stages of the value chain for priority NUS.** This involves producers and farming communities, researchers in agricultural research systems, and seed producers involved in formal and informal seed sectors.

- f Add value and develop the value chain** as well as establish sustainable markets at local, national and international levels. It is important to ensure the transition from small-scale agricultural production systems to large-scale intensive and industrial production systems, which would involve modernization of agriculture including mechanization. Post-harvest technology and conservation should be developed to promote commercialization.
- g Create a supportive policy environment** including a legal framework to protect the conservation of both cultivated and wild NUS at national and international levels. Governments need to provide incentives, such as subsidies, to promote targeted species at early stages of development.
- h Increase cooperation at national, regional and international levels.** NUS are mainly local and traditional, and so require scientific and political attention if they are to have global significance. Cooperation at national and international levels, as well as public and private sector involvement, is important to create multi-disciplinary and multi-stakeholder platforms. Such platforms have been important in the development of several NUS as commercial species; quinoa and kiwi for example. The following traits should be considered in the genetic improvement of NUS: higher yield potential, adaptation to low-input agriculture, heat and drought tolerance, water-use efficiency, tolerance to salinity, resistance to diseases, resistance/tolerance to insect pests and parasitic weeds, enhanced biological nitrogen fixation in the case of legume species, reduced growth duration, improved plant architecture and machine harvesting, and herbicide tolerance for effective weed control.

### 2.6 Examples of the evolution of specific NUS that have become important commercial crops

There are several examples of NUS that have become important commercial crops, including quinoa and lentil, which are examined in detail below.

#### 2.6.1 Quinoa (*Chenopodium quinoa*, Willd.)

Quinoa grain, which is similar to rice and can be cooked and used in the same way, originated in South America in the Andean region of Bolivia, Chile, Colombia, Ecuador and Peru (Fuentes *et al.*, 2008). It was domesticated 3 000 to 4 000 years ago for human consumption in the Lake Titicaca basin of Bolivia and Peru (Kolata, 2009).

**FIGURE 2.3** Australian Department of Agriculture and Food research officer Richard Snowball is conducting quinoa trials in Western Australia, as part of national research, to assess the best growing conditions for the crop



© Department of Agriculture and Water Resources Australia

It is now grown in North America and Europe. Based on FAOSTAT ([fao.org/quinoa/en](http://fao.org/quinoa/en)), both the cultivated area and total production of quinoa in the main producing countries of Bolivia and Peru almost doubled and tripled from 1992-2010, respectively. According to FAO, 2009 production in the Andean region amounted to approximately 70 000 tonnes.

Quinoa cultivation has been spreading exponentially, and it is now produced in more than 70 countries, including Denmark, France, Holland, Italy, Sweden and the United Kingdom. ([fao.org/quinoa/en](http://fao.org/quinoa/en)). It has also been developed successfully in India, Kenya and the United States.

Currently, Bolivia is the largest producer of quinoa followed by Peru. These countries export more than 50 percent of their produce (higher international demand has increased the domestic price of the crop). About 84 percent of global exports originate in Bolivia, Ecuador and Peru; the remainder comes from the United States of America, and from the European Union (Murphy and Matanguihan, 2015). Quinoa cultivation expanded to Australia in 2015 (Government of Western Australia, 2016, Figure 2.3). The fast evolution of quinoa becoming a commercially important food is due to its high nutritional value, good taste and quick cooking properties as indicated below:

- Compared with cereal grains, quinoa has the highest protein content (14 percent), making it a perfect choice for vegetarians and vegans. Quinoa provides all nine essential amino acids, making it a complete protein, and is gluten- and cholesterol-free.

- Quinoa seed is a good source of vitamin B complex, vitamin E and essential fatty acids (linoleic and alpha-linolenic acid). Quinoa is also an excellent source of calcium, copper, fibre, iron, magnesium, manganese and potassium.
- Quinoa is almost always organically grown.
- Quinoa takes less time to cook than other whole grains, even rice.
- Quinoa has multiple uses: boiled quinoa tastes great on its own, unlike other grains such as millet or teff.

In 2013, quinoa was promoted globally by the United Nations General Assembly via the International Year of Quinoa (IYQ) (UN, 2012; FAO, 2013). Although the importance of quinoa was apparent long before 2013, the IYQ 2013 was a valuable opportunity to enhance awareness of the grain's high nutritional value and other desirable qualities to various stakeholders including the public and private sector.

According to Murphy and Matanguihan (2015), breeders in the quinoa improvement programmes focused on developing cultivars adapted to diverse agro-climatic regions with high seed yields and quality components for food and industrial use. Within the available germplasm, significant diversity exists for some qualitative traits that breeders can use to improve the nutritional quality of quinoa (Murphy and Matanguihan, 2015).

Several breeding methods have been used to improve quinoa, such as individual plant selection and/or mass selection, introduction of exotic germplasm, hybridization, backcrossing and induction of desirable mutants.



**FIGURE 2.4** Landscape with quinoa (*Chenopodium quinoa*), Bolivia, Province La Paz (left) and commercial quinoa seeds for the health food market (right)



© FAO

© shutterstock/Cristina Gonzalez

**TABLE 2.2** Evolution of production (1 000 tonnes) and export value of quinoa from 1970 to 2014

Country	1970	1980	1990	2000	2010	2014
Peru	7.3	16.3	6.3	28.2	41.1	114.3
Bolivia	9.7	8.9	16.1	23.8	36.1	77.4
Ecuador	0.7	0.5	0.7	0.7	0.9	0.8
<b>Total Production</b>	<b>17.7</b>	<b>25.8</b>	<b>23.0</b>	<b>52.6</b>	<b>78.1</b>	<b>192.5</b>
<b>Export price (USD/kg)</b>	<b>\$0.08</b>	<b>\$0.49</b>	<b>\$0.85</b>	<b>\$1.25</b>	<b>\$3.03</b>	

Source: Food and Agriculture Organization of the United Nations (FAO, 2016)

According to FAO, global quinoa production and value evolved remarkably from 17 700 tonnes in 1970 to 192 500 tonnes in 2014, with the export price increasing from USD 0.08 in 1970 to USD 3.03 in 2010. Currently, two pounds of quinoa costs around USD 6 (Figure 2.4).

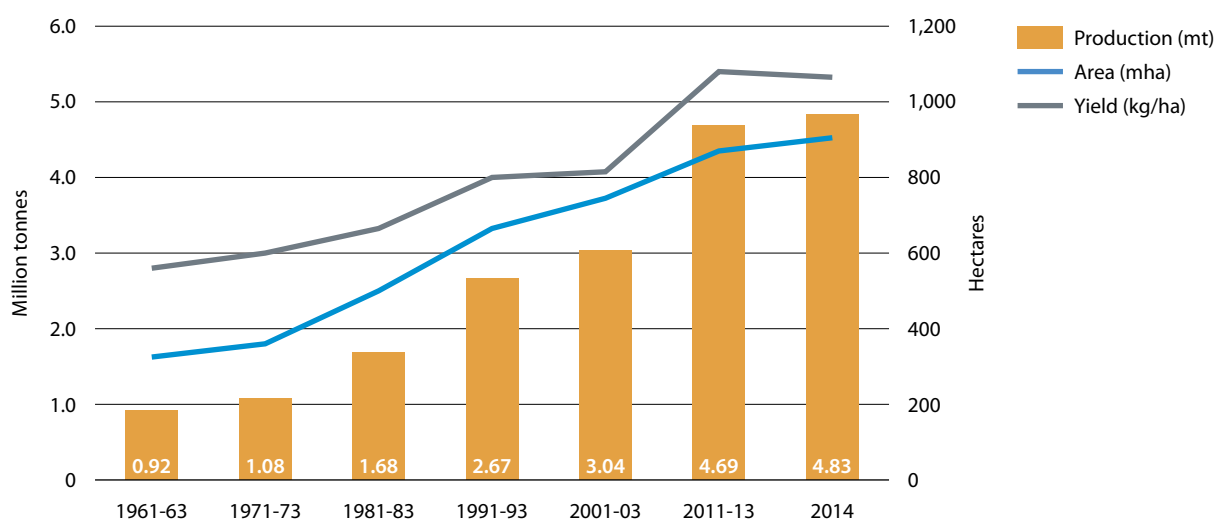
In summary, quinoa, a former underutilized crop, has become a valuable crop globally and is served in homes and restaurants throughout the world. It became a valuable alternative crop to help the world face critical challenges such as climatic change, food security, human nutrition, and overdependence on a few plant species for nutritional security. Considering the global goals of reducing hunger and malnutrition in the developing world, and increasing food and feed production in both quantity and quality in the context of climate change, quinoa offers an important alternative for those countries suffering from food insecurity and malnutrition.

### 2.6.2. Lentil (*Lens culinaris*, L.)

Lentil is a pulse crop that is high in protein (20-27 percent) and micronutrients (zinc and iron) with good carbohydrates and dietary fibre. This means lentils

can help provide a balanced diet to the low-income population. For this reason, it has been named, along with other pulses, as 'Poor Man's Meat' in the Middle East, North Africa and South Asia. In addition to nutritional advantages, lentil is well adapted to low-input agriculture. It can also fix atmospheric nitrogen, enriching soil fertility and ensuring agricultural sustainability.

Lentil originated as a subsistence crop in the Fertile Crescent (the crescent-shaped region covering historic Lebanon, Northern Iraq, Northern Syria, Palestine and South Eastern Turkey) where agriculture started 10 000 years ago. However, lentil evolved from a minor crop to an important pulse crop, and its production (area and yield) has grown considerably in the recent past (see Figure 2.5) due to high global demand. Global lentil production has increased six-fold from 0.85 million tonnes in 1961 to 5.13 million tonnes in 2013, almost doubling since 2008. Globally, the proportion of lentils in total pulse production (common beans, chickpea, faba bean, lentil and peas) almost quadrupled (from 4 percent to 15 percent) from 1961-63 to 2009-11 (Figure 2.6). Lentil soup, in particular, has made it onto restaurant menus in many parts of the world.

**FIGURE 2.5** Global growth in lentil production by acreage and productivity, 1961 to 2014

Source: Courtesy of Dr Shiv Kumar Agrawal of ICARDA, based on FAO statistics.

Unfortunately, most of the increases in lentil and pulse production have occurred in developed countries to meet the fast-growing demand in developing countries. North America contributes 45 percent to global lentil production from 31 percent of the total area compared with South Asia, with 32 percent of production from 45 percent of the total area. Australia, Canada and the United States of America are leaders in lentil and pulse production, mostly for export markets. Figure 2.7 shows the lentil importing and exporting regions of the world.

Most of the lentils produced in North America and Australia are exported to the Middle East, North Africa and India. Despite the high demand for lentils in these countries, production in the developing world has only increased substantially in India (see Figure 1.8), Turkey and Ethiopia, where lentil and other pulses are becoming cash crops due to the high demand for the high-quality local produce compared with lower-quality imported produce. The astronomic increase in pulse prices in the last ten years has increased the income and improved livelihoods of resource-poor farmers in developing countries. In the 2016/17 season, total pulse production in India was at a record level of 22.6 million tonnes, which was made possible by the Indian Government's interventions and substantial investment into research and technology transfer, and an excellent monsoon season. India is the first country in the developing world to approve subsidies for pulse crop production, after many years of receiving subsidies for rice and wheat. Ethiopia and Turkey have prioritized agricultural research and technology transfer.

#### Production constraints and lentil improvement efforts:

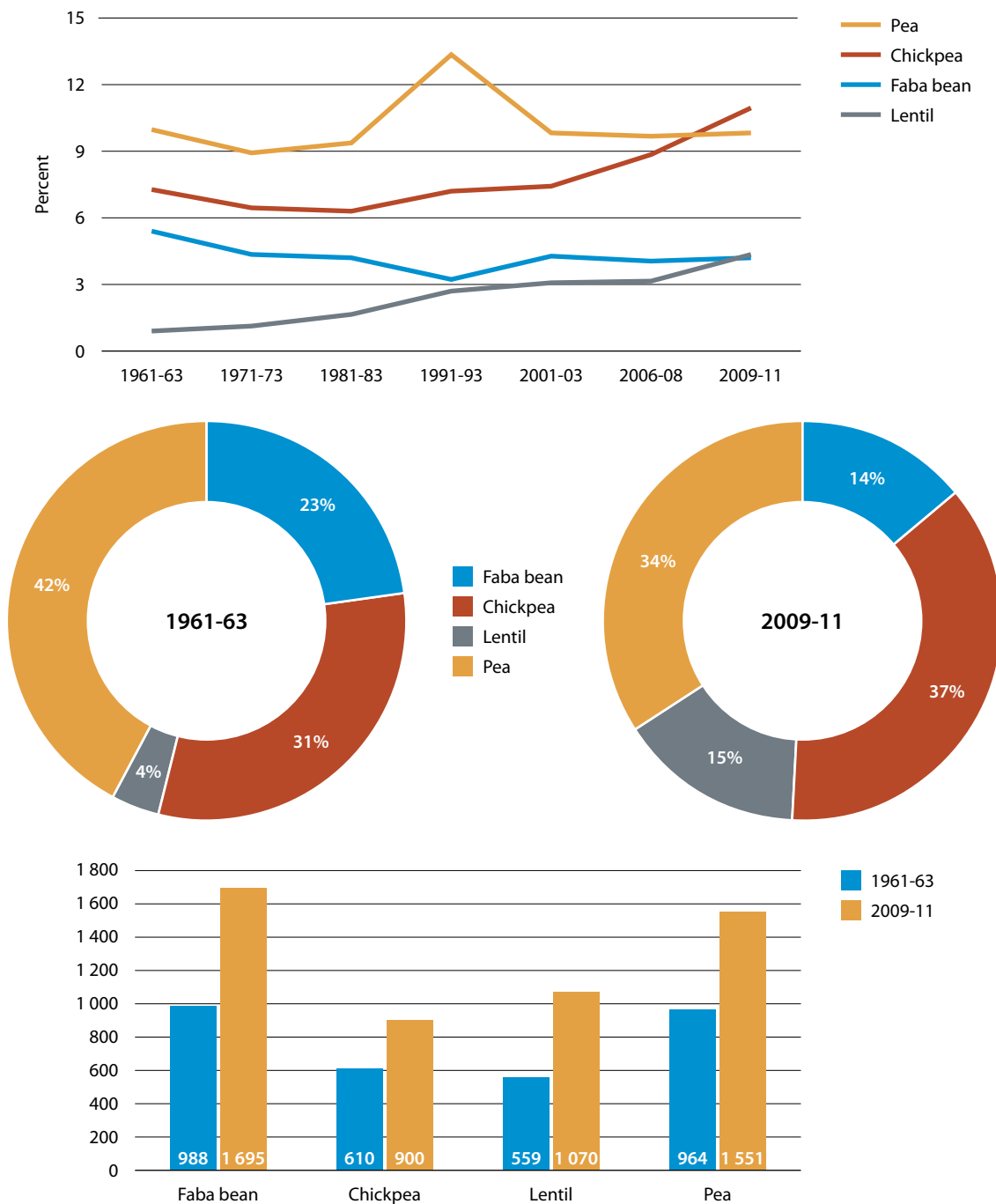
Lentil faces several production constraints: abiotic stresses (heat, drought, cold), diseases and insect pests of economic significance (meaning they cause

serious or substantial yield losses). Lentil is a poor competitor for weeds, including parasitic weeds (mainly *Orobanche* species), and requires costly hand harvesting. These constraints have been addressed in research to try to enhance economic competitiveness, and increase and stabilize productivity. The establishment of the International Center for Agricultural Research in Dry Areas (ICARDA) in 1977 – with a global mandate to improve lentil production – contributed to these efforts, in collaboration with national agricultural research systems, and transformed lentil from an underutilized crop to an important commercial crop globally.

The research and technology transfer efforts of ICARDA and national partners to enhance lentil productivity and production focused on the following:

- 1 Closing the yield gaps through better crop management and improved varieties
- 2 Crop genetic improvement and new genetic gains for higher yield potential and resistance/tolerance to abiotic (drought, heat and cold) and biotic stresses (diseases and insect pests)
- 3 Horizontal expansion of lentil production where land is available, notably the replacement of fallow in rice-fallow rotations in South Asia, specifically in India, Bangladesh and Pakistan
- 4 Sustainable intensification of lentil production systems
- 5 Reduced post-harvest losses, particularly from insect pests (e.g. bruchids) in storage
- 6 Plant architecture and mechanical harvesting
- 7 Developing extra short lentil varieties for multiple cropping

**FIGURE 2.6** Global trends in pulse production: chickpea, faba bean, lentil and peas, the relative proportions of these pulses grown globally, early 1960s to 2011



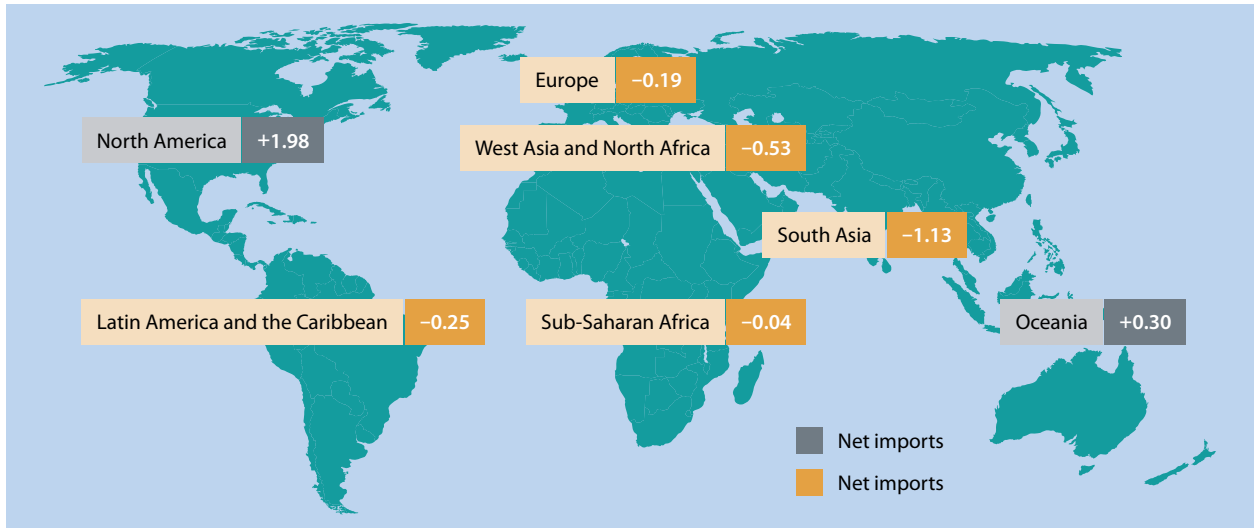
- 8 Quality aspects including bio-fortification of lentil for high iron and high zinc varieties
- 9 Value-adding through increased seed size and orange cotyledon colour

Examples of some achievements from the above list include bridging yield gaps by 65 percent to 75 percent in farmers' fields as a result of improved production packages for rain-fed agriculture. The potential to replace fallow by lentil and other pulses in rice-fallow rotations in South Asia is now being exploited by the

Governments of Bangladesh, India and Nepal in collaboration with ICARDA. The rice fallow covers 15 million ha and crops fallows cover 23 million ha in South Asia. India alone has 11.6 million ha of fallow from rice-fallow rotations.

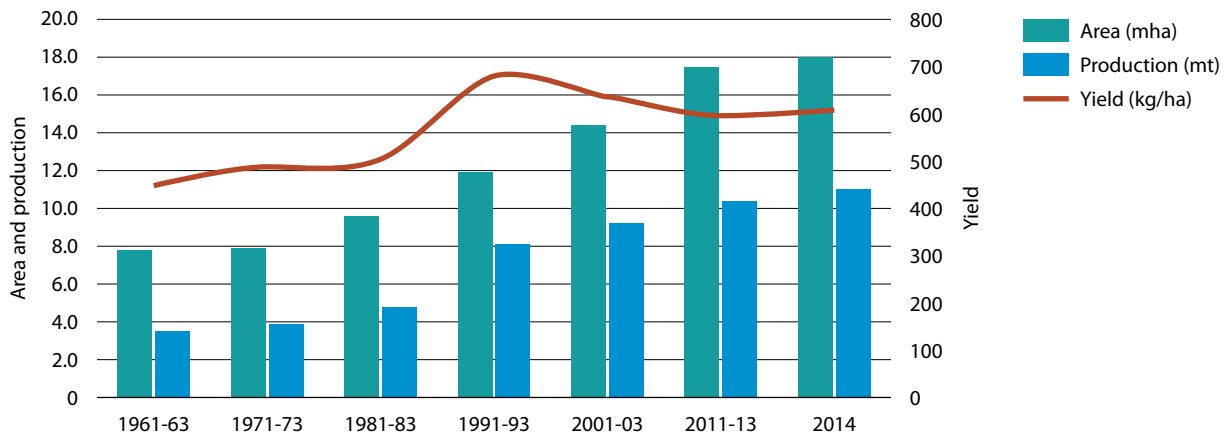
Improved lentil varieties for machine harvesting have been developed with good standing ability, being erect, tall and with more height before the first seed pods sprout. They are also less subject to pod drops or shattering and have more prominent tendrils.

**FIGURE 2.7** Lentil importing and exporting regions of the world, 2013



Source: FAO statistics, 2013

**FIGURE 2.8** Trends in lentil production, India, 1961 to 2014



Source: FAO statistics, 2006

(see Figure 2.10). This has reduced the high cost of manual labour, which was a restraint for traditional lentil production.

Another major achievement is the development of biofortified lentil, which is characterized by high iron and zinc, two important micronutrients that help overcome anaemia. Adding biofortified lentils to the diet of anaemic Sri Lankan children reduced anaemia after 60 days. Lentil cultivars with high concentrations of iron and zinc have been released in Ethiopia (*Alemaya* variety), Bangladesh (*Barimasur-4, 5, 6* and *7*), India (*Pusa* and *Vaibhav*), Nepal (*Sisir, Shita, d Shekhar, Khajurah-1, Khajurah-2*), Syria (*Idlib-2, Idlib-3* and *Idlib-4*), Turkey (*Myveci-2001*), and Portugal (*Beleza*). The five biofortified varieties released in Bangladesh now cover 90 000 ha which was 43 percent of the total cultivated area in 2014 with an average production of 1.3 tonnes per ha producing 115 000 tonnes of micronutrient-dense lentil.

## 2.7 Conclusions and Recommendations

NUS are important for conserving and enhancing biological diversity and protecting fragile ecosystems globally. They will remain important crops in specific niches and for traditional communities, particularly in rural areas, and any improvements will improve livelihoods in traditional communities and rural areas. However, the potential of NUS goes beyond local niches: they are globally important for enhancing food and nutritional security, as well as helping to meet the challenges of climate change.

**FIGURE 2.9** Development of pod plant architecture to facilitate machine harvesting of lentils



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Nutritionally, many NUS can add essential ingredients to the human diet: many NUS have a high protein content; others are a major source of micronutrients such as magnesium, iron and zinc. Some NUS are also rich in probiotic carbohydrates and dietary fibre.

In addition to their nutritional advantages, many NUS are adapted to harsh environments, for example:

- Most are adapted to low-input agriculture that can be of high commercial value.
- Many NUS can enhance soil nitrogen content, soil health and soil productivity.
- Some NUS, such as legumes, produce fewer greenhouse gas emissions than crops that require nitrogen-fertilization.
- NUS require less water and tolerate drought, waterlogging, heat and salinity.

**FIGURE 2.10** Lentils are an excellent FSF as they are rich in iron and zinc and offer an new income stream for farmers



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Therefore, it makes sense to invest more in improving NUS to enhance their productivity, production and commercial value to capitalize on their potential benefits nationally, regionally and globally, by:

- Including NUS benefits in school curricula.
- Investing more into research and technology transfer to make NUS more attractive to farmers, producers and consumers.
- Encouraging innovations in NUS products and ready-to-use products.
- Disseminating messages by celebrities and eminent personalities about the benefits of NUS in electronic media and print.
- Promoting national, regional and global events on the importance and potential of NUS.
- Producing short documentary films on the benefits of NUS to enhance public awareness at national, regional and global levels.

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# 3 Future Smart Food: Hidden treasures to address Zero Hunger in a changing climate

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## 3.1 Introduction

Sustainable Development Goal (SDG) 2 calls for the eradication of hunger and all forms of malnutrition. Food and nutrition security is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, WFP and IFAD, 2012). The challenge of achieving Zero Hunger becomes more profound if contextualized at a global scale, especially when considering climate change. During previous decades, crop production has focused on the cultivation of several starchy crops. While this approach of concentrating on a few high-yielding crops that respond well to high inputs has increased total food production and reduced food insecurity, it has left a significant nutrition gap due to the focus on a food basket that provides sufficient calories but a limited range of nutrients. Currently, most staple crops have reached their inherent growth limits, and future yield increases will not keep pace with population growth, leaving a production gap. Climate change is likely to reduce the area suitable for the cultivation of the current main staple crops, which would have enormous negative effects on agricultural production. This is especially important in Asia, where rice, a water-dependent crop, often dominates crop production. It follows from this scenario that Asian countries will not achieve Zero Hunger by following conventional approaches to agricultural development.

Alternative agricultural development strategies are required to close both nutrition and production gaps simultaneously. The past reliance on a few staple crops has to give way to agricultural diversification with sustainable intensification. FSF offer the potential for this diversification. They are neglected and underutilized species that are:

- nutritionally dense,
- climate-resilient,
- economically viable, and
- locally available or adaptable.

FSF are a promising resource and effective means for promoting agricultural diversification. Among FSF, pulses are an excellent example of crops that exhibit the above four criteria. The United Nations declared 2016 as the 'International Year of Pulses' under the banner 'nutritious seeds for a sustainable future'. In the context of this report, pulses can be regarded as a starting point for the promotion of FSF in fields and diets globally. The International Year of Pulses gave pulses – or leguminous crops – a highly visible platform. The particular advantages of pulses are that they require low inputs of synthetic fertilizers, pesticides and irrigation water, and so can be grown where traditional staple crops fail. At the same time, pulses add essential nutrients to the limited range provided by traditional staple crops and, therefore, have the potential to improve the nutritional status especially of poorer or marginalized people in Asia. It is recognized that a diversified diet based on a wide range of food crops improves nutrition, ensures better health, and provides benefits for human productivity and livelihoods (Chivenge *et al.*, 2015).

This chapter highlights the main challenges to conventional agriculture and the need to derive alternative strategies to address the inadequacy of staple crops in coping with climate change. Further, it discusses concerns about the sustainability of current agriculture and food systems, and illustrates the multi-functionality of FSF as a means to bridge production and nutrition gaps to achieve Zero Hunger in Asia and beyond.

### 3.2 Why do we need an alternative agriculture strategy?

There is a disconnect between low production diversity (over-reliance on a few staple crops), low dietary diversity, and malnutrition in Asia. Too much food is being produced without offering enough nutritional diversity, and too many people do not eat enough nutritious foods that can strengthen and maintain their health. The dependence on rice as the main staple leads to insufficient intake of nutrient-rich foods, which in turn leads to a significant 'nutrition gap'. From a production perspective, the lack of crop diversification and overemphasis on a few staple crops (mainly rice, in the case of Asia) severely limits the future food production increases needed to supply a growing population. Rice yields are unlikely to increase further; while improvements in rice breeding once stimulated the Green Revolution, current stagnating yield growth rates will lead to a production gap. The dual gap in both production and nutrition reveals a structural challenge in current agricultural and food systems.

Looking to the future, the structural challenge will not be overcome by maintaining a business-as-usual approach that favours a few staple crops. Over the next decades, world food security will need to be maintained in the face of population growth, a trend toward urbanization, and rising incomes. The global population is projected to increase from an estimated 6.9 billion in 2010 to around 9.7 billion in 2050 (UN DESA, 2015). FAO projections suggest that by 2050 agricultural production must increase by 70 percent globally – and by almost 100 percent in developing countries – to meet food demand (FAO, 2009). Population growth will increase the demand for food, which in turn, will put pressure on the agriculture sector to increase productivity. By 2050, about 70 percent of the global population will be urban, compared to 50 percent today. These demographic changes will drive the need for significant increases in food production. Rising incomes may translate into changing consumer preferences as well as concerns about quality and food safety, changing diets, and the rising demand for convenience foods. These trends may favour commercial production at the expense of smallholder agricultural producers – a development that could threaten agricultural diversity due to the economies of scale. Changing dietary patterns may also mean that consumers will reduce their intake of traditional staples, such as rice, and spend more on other cereals, pulses, fruits and vegetables; and they will likely eat more meat and dairy products.

From the supply side, there is already a worrying trend in the slowing yield increase in cereal crops, mainly rice and wheat. Globally, wheat and rice annual yield increases (as a percent of current yield) have been falling and are now just below 1 percent. For rice and wheat, yield growth in absolute terms (kg/ha per year) is falling in developing countries. From 1989–2008, farm yields (FY) of maize increased linearly at 1.6 percent per annum versus 1.2 percent for soybean and 1 percent for wheat and rice (Edmeades *et al.*, 2010). These yield increases are insufficient to meet future food demands without resorting to agricultural land expansion – but Asia has little arable land available for expansion. In addition, climate change predictions for the Asian region paint a scenario of rising temperatures, increased variability in rainfall, land degradation and increased frequency of extreme weather events such as drought and floods, which raises particular concerns for the agricultural sector. In many Asian economies, agriculture remains a source of livelihood and food security for large parts of the population, with much agriculture being rain-fed and subsistence-based. As a consequence of climate change, agricultural productivity in Asia is likely to suffer severe losses, and many sub-regions will experience a decline in productivity.

Rice production in Asia will be no exception. An Asia-wide study revealed that the effects of climate change would reduce rice yields in large parts of the continent (Hijioka *et al.*, 2014). In South Asia, the climate scenario is expected to result in a 14 percent decline in rice production relative to the no-climate-change scenario; a decline of 44 to 49 percent in wheat production and a fall of 9 to 19 percent in maize production (Nelson *et al.*, 2009). Higher temperatures will reduce rice yields due to the shorter growing periods. Some regions are already near the heat-stress limits for rice (Hijioka *et al.*, 2014). Rising sea levels will inundate low-lying areas and especially affect rice-growing regions. In the Indo-Gangetic Plains of South Asia, the most favourable and high-yielding wheat areas could decline in production by about 50 percent as a result of heat stress (Hijioka *et al.*, 2014). Consequently, current strategies centring on crop improvement in a limited set of staple crops would be unable to respond to climate change challenges. While the impacts of climate change vary across crops and regions, they put global food security even more at risk and heighten the danger of malnutrition in marginal regions. Smallholder farmers, who lack the resources to adapt and respond to climate change, will particularly feel these pressures. Given the vital importance of agriculture, there is an urgent need to develop strategies that can ensure the livelihoods of this vulnerable group of farmers (Chivenge *et al.*, 2015).

Finding solutions to bridge the production gap remains a considerable challenge. It can hardly be achieved without a fundamental transformation of the current agricultural and food systems. The complex interactions of water scarcity associated with climate change and variability in Asia, along with population pressure, require innovative strategies to address food insecurity and undernourishment. Recent research efforts have identified NUS as having the potential to reduce food and nutrition insecurity, particularly for resource-poor households in Asia (Chivenge *et al.*, 2015).

The growing demand for food in the face of mounting supply constraints paints a gloomy picture for the future of food and nutrition security in Asia. Production and nutrition gaps will widen if the conventional production pattern continues in the region. The current agriculture and food systems are unlikely to produce adequate amounts of food in the future, or sufficient nutritional diversity, especially when climate change threatens to alter the agricultural landscape. Investments in NUS, however, have the potential to bridge the production and nutrition gaps for food security and nutrition.

### 3.3 Future Smart Food: Promising resources to bridge production and nutrition gaps to address Zero Hunger

The best approach to achieve Zero Hunger in a climate change context will be agricultural diversification combined with sustainable intensification. NUS have a significant role to play to reduce mainstream agriculture's over-reliance on a limited number of staple crops. However, not all NUS will effectively foster food and nutrition security. NUS have to be prioritized following established criteria, based on comprehensive information about their traits. The FAO, in collaboration with international and national research partners, conducted a scoping/prioritization exercise of NUS in 2016 (the International Year of Pulses), to come up with a priority list of FSF (FAO, 2017). Currently, 39 FSFs have been prioritized by eight countries in Asia. Due to limited information and research, the complete traits of many other NUS remain unknown. The list of FSFs can be revisited/expanded when additional information becomes available.

Many of the prioritized FSFs used to be common in farmers' fields and were regular components of people's diets in the region. Due to economic and social changes, including changes in government policy, agricultural research and extension, they became undesirable and

marginalized. However, the prioritized FSFs have an outstanding capacity to thrive in difficult locations and are well suited for climate change adaptation and mitigation, in addition to providing nutritional benefits. This section will highlight the multi-functionality of FSFs by presenting examples of a few promising ones.

#### 3.3.1 Nutritional and health benefits

FSF are a source of valuable nutrients, especially protein and micronutrients. Compared to major staples, such as rice, many offer a wider range of nutrients. Pulses are an outstanding example of FSFs: they are rich in nutrients important for a healthy diet and can help to reduce the risk of developing several chronic non-communicable diseases. Pulses include chickpea, cow bean, field pea, dry bean, lentil, mung bean, pigeon pea and others. The FAO definition of 'pulses' excludes grain legumes used for oil extraction (soybean and peanut) (FAO, 1994). Although current global pulse production reached 73 million tonnes in 2011-13, pulses are underused in comparison to cereals (mainly rice, wheat and maize).

Between 1961 and 2012, maize, wheat, rice and soya made cumulative production gains between 200 percent and 800 percent due to the Green Revolution, while pulses expanded by only 59 percent over the same timeframe (FAO, 2016). Despite the known benefits of pulses for agricultural productivity, environmental sustainability and human health, they are a minor component of most human diets at present. Food security and soil fertility could significantly improve with greater pulse usage. The International Year of Pulses in 2016 highlighted the contribution of pulses to critical targets under SDG2, particularly those on food access, malnutrition, smallholder incomes, and sustainable and resilient agriculture.

Pulses provide nutritious human food and animal feed in both commercial and low-input subsistence agriculture. The health advantages of a pulse-rich diet are many-faceted. Pulses offer a food-based solution to decreasing the risk of certain diseases such as pre-diabetes and diabetes management, as well as diabetes-associated complications, especially cardiovascular disease. Since diabetes is a major risk factor for several cancers and neuro-degeneration, the future health of aging populations may depend on a food system that provides pulses in an affordable, palatable and sustainable way. A Chinese study found that all-cause mortality increased by 113 percent in Chinese women with a pulse-free diet and by 30 percent in Chinese men (Chang *et al.*, 2012). For every 20 g increase in daily grain legume intake, the mortality

hazard ratio declines by 7- 8 percent in older people globally (Foyer *et al.*, 2016). The first study to assess the link between the Mediterranean diet and health, which included a 20 g intake of pulses per day, found a 10 percent reduction in all-cause mortality (Darmadi-Blackberry *et al.*, 2013).

Most benefits from pulses are achieved at an intake of about 30 g per day, but lesser amounts are also beneficial. Recent studies in Western Australia consistently demonstrated that lupin-enriched (lupin is a pulse crop grown extensively in Western Australia) foods reduced blood pressure and glycaemic responses, providing strong evidence that they may have cardiovascular benefits, particularly in patients with diabetes who are at a significantly increased risk of cardiovascular disease. Lupins have negligible anti-nutritional properties and can be consumed as snack foods with minimal cooking. However, to increase the global consumption of pulses, more convenient, tasty pulse-based food products that meet the demands of consumers are needed.

Millets (*Panicum*) are another promising FSF. They were once widely consumed in Asian countries and played a key role in household food security and dietary diversity before rice began to replace millet as the staple grain in many regions. Even though they have been cultivated for centuries, minor millets account for less than 1 percent of the food grains produced in the world (Chang *et al.*, 2012). The so-called minor millets have a protein content close to that of wheat, and many millets are rich in B vitamins (especially niacin, B6 and folacin), calcium, iron, potassium, magnesium and zinc. Millets are rich in sulphur-containing amino acids and beneficial phytochemicals (Ravi, 2004).

There has been increasing recognition of millet's role as a staple crop in marginal agricultural regions, and their favourable nutritional properties are gaining credit. Millets are losing their stigma of being 'poor people's food' and are increasingly being appreciated as healthy foods by middle-income groups (Ravi *et al.*, 2010). Compared with rice, 100 g of cooked grain of foxtail millet contains about twice the protein, finger millet more than 38 times the calcium, and little millet more than nine times the iron (Gopalan *et al.*, 2004). In addition, millets are partly composed of non-starchy polysaccharides and dietary fibre, which is ideal for diabetic people who need foods that slowly release sugar on ingestion (Kang *et al.*, 2008).

A study on the health impacts of integrating minor millets into school feeding programmes in two millet-growing areas in Karnataka State, India, produced

encouraging results on indicators of nutritional status (Chang *et al.*, 2012). Height and weight measurements, as well as haemoglobin levels, were examined in 60 school children between the ages of 11 and 14 years to assess the impact of replacing rice with finger or foxtail millet. The baseline figures indicated that children suffered from chronic energy deficiency with a body mass index (BMI) of less than 16.0, and haemoglobin levels below 12.0 g per 100 ml. A three-month intervention significantly improved the weight and haemoglobin content in the children who were fed millets compared to rice. Haemoglobin levels of children eating millet-based school meals were 32.0-37.6 percent higher than those of the control group. More than 85 percent of the children perceived millet-containing meals as very tasty and satisfying. Millets have thus shown the potential to improve the nutritional status of school children (Fanzo *et al.*, 2013).

Sweet potato (*Ipomoea batatas*) is another example of a promising FSF. Studies conducted in sub-Saharan Africa established that the incorporation of orange-fleshed sweet potato varieties in children's diets led to an improved vitamin A status (Low *et al.*, 2007). Another study (Amagloh *et al.* 2012), concurred that due to their relatively high levels of vitamin A, orange-fleshed sweet potato varieties could be used as a complementary food for feeding infants.

#### 3.3.2 Environmentally friendly and climate-resilient benefits

FSFs could be the solution to many agricultural issues we face today, especially those related to climate uncertainty. Many NUS are well adapted to local growing conditions, which are often marginal and harsh, thus offering sustainable food production. They are well adapted to stress conditions of extreme environments and form part of subsistence farming. Most NUS can be grown successfully, with few inputs, in marginal and degraded wastelands. They contribute "to increased agricultural production, enhanced crop diversification, increased income opportunities and improved environment" (Adhikari, 2016). Historically, NUS crops have been part of the diets of indigenous communities, but their cultivation often became non-competitive and unattractive compared to the major staple crops, which were frequently promoted even in areas less suitable for their cultivation. Formal seed systems, as well as consumer demand, often favoured the major staple crops, with locally important crops not receiving sufficient research and extension support (Chivenge *et al.*, 2015).

Pulses are an excellent example of environmentally friendly cropping systems. They contribute to cropping system diversity when grown with crops of other plant families (e.g. cereals), disrupting the pest and disease cycles that develop during mono-cropping. Unlike cereal and oilseed crops, pulses can symbiotically fix nitrogen, leading to significant advantages for agricultural sustainability, both in developing and developed countries (Foyer *et al.*, 2016).

Pulses contribute to soil fertility, primarily through biological nitrogen fixation, but also by adding organic matter and releasing soil phosphorus. As a good source of protein, pulses could lead the shift in land use away from livestock – a move that would substantially lower the carbon footprint for protein production for human consumption. Side products, such as stems and greens that are not suitable for human diets, can be used as a feed source, and bring added value to the sustainability and productivity of cropping systems.

Pulses play a significant role in improving cropping systems due to their environmental benefits. Well-grown pulse crops typically fix between 80 and 120 kg nitrogen per hectare. Projected on a global scale, nitrogen fixation by pulses could account for up to 27 megatonnes of nitrogen without increasing the current area planted to pulses. Hence, about 9 megatonnes of soil nitrogen would be available for the crops that are planted following the pulses (most often cereals), which is equivalent to about 10 percent of global consumption of nitrogen fertilizer and worth USD 8-12 billion. Moreover, the grain protein content of cereal crops following a pulse crop increases, and soil structure and health improve after growing pulse crops. Accordingly, nitrogen-fixing pulses provide unparalleled sustainable opportunities for minimizing nitrogen fertilizer use.

The inclusion of pulses in cropping systems can increase the cropping intensity, which enhances annual productivity, increases diversity and reduces overall risk caused by the reliance on just a few staple crops. Despite the apparent advantages, pulse production is static or declining in several traditional producer countries, although global demand is increasing. For example, India is the largest producer and consumer of pulses, but current pulse production in India has remained mostly static; hence, about 4-5 million tonnes of pulses are imported annually from countries such as Australia, Canada, Myanmar and Turkey. Several studies in India show that a yield gap exists in pulses; meaning that realized yields were often only half of what they could be, but with considerable spatial and temporal variations. The yield gap can be analysed from two perspectives:

- 1 the difference between achievable yields (obtained from on-farm demonstrations incorporating currently recommended production technology) and farmer yields; and
- 2 the difference between model-calculated potential and achievable yields.

The first perspective is usually more significant than the second, suggesting that there is scope for applying known technology. Research aimed at narrowing yield gaps depends on an understanding of the causes of those gaps.

Drought tolerance is another important trait of FSF. Millets perform well in this regard, as they are resilient to a variety of agro-climatic adversities, such as poor soil fertility and limited rainfall. They play an important role in supporting marginal agriculture, for example in the hilly and semi-arid regions of India (Ravi, 2004). Millets are annual C4 plants (which photosynthesize following the C4 photosynthesis mechanism) that can grow in a wide variety of soils ranging from clay loams to deep sands, but the best soil for cultivation is deep, well-drained soil. This makes millets suitable for cultivation by smallholder farmers in semi-arid areas where deep sands and sandy loam soils dominate.

Sweet potato is a potentially significant root crop for climate resilience due to its suitability to low-input systems, drought tolerance and considerable environmental plasticity, which allow it to be planted and harvested at any time of the year (Motsa, 2015). Taro tolerates waterlogging (Modi, 2004) and could be an ideal crop for dry areas that are predicted to experience incidences of flash floods with reported moderate drought tolerance (Chivenge *et al.*, 2015).

Another potential FSF is cowpea (*Vigna unguiculata*), a legume crop and one of the oldest crops known to humankind, with its centre of origin and domestication being closely related to pearl millet and sorghum in Africa. Cowpea is an important legume, which serves as a source of protein in the diets of vulnerable populations and is remarkably resistant in the event of drought and nutrient mining (Chivenge *et al.*, 2015).

### 3.3.3 Economic viability

Many studies have highlighted the consistent contribution of NUS to generating income in both domestic and international markets (Asaha *et al.*, 2000; Mwangi and Kimathi, 2006; Chadha and Oluoch, 2007; Joordan *et al.*, 2007; Rojas *et al.*, 2010). Non-timber forest products (NTFPs) – also known as minor, special, non-wood, alternative and secondary forest products

– are part of NUS. The FAO estimated that 80 percent of the populations in developing countries use NTFPs to meet their needs in health and nutrition (FAO, 1998; Padulosi *et al.*, 2013). In India, adding value to little millet enhanced farmer incomes three-fold and generated employment in villages, particularly for women, which improved their social status and self-esteem (Vijayalakshmi *et al.*, 2010; Padulosi *et al.*, 2013). Globally, there is a rising interest in promoting healthy diets, and NUS, with its multiple benefits, could contribute in novel ways to human health and nutrition. The growing demand, through proper awareness-raising, promoting and facilitation, could be exploited to develop markets for promising NUS for the benefit of local communities and indigenous groups (Padulosi *et al.*, 2013). Promoting niche markets through eco-labelling, fair trade, organic and slow food initiatives (Kahane *et al.*, 2012), geographic indications, Globally Important Agricultural Heritage systems (an FAO initiative started in 2002) and one-village-one-product may be particularly useful (Padulosi *et al.*, 2013).

Studies demonstrated that a quick crop of finger millet could be raised on the same land where cassava was planted, and so the land could be profitably used to meet both the food and cash needs of the farm family (ICRISAT, 1974). Finger millet intercropped with cassava can offer 50 percent more income than that from cassava alone. This study demonstrated that the advantages offered by NUS with high adaptive capacities under marginal agro-ecological and edaphic situations enhanced farmer incomes, as well as food and nutritional security of local communities. The importance of these crops in local food security and cultural diversity is well appreciated (Swaminathan, 2005; Ravi *et al.*, 2010).

Pulse crops or other FSF will achieve a competitive advantage only if their profitability to the farmer is similar to or exceeds that of the dominant cereal crops. Despite their distinct advantages, especially those of pulses, NUS have received limited attention from policymakers and governments. The current level of research and development funding for pulses is low and unstable. A recent global survey showed an investment of US\$175 million per annum for the 13 pulse crops, a trifling amount compared to the billions of dollars invested in the three major cereal crops each year (Murrell, 2016).

#### 3.3.4 Local availability and adaptation

NUS have remained locally important crops in remote and marginal locations. They have proved their suitability for low-input systems, drought tolerance and environmental plasticity, and are capable of contributing to the food and nutritional security of smallholder farmers residing on marginal production lands (Chivenge *et al.*, 2015).

A recent trend is the increasing market demand for 'traditional' foods. An African Leafy Vegetables project in Kenya, led by Bioversity International, managed to increase sales in Nairobi supermarkets by 1 100 percent in just two years (Baena *et al.*, 2012). More affluent urban consumers rediscovered local foods, leading to a revival of traditional food systems intertwined with the cultural identity not only of indigenous peoples. Fostering NUS and conserving traditional food systems is a powerful way to contribute to saving local ecosystems and food sources (Padulosi *et al.*, 2013).

### 3.4 Conclusion

In an increasingly globalized and interdependent world, eradicating hunger is a prerequisite for peace and world security. FSF have the potential to contribute to food security at local and regional levels. If we are to feed nine billion people by 2050 in a sustainable way – while protecting the environment, providing healthy and nutritious food for all, and enhancing the livelihoods of farmers – we need more diverse agricultural and food systems. At the national level, NUS can strengthen a country's food security, and buffer economic and social shocks that result from concentrating on fewer crops. With proper promotion and development, NUS can also provide a safer path to ensure development, despite climate stress and environmental crises (Padulosi *et al.*, 2013).

This chapter has shown that the promotion of FSFs will:

- contribute to closing nutrition gaps and to food security and nutrition;
- reduce the risk of over-reliance on the limited numbers of staple crops and increase sustainability of agriculture through reduced inputs, such as fossil fuel-derived nitrogen fertilizers and fuel for agriculture;

- focus efforts on helping marginalized and indigenous people to improve their livelihoods and income; and
- contribute to preserving and celebrating cultural and dietary diversity (Mayes *et al.*, 2011).

The potential of FSFs needs to be exploited to enhance food security while overcoming malnutrition. Most FSFs do not require high inputs, can be grown on marginal and degraded lands and contribute to increased agricultural production, crop diversification and a better environment. In turn, food security and nutrition security improve. Pulses, in particular, are a potential health food, reducing the risks of chronic diseases, obesity and other conditions. Our current over-reliance on a handful of major staple crops (maize, potato, rice and wheat) has inherent agronomic, ecological, nutritional and economic risks. It also overlooks the potential contributions made by NUS. National and international research bodies, non-government organizations, community-based organizations and commercial entities interacting with farmers have not paid enough attention to NUS.

Governments need to move away from the strong focus on limited staple crops and tap into the enormous potential of alternative crops that are nutritionally dense and climate-resilient as well as locally available. This is especially meaningful for the rural poor, who suffer the most from production and nutrition gaps, as well as shocks and uncertainties. One should not forget that traditional food systems in Asia have developed over hundreds of years and once featured an abundance of foods that were nutritionally dense and climate-resilient. Promoting these alternative options offers greater yield-increase potential, and an opportunity to diversify dietary patterns and generate income for the rural poor. While these alternative crops were often traditionally grown by local farmers, there have been no incentives to maintain or increase production (incentives were mostly geared toward rice production). It is time to rediscover these hidden treasures for the rural poor.



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# 4 Future Smart Crops for paddy fallow agri-food systems in Southeast Asia

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## 4.1 Achieving global food security

Food security, as defined by the United Nations' Committee on World Food Security, is the condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Over the coming decades, a changing climate, growing global population, increasing incomes, changes in food choices, rising food prices, and environmental stressors, such as increased water scarcity and land degradation, will have significant yet uncertain impacts on food security. There are different aspects having direct links to meeting food security at the global level, including globalization of markets.

### 4.1.1 Growing food demand

Ensuring global food security for the ever-growing population, which will reach over nine billion by 2050, and reducing poverty is a challenging task. Growing per capita incomes in emerging economies such as Brazil, China, India and Russia imply additional pressure on global food production due to changing food habits. Increased food production has to come from the available and finite water and land resources that are declining in quality (Wani *et al.*, 2011a). The amounts of available water and land have not increased since 1950, but the availability of water and land per capita has declined significantly with the increase in the global human population. For example, in India, the per capita water availability has declined from 5 177 m<sup>3</sup> in 1951 to 1 820 m<sup>3</sup> in 2001, with the population increasing from 361 million in 1951 to 1.02 billion in 2001. India's population is expected to rise to 1.39 billion by 2025 and to 1.64 billion by 2050, with associated reductions in per capita water availability of 1 341 m<sup>3</sup> by 2025 and 1 140 m<sup>3</sup> by 2050. The distribution of water and land varies between countries and regions, as do the current

population and anticipated growth, which is likely to be more in developing countries. In 2009, more than one billion people were undernourished, not due to food shortages (availability), but to poverty (accessibility). While the percentage of hungry people in the developing world has been dropping for decades, the absolute number of hungry people worldwide has barely changed.

### 4.1.2 Limited fresh water resources

Water is the most common natural resource on Earth and covers 70 percent of its surface. However, 97.25 percent is salt water found in the oceans, while 2.75 percent is freshwater found in the icecaps, glaciers, groundwater, lakes, rivers and the atmosphere (Postel, Daily and Ehlich, 1996; Rockström, Gordon and Folke, 1999). Less than 1 percent of the Earth's water is considered available as freshwater. Water circulation in the hydrological cycle of evaporation, transpiration and precipitation is mainly driven by various climatic and land management factors (Falkenmark, 1997). Rockström, Gordon and Folke (1999) reported that about 35 percent of annual precipitation (110 305 km<sup>3</sup>) returns to the ocean as surface runoff (38 230 km<sup>3</sup>) while the remaining 65 percent is converted into water vapour flow. Moreover, major terrestrial biomes – forest, woodlands, wetlands, grasslands and croplands – consume approximately 98 percent of global green water flow and generate essential ecosystem services (Rockström, Gordon and Folke, 1999; Rockström and Gordon, 2001). With the increasing population pressure, the availability of freshwater for food production is a concern. An estimated 6 700 and 15 100 km<sup>3</sup> y<sup>-1</sup> of freshwater is used by croplands and grasslands, respectively, to generate food and animal protein for human consumption. This quantity is 30 percent of total green water flux on the Earth (Rockström and Gordon, 2001).

### 4.1.3 Challenges and opportunities of water management in rain-fed agriculture

Water is the primary limiting factor in dryland agriculture (Falkenmark, *et al.*, 2008). Rainfall in dryland areas is characterized by an erratic and non-uniform distribution that results in frequent dry spells during the monsoon. A study (Barron, Rockström, Gichuki J. *et al.*) in 2003 looked at dry-spell occurrence in semi-arid locations in Kenya and Tanzania; where 70 percent of dry spells lasting longer than ten days occurred during the water-sensitive flowering stage of the crop (maize). In the semi-arid Nandavaram watershed, Andhra Pradesh, India, with approximately 650 mm of annual rainfall, there is a greater than 40 percent risk of dry-spell occurrence during vegetative and flowering stages of the crop, while in the semi-arid Xiaoxingcun watershed in Yunan province in southern China, with similar rainfall, there is only a 20 percent risk of early-season dry spells (Rao, *et al.*, 2010).

To achieve better crop growth and yield, a certain amount of water is required to meet plant metabolic and evaporative demands (Stewart, 1977). A direct relationship exists between consumptive evapotranspiration (ET) water use and crop growth/yield. Rockström, Hatibu and Oweis (2007) explained that if all the green water captured in the root zone is utilized fully by the crop, yields of 3 tonnes per hectare are achievable in rain-fed agriculture. If the water is lost to deep percolation and surface runoff, then crop production levels would reach 5 tonnes per hectare and perhaps up to 7.5 tonnes per hectare, assuming that plant nutrient availability is non-limiting. In reality, only a small fraction of rainfall is used by plants (through transpiration), and the rest is channelled into non-productive use or lost as evaporation. Water stress, particularly during critical growth stages, reduces crop yield and may even damage the entire crop. Extensive data from productivity enhancement studies in Africa and Asia demonstrate the enormous potential to enhance green water-use efficiency as well as increase the availability of green water (Wani Pathak and Tam, 2002; Wani, Pathak and Jangawad, 2003; Wani, Joshi and Raju, 2008; Wani, Sreedevi and Marimuthu, 2009b; Wani, and Rockström, 2011c; Rockström, Hatibu and Oweis, 2007; Barron and Keys, 2011).

Green water management in rain-fed agriculture is of the utmost importance for enhancing water-use efficiency. Of the 1 338 million poor people worldwide, most live in the developing countries of Asia and Africa in dryland/rain-fed areas (Rockström, *et al.*, 2007; Wani, *et al.*, 2009a and 2011b; Anantha and Wani, 2016). Approximately

50 percent of the total global land area is in dry and arid regions (Karlberg, Rockström and Shiklomanov, 2009). The reliance on rainfed agriculture varies regionally. In sub-Saharan Africa, more than 95 percent of the farmed land is rain fed, with almost 90 percent in Latin America, 60 percent in South Asia, 65 percent in East Asia, and 75 percent in the Near East and North Africa (FAOSTAT, 2010). A large proportion of the global expansion of cropland areas since 1900 has occurred in rain-fed regions. Native vegetation, such as forests and woodlands, were converted into croplands and grasslands to produce more staple foods and animal protein. This has led to severe land degradation, depletion of soil nutrients and loss of biodiversity, which resulted in poor productivity and a loss of system resilience and ecosystem services (Gordon *et al.*, 2005.). Most countries depend on rain-fed agriculture for grain food production. In many developing countries, a significant number of poor families face poverty, hunger, food insecurity and malnutrition, which intensify with adverse biophysical growing conditions and poor socio-economic infrastructure (Wani, *et al.*, 2011a). In other words, where water limits crop production, poverty is strongly linked to variations in rainfall and to the farmers' ability to bridge intra-seasonal dry spells (Karlberg Rockström and Shiklomanov, 2009).

### 4.1.4 Climate change impact

Climate change is one of the major challenges faced by agriculture worldwide. Crop production, which is vital to global food security, is already being affected by climate change, more so in impoverished communities. It has been predicted that over the next decades, billions of people, especially those living in developing countries, will face water and food shortages, and greater risks to health and life because of climate change. With fewer social, technological and financial resources for adapting to changing conditions, developing countries are the most vulnerable to the impacts of climate change (UNFCCC, 2007). Although some crops may benefit, the overall impacts of climate change on agriculture are expected to be negative (IFPRI, 2009).

With climate change, temperatures are increasing, and rainfall variability is expected to increase further. A decrease in rainfall, coupled with higher atmospheric requirements due to elevated temperatures, is likely to shorten the rain-fed crop-growing period. A study carried out by ICRISAT on climate change revealed a net reduction in the dry sub-humid area in India (10.7 million ha) between 1971-1990 and 1991-2004, indicating that moderate climates are shifting towards both drier and wetter types. Similarly, a recent study by ICRISAT revealed that maize and sorghum yields in the

Nalgonda district (Telangana state) and Parbhani district (Maharashtra state) in India have declined in the last few years due to rising temperatures (Kumara, Moses, Bantialn *et al.*, 2016). The length of the growing period has decreased by 15 days in Nalgonda district, leading to crop moisture stress and ultimately reduced yields (Rao and Wani, 2010). Simulation studies using the Decision Support System for Agricultural Technologies (DSSAT) predicted that the estimated 3.3°C temperature increase expected by the end of this century would, on average, reduce crop yields by 27 percent in the Parbhani district, Maharashtra state (Wani *et al.*, 2009a).

Even though the exact nature and extent of climate change remain uncertain, it is widely believed that it is the poor who will be the hardest hit. With undesirable climatic conditions such as droughts and floods increasing the risk of crop losses, an approach is needed to educate farmers on the impact of climatic variation. Crop success or failure is dependent on the prevailing environmental factors, and the mechanisms for managing environmental stress continue to be the subject of extensive studies in a variety of disciplines. Crop production is increasingly vulnerable to the risks associated with climatic change, including more extreme weather events, such as heavy precipitation, higher coastal waters, geographic shifts in storm and drought patterns, and warmer temperatures (IPCC, 2012).

Climate change is expected to cause substantial crop reductions in South Asia (up to 10 percent for staples, such as paddy, and greater than 10 percent for millet and maize) and in southern Africa (up to 30 percent for maize) by 2030 (Lobell *et al.*, 2008). In the mid to high latitudes, crop productivity may increase slightly with a 1-3°C increase in local mean temperatures. At lower latitudes, crop productivity will decrease even with a relatively minor change in temperature (IPCC, 2007). Localized extreme events and sudden pest and disease outbreaks are already causing greater unpredictability in production from season-to-season and year-to-year, and require rapid and adaptable management responses (FAO-PAR, 2011). By 2050, it is predicted that the global population will be more than 9 billion people, increasing the demand for food and other agricultural products. At the same time, the world faces challenges including land and water scarcity, increased urbanization, and climate change and volatility. Agricultural production remains the main source of income for most rural communities (about 86 percent of the rural population or 2.5 billion people). Improving the adaptability of crops to the adverse effects of climate change is imperative for protecting and improving the livelihoods of the poor and ensuring food security (FAO, 2012). According to

the Consultative Group on International Agriculture Research (CGIAR), one third of all greenhouse gas emissions caused by humans, come from our food system (Thornton, 2012). Climate change adaptation requires more than simply maintaining the current levels of performance of the agricultural sector; it requires developing a set of robust yet flexible responses that will improve the sector's performance even under the changing and challenging conditions brought about by climate change.

Efforts should include the promotion of a holistic, integrated approach to harness the full potential of existing resources by increasing efficiencies of, and integrating all available resources. Such a holistic approach should focus on:

- conserving and utilizing natural endowments, such as land, water, plant, animal and human resources, in a harmonious and integrated manner with low-cost, simple, effective and replicable technology; and
- minimizing the inequalities between irrigated and rain-fed areas, and poverty alleviation.

This approach aims to improve standards of living through an increased earning capacity, and by making available the facilities required for optimum production and disposal of marketable surplus (Wani, Ramakrishna and Sreedevi, 2006). This approach should include the adoption of land- and water-conservation practices, water harvesting in ponds and recharging of groundwater to increase the potential of water resources, an emphasis on crop diversification, use of improved varieties of seeds, integrated nutrient management, and integrated pest management practices.

In the following section of this chapter, we focus on strategies to increase the productivity of rice-based cropping systems by bringing vertical integration into the existing cropping system in Southeast Asian countries to meet the increasing food demand. We analyse the current status of paddy fallows in Cambodia, Indonesia, Lao PDR, Myanmar and Thailand, and assess the potential for intensifying cropping systems. Based on this analysis, we propose a new paradigm for enhancing agricultural productivity per unit area through the introduction of more adaptable crops with a holistic management approach. We outline an integrated genetic natural resource management (IGNRM) strategy based on hands-on experiences in India for harnessing the untapped potential of rain-fed paddy fallow areas to increase food production, and improve the livelihoods of people with finite and scarce resources by enhancing resource-use efficiency.

**TABLE 4.1** Paddy area and paddy fallow area (million ha) by cropping system and water source for Asian regions, 2000-09

Cropping system	South Asia	Southeast Asia	East Asia	Total
<b>Irrigated</b>	30.6	19.6	30.7	80.8
<b>Paddy-Fallow</b>	9.5	0.8	10.2	20.6
<b>Paddy-Other</b>	13.9	1.7	5.7	21.3
<b>Paddy-Paddy or Paddy-Paddy-Paddy</b>	5.7	10.5	5.6	21.8
<b>Paddy-Paddy-Other</b>	1.4	6.5	9.2	17.2
<b>Rainfed</b>	30.7	27.3	2.3	60.3
<b>Paddy-Fallow</b>	21.1	11	2.3	34.4
<b>Paddy-Other</b>	4.2	5.7	0.0	9.9
<b>Paddy-Paddy</b>	5.4	10.6	–	16.0
<b>Grand total</b>	<b>61.3</b>	<b>46.9</b>	<b>33.0</b>	<b>141.2</b>

Source: Compiled by IRRI from IRRI (2010); Huke and Huke, 1997; Maclean *et al.*, 2002; Gumma *et al.*, 2016

## 4.2 Sustainable intensification of paddy fallows

Paddy remains the most important crop grown in Southeast Asia. Approximately 46.9 million ha or 45 percent of Southeast Asia's cropland is planted to paddy in irrigated (18 million ha), rain-fed (18 million ha), and other cropping systems (see Table 4.1). South Asia accounts for 40 percent of the world's harvested paddy area (USDA, 2010), which supplies almost 25 percent of the world's population (FAO, 2015). The most extensive areas under irrigated paddy are in Indonesia, followed by Viet Nam, the Philippines and Thailand. The largest area under upland paddy is also in Indonesia, and significant amounts of land are planted in flood-prone areas in Cambodia, Myanmar and Viet Nam. At present, Southeast Asia produces 150 megatonnes of paddy per year (25 percent of world production), of which 95 percent is consumed within the region. While the per capita demand is expected to decrease in the future, total demand for paddy in Southeast Asia is expected to increase to more than 160 megatonnes per year by 2020 due to population growth (Mutert and Fairhurst, 2002).

In Southeast Asia, paddy is mostly grown in the *kharif* season. A substantial part of this area (15 million ha) remains fallow during the *rabi* (post-rainy) season, primarily due to limited soil moisture availability in the topsoil layer for crop establishment (Subbarao *et al.*, 2001). Paddy fallow is the land used to grow paddy in the *kharif* season but is left uncropped during the following *rabi* season. Of the total paddy fallow area in South and Southeast Asia, 2.11 million ha (33 percent of the *kharif* paddy growing area) is in Bangladesh,

0.39 million ha (26 percent) is in Nepal, and 11.65 million ha (29 percent) is in India. Since paddy is grown on some of the most productive lands in this region, there is scope for increasing the cropping intensity by introducing a second crop during the *rabi* season using appropriate technologies.

The exact area under paddy fallow per country in Southeast Asia is not available but is needed to plan sustainable intensification. In South Asia, there are approximately 15 million ha of paddy fallow, which is nearly 30 percent of the paddy growing area. In India, nearly 82 percent of the paddy fallow is located in the states of Assam, Bihar, Chhattisgarh, Madhya Pradesh, Orissa and West Bengal. GIS analysis of this fallow land identified diverse soil types and climatic conditions (Kumar Rao *et al.*, 2008). The available soil water-holding capacity (1 m soil profile) for most of this land ranges from 150-200 mm (Singh *et al.*, 2010). If we assume that these soils are fully saturated during most of the paddy-growing season, then there will be residual moisture in the soil at paddy harvest that could be used by the following crop. Wani *et al.* (2009a) reported that these paddy fallows offer a potential niche for legume production due to the considerable amount of available green water after the monsoon, which could be used by a short-duration legume crop after simple seed priming and micronutrient amendments (Kumar Rao *et al.*, 2008; Singh *et al.*, 2010).

Large areas of land lying fallow for a significant proportion of the calendar year are of particular concern in Southeast Asia for two reasons:

- 1 The large and growing population of the region requires ever-increasing quantities of locally available food grains and this fallow land represents an under-utilization of agricultural land resources.
- 2 Continuous cereal cropping, in this case paddy, is unsustainable over time and some form of crop rotation or diversification is desirable for sustainable agricultural production (Paroda *et al.*, 1994; Hobbs and Morris, 1996).

Taking advantage of the sufficiently available soil moisture after paddy harvest, growing early-maturing chickpea in paddy fallow areas with best-bet management practices provides an opportunity for intensification (Kumar Rao *et al.*, 2008; Harris *et al.*, 1999; Wani *et al.*, 2011a).

### 4.3 Challenges for crop intensification in paddy fallow

In most Southeast Asian countries, lowland paddy is grown as a single crop in the wet season, leaving the land fallow during the *rabi* season. However, there is tremendous global pressure to produce at least 50 percent more food to feed the projected world population of 9.15 billion by 2050 (Alexandratos and Bruinsma, 2012). To achieve food and nutritional security, we need to ensure a sustainable, profitable, and resilient smallholder agricultural sector for the growing populations of Asia and Africa (FAO, 2015). However, increasing production by expanding sown areas or through technological means such as supplemental irrigation, fertilizer or mechanization is limited due to increasing pressure on cropland for alternative uses as well as environmental concerns, production costs, and severe stresses on water availability in a changing climate scenario (Garnett *et al.*, 2013; Gray *et al.*, 2014). In addition, urbanization, industrialization and salinization are putting more pressure on existing crop areas (Foley *et al.*, 2011).

In Southeast Asia, after the *kharif* season (June–October) of rain-fed and/or irrigated paddy, the fallow that remains during the *rabi* season (November–February) does not have sufficient residual moisture to grow long-duration staple crops (e.g. paddy, wheat). However, there is an opportunity to grow water-efficient short-season grain legumes, which have a high market demand and can improve soil health via nitrogen fixation (Dabin *et al.*, 2016; Dixon *et al.*, 2007; Ghosh *et al.*, 2007). The success of dry season (post-rainy season) crops generally relies on climatic conditions prevailing during crop establishment and various

management practices. The performance of dry season crops is also influenced by limited inputs and management, as well as limited research and extension advice.

Paddy fallow is an underutilized resource of poor farmers with subsistence agricultural practices. There are biophysical, production and socio-economic constraints to promoting the second crop in paddy fallow. Biophysical constraints comprise the persistence of rain-fed ecology, high runoff and low moisture storage, water stagnation/excessive moisture in coastal regions and low residual moisture in dry regions. Poor physical condition of topsoil layers due to puddling in paddy fields, development of deep cracks in soil, low soil organic content, and poor microbial activity, are other factors. Production constraints include the narrow window of opportunity for planting, lack of short-duration and high-yielding varieties, poor plant stands due to poor soil-seed contact in relay sowing, lack of fertilizers/chemicals, severe weed infestations including parasitic weeds, high incidence of diseases, moisture stress, and terminal drought. Socio-economic constraints include traditional practices, such as leaving animals to open graze after the harvest of *kharif* paddy, the low volume of crop produce, lack of suitable markets for *rabi* crop produce, resource-poor farmers, lack of credit and market infrastructure, non-availability of critical inputs, scarcity of human labour after paddy harvest due to migration to urban areas, and lack of mechanization/draft power.

### 4.4 Climate-smart food crops or Future Smart Food

As global warming sets in, agricultural production worldwide is projected to fall by 2 percent per decade, as food demand increases by 14 percent. Global bodies are pushing for climate-smart farming with smart crops in a bid to reduce the carbon footprint of agriculture. Dryland cereals and grain legumes branded as smart food crops (ICRISAT, 2017) benefit consumers, farmers and the planet as they diversify farming systems and help smallholder farmers adapt to climate change. Climate change is already affecting crop production, which will impact farmer livelihoods and food availability. So climate-smart crops and management offer sustainable options to farmers to both adapt to and mitigate climate change (FAO, 2017).

FSF include a variety of warm-season legumes (e.g. black gram, groundnut, mung bean, pigeon pea, soybean) and cool-season legumes (e.g. chickpea, faba bean, lathyrus, lentil, pea), along with nutrient-rich



cereals and millets (finger millet, pearl millet, sorghum), that are good candidates for the Southeast Asian region. These low-water-requiring crops need minimal tillage and enhance the organic matter stored in the soil while supporting biological processes, and nutrient and hydrological cycling (Milder *et al.*, 2011; Hobbs and Govaerts, 2009), which is critical for increasing agricultural resilience to climate change. The inclusion of FSF crops, such as legumes, into paddy-based cropping systems should improve soil structure and nutrition, providing the basis for paddy yield enhancement. As these crops require less water than paddy, they are good options for additional income. Resilience to climate change depends on the identification of FSF crops and management practices, as well community awareness of their benefits. These crops can contribute to many of the SDGs which aim to reduce poverty and hunger, improve health and gender equity, promote responsible consumption, and help nations adapt to climate change.

FSF crops can withstand temperatures in desert-like regions where there are significant differences between day and night temperatures. Specific examples of the advantages of FSF crops include pigeon pea crops, which, when destroyed by unseasonal rain, have the potential for a second flush to produce a good harvest; and pulses, which help to improve soil health through nitrogen fixation and increasing soil microbe diversity. In addition, their leaf droppings provide green manure, help to conserve topsoil and rejuvenate degraded land in severely eroded soils.

In terms of nutritional benefits, FSF include nutri-cereals such as finger millet, pearl millet and sorghum, that are high in iron, and pulses which play an important role as a main source of dietary protein. The high dietary fibre in pulses lowers the risk of diabetes, heart ailments and gastrointestinal diseases. Pulses also provide substantial amounts of micronutrients (vitamins and minerals) including vitamin E, vitamin B6, folic acid, iron, potassium, magnesium, calcium, phosphorus, sulphur and zinc. Chickpea and pigeon pea are excellent sources of iron, manganese and zinc, and can play a key role in countering iron-deficiency anaemia – a serious health issue, with pregnant women being the most susceptible. More effort is needed to improve the productivity and popularization of FSF, to support farmer seed-sharing networks to ensure availability of diverse crop varieties, and to encourage a diverse farming economy at the landscape level.

## 4.5 Interventions to harness the potential of paddy fallow

To ensure successful cropping system intensification in paddy fallow, concentrated efforts are needed in the systemic management of the entire paddy-based cropping system and promotion of technological interventions for utilization of paddy fallows.

### 4.5.1 Managing the planting window

Improving system productivity in paddy-based cropping systems is affected by climate conditions such as rainfall and minimum daily temperatures. Since rain-fed lowland paddy depends on the reliability and amount of rainfall, the growth of subsequent crops can be restricted by low and erratic rainfall. As a result, subsequent crops rely on residual moisture from the wet-season crops. In regions with high rainfall, farmers tend to postpone planting or provide surface drainage to avoid waterlogging. Since planting time is vital for the success of *rabi* crops, targeting the narrow planting window is important, and defined by the interaction between crop growth and environmental conditions. Many studies have shown that good management practices, including planting time adjustment, water management and tillage, could be used to maximize *rabi* season production. However, these practices are time-consuming and expensive. Therefore, we proposed that paddy fallow systems in Southeast Asia are intensified with FSF crops (grain legumes/dry season crops).

The key factors for success in crop intensification is sowing time and the selection of appropriate FSF crops and varieties. In an integrated system, the continued use of long-duration rain-fed paddy (as promoted by paddy breeders who often consider paddy only in isolation) limits the potential for successful sowing of rain-fed *rabi* crops and, therefore, total system productivity. The practice of direct seeding of paddy helps to overcome this limitation as it reduces the time to maturity and opens the window for the successful introduction of FSF crops during the *rabi* season. Paddy varieties with a shorter duration (8-10 days) will also help in the successful utilization of residual soil moisture by *rabi* crops.

### 4.5.2 Balanced plant nutrition

Soil-fertility management needs to be considered along with water-stress management given the fragile nature of the soil resource base (Wani *et al.*, 2009a; Sahrawat, Wani and Parthasaradhi, 2010; Sahrawat, Wani and Pathak, 2010), particularly in paddy fallows. Moreover, it is commonly believed that relatively low crop yields

in rain-fed soils are obtained because these soils have major nutrient deficiencies, especially lacking nitrogen and phosphorus (El-Swaify *et al.*, 1985; Rego *et al.*, 2003; Sharma *et al.*, 2009). Less attention has been given to diagnosing the extent of secondary nutrient deficiencies such as sulphur and micronutrients in various crop production systems (Rego, Wani and Sahrawat., 2005; Sahrawat, Wani and Rego, 2007, Sahrawat, Wani and Pathak, 2010, Sahrawat *et al.*, 2011) on millions of small and marginal farmers' fields. Since 1999, ICRISAT and its partners have conducted systematic and detailed studies on the diagnosis and management of nutrient deficiencies in the semi-arid regions of Asia with an emphasis on India under the integrated watershed management programme (Wani *et al.*, 2009a). These studies revealed widespread deficiencies in multiple nutrients including micronutrients, such as boron, zinc and sulphur, in 80-100 percent of farmers' fields (Rego, Wani and Sahrawat, 2005; Sahrawat, Wani and Rego, 2007; Sahrawat, Wani and Parthasaradhi, 2010; Sahrawat *et al.*, 2011).

Research conducted by ICRISAT on sweet sorghum revealed that balanced nutrient management, including the optimum nitrogen dose, enhances yield and significantly improves resource-use efficiency (Sawargaonkar *et al.*, 2013; Sawargaonkar and Wani, 2016). Similarly, on-farm trials conducted in several states of India (Andhra Pradesh, Chattisgarh, Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu and Uttar Pradesh) showed that yields significantly increased (30-120 percent) in various crops with soil amendments using micro- and secondary nutrients, which resulted in an overall increase in water and nutrient-use efficiencies (Wani, Ramakrishna and Sreedevi, 2006; Wani *et al.*, 2009a and 2011a; Rego, Sahrawat and Wani, 2007). Similarly, studies on the cultivation of FSF crops in paddy fallow revealed that these crops respond positively to balanced nutrient management inclusive of secondary and micronutrients.

The original concept for site-specific nutrient management was developed in 1996 (Dobermann and White, 1999), and has been tested on irrigated paddy systems in China, India, Indonesia, the Philippines, Thailand, and Viet Nam since 1997. Similar results have been reported from watersheds in China, India, Thailand and Viet Nam (Wani, Pathak and Jangawad, 2003; Wani, Joshi and Raju, 2008; Wani *et al.*, 2009a). In the Thanh Ha watershed in Viet Nam, improved management practices, including balanced nutrient management, increased mung bean yield by 34 percent in 1999–2000, and in the Tad Fa watershed in northeastern Thailand, maize yield increased by 12.3 percent (4.1 tonnes per hectare) compared to the farmers' normal yield (3.65 tonnes per hectare).

### 4.5.3 Managing timely seed availability

The overriding challenge for intensification in all six countries is the availability of sufficient seed, particularly for short-duration chickpea. Chickpea is a crop that attracts little private-sector involvement because of its low seed-multiplication rate, its production being limited to the *rabi* season, and vulnerability to storage pests throughout the intervening rainy season. In addition, the seeds are bulky and difficult to distribute cheaply. Nevertheless, the current high market price for grain makes it attractive for smallholders if they have access to farm-saved or locally produced seeds. National policies that promote crop diversification are in place in some countries (e.g. Bangladesh), but the support for alternative crops is small in comparison to that for staple crops such as paddy. Therefore, the establishment of decentralized but assured quality seed banks, particularly those managed by women's self-help groups at village/block level to help alleviate poverty, needs to be promoted.

### 4.5.4 Ensuring better crop establishment

To harness the optimum yield of FSF, crop establishment needs to improve, and the residual soil water after paddy must be utilized efficiently. The success of crop establishment can be achieved by rapid germination, which relies on soil water content and seed-soil contact. Growing crops with drought and heat tolerance is one method for adapting to the vagaries of climate. The strategy would be to develop a sustainable farmers' participatory seed production system for FSF, and promote improved agronomic management practices, such as seed priming, soil-test-based balanced fertilizer that includes micro- and secondary nutrients, biofertilizer, and integrated crop management for better crop establishment in paddy fallow.

Suitable paddy cultivars need to be piloted and identified to help make use of residual moisture for the promotion of short-duration pulses during the *rabi* season. Experimental research and farmers' participatory demonstrations made in the northern states of India (Chhattisgarh, Jharkhand and Orissa) by ICRISAT have shown that short-duration pulses, such as chickpea and blackgram, are suitable for cultivation in paddy fallow and can achieve average yields from 700-850 kg per hectare, provided that suitable varieties and technologies including mechanization for crop establishment are made available. Based on ICRISAT's experience, it is recommended that seed priming, which includes soaking seeds for 4 to 6 hours with the addition of sodium molybdate to the priming water (with further refinement possible), and then sowing with minimum tillage at the optimum seed rate, is used as a simple and

effective practice in relay cropping (Musa *et al.*, 2001; Harris *et al.*, 2002). Seed priming can enhance seed germination and, therefore, crop growth, plant stand and yield.

#### 4.5.5 Minimum tillage or conservation agriculture

Paddy cultivated as lowland crop on vertisols and associated soils is difficult to till as the soil becomes hard, and farmers are facing difficulties with cultivation during the rainy season. During an ICRISAT initiative in central India on *kharif* fallow, it was found that there is a practice of fallowing vertisols and associated soils in Madhya Pradesh, as well as central India, which accounts for around 2.02 million ha during the *kharif* season (Wani, Pathak and Tam, 2002; Dwivedi *et al.*, 2003). Therefore, ICRISAT targeted these *kharif* fallows using different management options for minimum tillage, or conservation agriculture, along with a change in cultivar selection.

There is a direct relationship between consumptive water use or evapotranspiration (ET) and crop yield. ET comprises two major processes: non-productive evaporation and productive transpiration. Evaporation cannot be avoided completely but it can be minimized through various field-scale management practices. The three basic elements of conservation agriculture are:

- 1 zero or minimum tillage without significant soil inversion;
- 2 retention of crop residues on the soil surface; and
- 3 growing crops in rotations appropriate to the soil-climate environment and socio-economic conditions of the region.

On-farm trials on conservation tillage were conducted with short-duration soybean in Madhya Pradesh (Guna, Vidisha, and Indore districts) to intensify the *kharif* fallow areas using suitable landform management (broad bed furrow system). The trials then adopted zero-till planters to sow the succeeding *rabi* chickpea with minimum tillage to enhance the cropping intensity. The results revealed increased crop yields (40-200 percent) and incomes (up to 100 percent) using landform treatments, new varieties and other best-bet management options (Wani, Joshi and Raju, 2008) through crop intensification. So, for better utilization of residual soil moisture, practices such as zero/minimum tillage and relay planting are recommended. Specially designed machinery, such as the zero-tilled multi-crop planter, can be used effectively to sow in paddy fallow without severely affecting soil moisture.

#### 4.5.6 Improving per unit productivity

Current water-use efficiency (WUE) in agriculture (rain fed and irrigated) can be doubled from 35-50 percent to 65-90 percent with large-scale interventions of scientifically proven management (land, water, crop and pest) options. The *Pradhan Mantri Krishi Sinchayi Yojana* (PMKSY) scheme of the Government of India enables the handling of green and blue water resources together by adopting holistic and integrated water management approaches (Wani, *et al.*, 2012, Wani *et al.*, 2016). It is important that all components of the PMKSY scheme be implemented together in rain-fed or irrigated areas with micro watersheds as an implementing unit in the districts. Measures to enhance WUE are discussed elsewhere in this chapter and are reiterated here for continuity:

- efficient use of rainwater stored in soil as soil moisture (green water)
- conjunctive use of blue water through rainwater harvesting in farm ponds
- improved landform for efficient irrigation and water management
- protected cultivation of high-value crops
- soil-test-based integrated nutrient management
- improved crop management practices
- efficient irrigation using micro-irrigation (zero-flood irrigation)
- water-balance-based irrigation scheduling in place of calendar-based irrigation scheduling
- crop rotations and intercrops
- improved crop cultivars (drought tolerant and water efficient)
- integrated pest and disease management
- enabling policies and innovative institutional mechanisms
- organic matter amendments through *in situ* generation of green manuring and composting (vermicomposting and aerobic composting)
- minimum tillage

#### Improved method of irrigation system

Despite water scarcity in most farmers' fields in semi-arid tropic locations, water is carried through open channels, which are usually unlined and, therefore, a significant amount of water is lost through seepage. In India, farmers irrigate land rather than crops. For example, for alfisols and other sandy soils with more than 75 percent sand, practices may include the lining of open field

channels with some hard cementing material, covering of channels with solar panels as in Gujarat or using irrigation pipes to reduce high seepage and evaporation water losses, and enhance productivity and profitability. The use of closed conduits (plastic, rubber, metallic, and cement pipes) should be promoted (Pathak, Sahrawat and Wani, 2009) to achieve high WUE. Micro-irrigation, in general, is practiced for high-value and horticulture crops. Similarly, micro-irrigation in field crops, including paddy-based cropping systems, should be promoted on a large scale to address the issue of groundwater depletion and water scarcity. Some field trials undertaken in Raichur under the Bhoosamruddhi programme on drip irrigation in paddy revealed that growth parameters (plant height, tiller number, soil plant analysis development and leaf area) improved significantly under sub-surface and surface drip irrigation with laterals spaced 60 cm apart. The highest grain yields of paddy of 10.1 and 9.0 tonnes per hectare were recorded in direct-seeded paddies compared with transplanted paddy under surface drip irrigation with laterals placed 80 cm apart and 60 cm, respectively (Bhoosamruddhi Annual Report, 2016).

Similarly, drip irrigation trials in wheat at Tonk and Udaipur, Rajasthan; and Motavadala, Gujarat showed that 40-50 percent of water could be saved using improved irrigation techniques. For water-loving crops, including sugarcane and banana, it is necessary to popularize water-saving technologies, such as drip irrigation, by making them mandatory. In Jharkhand, to use the available water efficiently, drip irrigation was promoted by ICRISAT for vegetable cultivation in Teleya village in Gumla district, which increased the net profit to farmers from Rs 8 000 to Rs 10 000 per acre.

#### Water balance model-based irrigation scheduling

Needs-based irrigation scheduling can further enhance WUE and crop yields. Farmers, in general, adopt calendar-based irrigation scheduling irrespective of the variability in soil physical parameters (water-holding capacity, soil depth, etc.), resulting in either excess or deficit water application. ICRISAT developed a simple decision-making tool called the 'water impact calculator' (WIC) for irrigation scheduling that requires simple data on the field and its management. The tool provides an irrigation schedule for the entire season as a per water-balance approach (Garg *et al.*, 2016).

An ICRISAT-led consortium with local partners (NGOs) and an irrigation company (Jain Irrigation Ltd.) evaluated WIC in farmer participatory field trials between 2010 and 2014 at different sites: Mota Vadala in Jamnagar, Gujarat; Kothapally in Ranga Reddy, Telangana; Parasai-Sindh watershed, Jhansi; Dharola Tonk, Rajasthan, and the

ICRISAT research station. Irrigation was scheduled according to WIC calculations, and the exact quantity of water was applied as per recommendations. Deep percolation losses in WIC-managed fields declined by 50-80 percent compared to calendar-based irrigation. Despite applying 30-40 percent less water, WIC-managed fields had comparable yields to controls. For example, at Mota Vadala, Gujarat, Jamnagar in 2011-12, the WIC-managed plot yielded 5.8 tonnes per hectare of wheat compared to 5.9 tonnes per hectare in the calendar-based irrigation plot; in addition, the drip irrigation plot (guided by WIC) yielded 6.3 tonnes per hectare (see Table 4.2). Similar results were recorded in different years at various testing sites; thus, such decision-making tools need to be promoted as a way of optimizing water resources.

#### Normalization of micro-irrigation policy incentive guidelines

Despite the vast promotion of micro-irrigation by the Government of India, there has been a considerable time lag between the uptake of the subsidy and actual implementation. At present, different government departments or agencies are involved in the implementation of subsidy-oriented schemes. Due to variation in the norms with different states in India, it is difficult to get all the details required by the scheme (Palanisami *et al.*, 2011). Moreover, a differential subsidy pattern for different crops, as well as paddy, is being followed in different regions, which is affecting farmers and implementing agencies' ability to follow and avail the benefits of a given scheme. Hence, it is important to introduce a uniform subsidy across all states in India (Palanisami *et al.*, 2011).

#### 4.5.7 Social engineering

Awareness raising among farmers that crops can be grown on residual soil moisture after paddy was a major factor in promoting crop intensification in paddy fallows (Joshi *et al.*, 2002; Bourai Joshi and Nityanand, 2002). Along with technology demonstrations, and bringing awareness to all stakeholders and policymakers, social engineering is needed to intensify crop production in these fallows by adopting collective action at the cluster level. For effective implementation and scaling-up of sustainable intensification of paddy fallow systems, the development of effective monitoring and evaluation systems is required. These crop intensification technologies should be demonstrated on a pilot basis, followed by a phased-in scale-up to farmers' fields. The anticipated impacts of this initiative would be increased farm incomes and improved rural livelihoods, including enhanced nutritional status. Such initiatives would strengthen environmental benefits/ecosystem services,

TABLE 4.2 Experimental results on enhancing water use efficiency

Particulars	Water applied by farmers in WIC-trial fields	Water applied by farmers in WIC-trial fields	Water applied by farmers in traditionally managed control field (calendar-based)
Method of irrigation	Drip	Flood	Flood
<b>1 Mota Vadala, Gujarat</b>			
<b>a Crop</b>	<b>Wheat</b>	<b>Wheat</b>	<b>Wheat</b>
Irrigation water (mm)	460	520	950
Number of irrigations	7	6	13
Crop yield (t ha <sup>-1</sup> )	6.3	5.8	5.9
Deep percolation (mm)	80	150	540
<b>b Crop</b>	<b>Chickpea</b>	<b>Chickpea</b>	<b>Chickpea</b>
Irrigation water (mm)	300	420	580
Number of irrigations	5	6	9
Crop yield (t ha <sup>-1</sup> )	2.2	1.8	1.8
Deep percolation (mm)	50	150	310
<b>2 Dharola, Tonk, Rajasthan</b>			
<b>a Crop</b>	<b>Wheat</b>	<b>Wheat</b>	<b>Wheat</b>
Irrigation water (mm)	260	300	410
Number of irrigations	5	4	5
Crop yield (t ha <sup>-1</sup> )	3.5	3.4	3.5
Deep percolation (mm)	10	30	90
<b>3 Kothapally, Telangana</b>			
<b>a Crop</b>	<b>Tomato</b>	<b>Tomato</b>	<b>Tomato</b>
Irrigation water (mm)	400	590	700
Number of irrigations	9	8	10
Crop yield (t ha <sup>-1</sup> )	8.7	8.3	8.3
Deep percolation (mm)	20	150	220

Source: Wani *et al.*, 2016

including improved land- and water-use efficiencies, and more resilient paddy-based cropping systems with balanced fertilizer inputs and improved soil fertility. At the national level, the Government of India's expenditure of hard currency for pulse importation will decline due to the increased domestic availability of chickpea and other pulses.

To address the prevailing common practice of open animal grazing after the paddy crop harvest in northern and eastern India, concerted efforts were undertaken by ICRISAT in Jharkhand to impart training and awareness building to different stakeholders (including farmers and development agencies), strengthen formal and informal seed systems, and increase access to other inputs to enhance adoption of improved cultivars and technologies. These efforts increased cropping intensity by 25 percent and system productivity by 30-40 percent.

**TABLE 4.3** Evaluation of chickpea cultivars in paddy fallows in Jharkhand, post-rainy 2010-13

District	Block	Crop	Variety	Yield (kg ha <sup>-1</sup> )
Gumla	Raideh	Chickpea	KAK 2	1 520
			JG 11	1 340
Seraikella-Kharsawan	Sariekela	Chickpea	KAK 2	1 490
			JG 11	1 280

#### 4.6 Case study: Paddy fallow management in northeastern states of India

The Sir Ratan Tata Trust (SRTT) supported ICRISAT's proposal to increase the impact of development projects in northeastern states of India (Jharkhand, Odisha and Chhattisgarh) by technical backstopping and empowering stakeholders to improve livelihoods through increased agricultural productivity and opportunities via the sustainable use of natural resources. To bridge the gap between the 'desired' and 'achieved' yield, bring quantitative as well as qualitative improvements to fulfil national food needs, sustain the agricultural resource base, and provide livelihood security to millions of rural masses, ICRISAT adopted a holistic system management approach that respects the integrity of ecosystems while humans meet their food needs.

In these targeted pilots, *kharif* paddy was the predominant mono-cropping system, leaving the land fallow during the *rabi* season. Utilization of the paddy fallow is an opportunity that presents considerable scope for crop intensification and to increase farmer incomes. An estimated 11 million ha of paddy area remains fallow during the post-rainy season in the northeastern states of India, providing ample opportunity to enhance land- and water-use efficiency by promoting short-duration pulse/oilseed crops in identified areas. ICRISAT adopted a system approach that linked the farm, as a unit targeting the adoption of modern management practices pertaining to seeds, water, labour, capital or credit, and fertilizer and pesticide use, with other agriculture allied activities for efficient resource management and to enhance system profitability. The pilot addressed the constraints of establishing a succeeding crop and promoted improved paddy cultivars of suitable duration to leave sufficient time for a *rabi* crop to be planted.

ICRISAT analysed paddy fallows to identify bottlenecks associated with their effective and sustainable utilization. The analysis showed that sufficient stored moisture remains in the soil after the rainy season crop to grow

a post-rainy season crop and that introducing appropriate legumes into paddy fallows is likely to have a significant impact on farmer income. The strategy was promoted to develop a sustainable farmers' participatory seed production system for pulses and to promote improved agronomic (e.g. seed priming, soil-test-based balanced fertilizers including micro and secondary nutrients, biofertilizers, integrated management, etc.) and water conservation practices (e.g. zero/minimum tillage/relay planting) for better crop establishment in paddy fallows.

The scaled-up on-farm research showed that short-duration pulses are suitable for cultivation in paddy fallow and yield as well, provided that suitable varieties and technologies (including mechanization for crop establishment) are available. Participatory trials in Jharkhand state, with the purpose of demonstrating and evaluating chickpea cultivars (KAK 2 and JG 11) in post-rainy fallow, yielded 1 490-1 520 kg per hectare for KAK 2 and 1 280-1 340 kg per hectare for JG 11 (see Table 4.3). This indicates that chickpea is a suitable crop to grow after paddy with the benefits of additional income and enhanced rainwater-use efficiency. An economic analysis showed that growing legumes in paddy fallows is profitable for farmers, with a benefit-cost ratio of greater than 3.0 for many legumes. Such systems could generate 584 million person-days of employment for South Asia and make the region self-sufficient in pulse production.

In several villages in the states of Jharkhand and Madhya Pradesh in India, on-farm participatory research trials sponsored by the Ministry of Water Resources demonstrated enhanced rainfall-use efficiency with paddy fallow cultivation, with total production of 5 600 to 8 500 kg per hectare for two crops (paddy and chickpea). This increased average net income per hectare from INR 51 000 to 84 000 (USD 1 130 to 1 870) (Singh *et al.*, 2010). Similarly it was observed that cultivation of legumes improves soil fertility and has follow-on beneficial effects on paddy performance. The soil-building integrated approach promoted in the pilot sites emphasized recycling of local materials and reduced reliance on external inputs.

**TABLE 4.4** Percent increase in paddy and chickpea yields with improved management from 2007-08 to 2008-09

District	Number of farmers involved	Area sown (ha)	Biomass yield (kg ha <sup>-1</sup> )		Grain yield (kg ha <sup>-1</sup> )		% Increase in grain yield
			Trade	Import	Trade	Import	
<b>Paddy (Kharif season)</b>							
Ambikapur	48	15	11 110	12 460	5 520	5 970	8.1
Kanker	36	15	12 930	14 880	6 090	7 370	20.9
Bastar	18	15	8 260	10 100	3 910	5 060	29.4
<b>Chickpea (Rabi season)</b>							
Ambikapur	28	4.8	–	480	–	220	–
Kanker	80	19.7	–	1 980	–	1 140	–
Bastar	41	14.3	–	1 020	–	540	–

**TABLE 4.5** WUE of Paddy and paddy and chickpea during 2007-08 to 2008-09

District	Rainfall (mm)	Irrigation (mm)	Soil moisture extraction (mm)	WUE (kg ha <sup>-1</sup> mm <sup>-1</sup> )	
				Trade	Import
<b>Paddy (Kharif season)</b>					
Ambikapur	495	9	–	10.9	11.8
Kanker	334	15.5	–	17.4	21.1
Bastar	351	0	–	11.1	14.4
<b>Chickpea</b>					
Ambikapur	512	48	54	–	10.1
Kanker	337	56	25	–	20.3
Bastar	359	45	34	–	12.8

In Chhattisgarh, the on-farm participatory research trials sponsored by the Ministry of Water Resources revealed that the introduction of best management practices such as zero-tilled sowing of *rabi* crops, seed priming, etc. in paddy-based cropping systems enhanced productivity of *rabi* crop and, thereby, total system productivity. Early sowing of paddy along with good management practices increased paddy productivity by 8–29 percent (see Table 4.4) with scope for cultivation of *rabi* crops on the residual moisture.

Significant variation in WUE was recorded for paddy-based cropping system productivity with double cropping. The WUE was calculated as rupees earned per hectare per mm<sup>-1</sup> of rainfall. The WUE for paddy ranged from 11.8-21.1 percent (see Table 4.5) and for chickpea ranged from 10.1-20.3 percent, a clear increase in system productivity by adopting cropping system intensification in Chhattisgarh.

In an initiative supported by the Department of Agriculture, Co-operation and Farmers Welfare (DoAC&FW) in India, ICRISAT focused on crop intensification in paddy fallows through the introduction of chickpea, bringing in 3 million ha of paddy fallow from the eastern state under FSF crops. DoAC&FW along with ICRISAT conducted a national-level workshop at Bhubaneswar for scientists, researchers, farmers and policymakers on the introduction of FSF crops to existing single cropping of paddy. In 2016/17, a DoAC&FW-led consortium introduced chickpea to almost 1.8 million ha along with best management practices, including seed priming and mechanized sowing with zero-till multi-crop planters with minimal tillage. The farmers harvested 650-800 kg per hectare of chickpea with net economic benefits ranging from INR. 15 000-20 000 per hectare.

## 4.7 Conclusion

Paddy fallow offers a potential niche for legume cultivation in Southeast Asia. A combination of short-duration FSF crops holds the key to increased production in paddy-based cropping systems through vertical integration. Cultivation of paddy fallow has the following benefits:

- 1 Diversification of cropping in paddy fallow is the key to poverty alleviation in this agro-ecosystem and deserves priority attention.
- 2 Early sowing, minimal tillage and seed priming are effective management options for farmers to grow a rain-fed *rabi* crop in paddy fallow.
- 3 Regular cultivation of FSF crops improves soil fertility and has follow-on beneficial effects on paddy performance.
- 4 Additional income, better family nutrition, and increased empowerment as a result of social mobilization will improve farmer wellbeing and capacity to cope with climate change.
- 5 The presence of ground cover for most of the year reduces the risk of soil erosion.
- 6 Farmers have more cropping choices and land-use options that will help increase agro-biodiversity and improve system resilience.

Sustainable intensification of paddy fallow is an urgent need and should be effectively addressed to ensure long-term food security.



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# 5 Mainstreaming Future Smart Food for improving nutrition security

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## 5.1 Introduction

It is often said that the healthier the people, the healthier the nation, and that health is an ideal index of prosperity. The health of the people mainly depends on the daily diet they consume; hence, diversity in the food basket and a diversified diet are imperative to address the issues of undernutrition and malnutrition. Important factors that cause hunger and malnutrition include the ever-increasing population, especially in developing and underdeveloped countries, and declining natural resources such as arable land, water, soil health and large-scale erosion of biodiversity. Added to this, climate change and the uncertainty surrounding it have accelerated problems associated with agricultural production and productivity.

Meeting the food needs of the increasing population has led to cultivation of a few crops such as rice, wheat and maize over vast areas, resulting in large-scale replacement of numerous landraces, traditional and lesser-known crops, as well as their wild relatives. Three cereals (rice, maize and wheat), two vegetables (potato and tomato) and five animal species provide 60 percent of the world's food and energy. The dwindling diversity of the food basket and monotonous diet has resulted in micronutrient deficiencies in iron, zinc and iodine, along with vitamins A, B12 and D, which are now widespread, especially among women and children in both underdeveloped and developing countries. Given this situation, diversification of the food basket and diet, particularly fruits and vegetables, is vital to overcoming the challenges of undernutrition and malnutrition. Mainstreaming biodiversity for food and nutrition security and climate resilience has been emphasized by the Convention on Biological Diversity (CBD) (1992), (FAO, 1996a and b), FAO (2017) and Bioversity International (2017). This objective of the chapter is to share the experience of Bioversity International in promoting and mainstreaming potential neglected and underutilized species (NUS) as Future Smart Food (FSF) to improve food security and nutrition.

## 5.2 Why neglected and underutilized species?

Biodiversity, in general, and NUS, in particular, are promising options for addressing several human nutrition and health-related issues. In addition to being good food sources, NUS yield other products, such as beverages, fibre, gums and resins, of high economic value. Due to the aesthetic and religious values of fruits and spices, some of these have become part of local religious functions and ceremonies (Pareek and Sharma, 2009a and b). A large proportion of NUS, including minor millets, vegetables, legumes, fruit species, root and tuber crops, form major components of underutilized biodiversity and provide immense support to ecosystem services. Local people, especially tribal communities, have contributed a great deal of information and knowledge on the multipurpose uses of traditional and wild crop species in their daily diets. For example, wine and local drinks are prepared after fermentation, while some species are used for medicine to cure various chronic and serious health ailments. Traditional and ethnic food recipes developed for the preparation of several local food products are very popular in the present-day. Fruit trees serve as an excellent source of pollen and nectar for honey bees and contribute immensely to honey as well as other crop production through pollination.

Since NUS are generally rich in nutrients and health-promoting compounds with preventive effects against malnutrition and some chronic diseases, they have the potential to improve the nutrition and health of indigenous communities in many parts of the world. Two international consultations, one by the M S Swaminathan Research Foundation (MSSRF), Chennai, India (1999) and the other by the International Center for Underutilized Crops (ICUC), Colombo, Sri Lanka (2006), highlighted the need for mainstreaming NUS. Therefore, broadening the food basket with diversified diets by including these neglected species could be a useful tool for improving overall human nutrition and health.

NUS are characterized not only by local importance but also by their potential for improving diet diversity in a specific region (Baldermann *et al.*, 2016). Considering this potential, NUS are gaining the attention of many nutritionists and biological and agriculture scientists looking to address the challenges of food and nutrition insecurity.

### 5.3 Neglected then and important now

Research shows that early man used 40 000 to 100 000 plants for his day-to-day needs, including for industrial, cultural and medicinal purposes (Eyzaguirre *et al.*, 1999). According to an ethnobotanical survey, more than 7 000 plant species have been cultivated and harvested since people started farming (Rehm and Espig, 1991; Wilson, 1992). However, according to FAO (1996a and b), only 150 crops are now grown commercially on a significant scale. These are being recognized as crops of the future because of their multiple benefits such as nutraceutical values, medicinal properties and climate resilience (Padulosi, 2000). Minor crops are widely distributed in both the northern and southern hemispheres, covering tropical, subtropical and, to some extent, semi-temperate regions of the world. However, they are more abundant in tropical and subtropical regions in wild/semi-domesticated conditions (Pareek *et al.*, 1988; Pareek and Sharma, 2009a and b). Arora (2014) calculated that some 778 species of underutilized and lesser-known minor food plants are grown in different regions of the Asia-Pacific including 261 fruits, 213 vegetables, 55 root/tuber types, 34 nuts, 28 pseudo-cereals and millets, 14 grain legumes/pulses, 25 industrial crops, and 148 others. In most of the rural areas, these species are grown in front and backyards of dwellings, and on the farms for family use. Many NUS have not attracted the attention of the researchers, extension agencies and policymakers and, due to this restricted and limited use, were deprived of in-depth research and popularization. As reported in early reviews by William and Haq (2000), Padulosi *et al.* (2006) and Baldermann *et al.* (2016), various NUS have remained orphaned/underutilized due to:

- Poor income generation, rendering them economically not viable for commercial cultivation
- Distribution restricted to a small geographical area, especially in and around their centre of origin
- Consumed by very small population, especially tribal/local inhabitants
- Inadequate research on these crops for their improvement, multiplication, cultivation and nutritional potential

- Lack of modern processing and post-harvest technical know-how for value-added products
- Promotion and popularization of very few crops as staple foods, such as rice, wheat, maize, potato, etc.
- Constant disturbance of ecosystem and habitat destruction leading to disappearance of interspecific and intraspecific variability and, in turn, the species themselves
- Lack of value chain and policy support for popularization
- The stigma attached to NUS as being 'foods of the poor'

However, they are being recognized as crops of the future due to:

- Offering increased food and nutritional insecurity
- Being a source of desirable traits for various biotic and abiotic stress resistance/tolerance
- Having a climate-resilient nature due to high genetic plasticity/variability
- Being hardy crops adaptable to wider/harsher ecological conditions
- Being rich in nutritional and nutraceutical values
- Some species have high medicinal value for treating health ailments
- Some species are a good source of industrial raw material

### 5.4 Review of literature on NUS

The increasing recognition of NUS has resulted in the organization of numerous research initiatives, conferences and expert consultations all over the world. Anthony, de Groot and Haq (eds., 1993) provided a detailed account of fruits and nuts that grow in Asia. In the first national coordinators meeting held in Bangkok, Anthony and Haq (1997) spoke on the importance of the underutilized tropical fruits of Asia. Arora *et al.* (2006) enumerated underutilized crops of Indian origin. To enhance the use of NUS, Bhag Mal, Paroda and Kochhar (1997) reported on the incorporation of underutilized crops into farming research. Gundel *et al.* (eds., 2003) detailed the role of underutilized plant species in poverty alleviation. Kermali, Anishtetty and Cooper. (1997) suggested promoting the development and commercialization of underutilized crops and species in the FAO global plan of action. Monti (1997) highlighted the landscape and cultural importance of neglected plant genetic resources in the Mediterranean region.

MSSRF (1999, 2002) gave a detailed account of nutritious minor millets in addressing food security challenges. Nath *et al.* (2008, 2009) provided a detailed account of lesser-known tropical and subtropical arid and semi-arid zone fruits. Jaenicke *et al.* (2006) and Jaenicke and Hoschle-Zeledon (2006) reviewed the development of NUS from 1970 to 2005. Padulosi *et al.* (2008) revised and updated the information on international, regional and national dialogues, conferences and consultations held from 1970 to 2008. Dandin and Mathur (2015) reported the *ex-situ* conservation of underutilized tropical and subtropical fruits. Baldermann *et al.* (2016) updated the information to 2016 with a country-wide revision and identification of potential NUS along with nutritional values for mainstreaming.

## 5.5 Promoting and mainstreaming promising NUS: Experience of Bioversity International

Although NUS make up a large component of biodiversity, they are often ignored due to the importance given to a few crops, particularly maize, potato, rice, tomato and wheat, which are cultivated in large areas. This has resulted in disappearance of land races, crop wild relatives, endemic crops etc. Further, several potential NUS species need to be identified to make them more popular, and need to be promoted to create a level playing ground with other major crops both in research and develop support and future policy considerations.

### 5.5.1 Identification of promising NUS

The common objective of many studies associated with NUS is to identify potential species, and popularize them for inclusion in the daily diet to improve human nutrition and health, as well as overcome climate-change effects and livelihoods/income for small farmers. Eyzaguirre *et al.* (1999), William and Haq (2000), Padulosi *et al.* (2006, 2013) and Baldermann *et al.* (2016) suggested various criteria for mainstreaming NUS. These include food and nutritional composition, local adaptability for large-scale cultivation and yield potential, market potential, local acceptance both for cultivation and consumption, and a broad genetic base for climate resilience.

Following the above criteria, scientists have identified potential species in various countries and regions. Potential crops include minor millets, vegetable and grain legumes, leafy vegetables, root and tuber crops, fruits and nuts, and spices and condiments, along with a few industrially important species.

Considering the importance of these NUS, Bioversity International has been working on the management

and mainstreaming of these crops for more than 15 years. A number of programmes have been initiated by Bioversity International, including:

- 1 Enhancing the Contribution of Neglected and Underutilized Species to Food Security and to Incomes of the Rural Poor, funded by IFAD and implemented from 2001 to 2006. The project countries covered were Bolivia, Egypt, Equator, India, Nepal, Peru and Yemen and included a large number of crops of nutraceutical, medicinal and culinary importance. Characterization of important species along with documentation of traditional knowledge, conservation and commercial issues have been addressed.
- 2 *In-situ/On-Farm Conservation and Use of Agricultural Biodiversity (Horticultural Crops and Wild Fruit Species)* in Central Asia was funded by UNEP-GEF. The programme was implemented from 2005 to 2013 in temperate regions covering China, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. Genetic diversity of almond, alycha, apricot, fig, peach, pear, plum pomegranate, walnut etc. and their wild relatives was studied. Legislation and policy recommendations were made to support *in-situ/on-farm* conservation involving custodian farmers and protection of their rights, as well as mechanisms for benefit sharing.
- 3 Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihood, Food Security and Ecosystem Services, funded by UNEP-GEF from 2009 to 2015, with a regional focus covering India, Indonesia, Malaysia and Thailand. This covered tropical fruit tree conservation of citrus, mango, mangosteen and rambutan. Details of the custodian farmers who identified varieties of these crops, and are maintaining the diversity of these crops, along with the good agriculture practices being followed for *in-situ* and on-farm conservation that supports livelihoods, have been documented.
- 4 “Reinforcing the resilience of poor rural communities in the face of food insecurity, poverty and climate change through on-farm conservation of local agrobiodiversity” (the first part), funded by IFAD from 2009 to 2015. The crops covered were Andean grains and minor millets in Bolivia, India and Nepal.
- 5 “Improving smallholder farmers’ food and nutrition security through sustainable use and conservation of agrobiodiversity” (the second part), funded by IFAD from 2013 through 2015, and implemented in Bolivia, India and Nepal. This second part of the programme included in-depth studies carried out on Andean grains and minor millets.



**TABLE 5.1** Potential NUS crops identified for mainstreaming under different projects

Sl. No.	Botanical name	Common name
1	<i>Setaria italic</i>	Foxtail millet
2	<i>Panicum miliaceum</i>	Proso millet
3	<i>Eleusine coracana</i>	Finger millet
4	<i>Fagopyrum esculentum</i>	Buckwheat
5	<i>Amaranthus species</i>	Amaranth (leaf and grain)
6	<i>Moringa olifera</i>	Drumstick
7	<i>Momordica charantia</i>	Bitter gourd
8	<i>Trigonella foenum-graecum</i>	Fenugreek
9	<i>Hibiscus sabdariffa</i>	Rosella
10	<i>Trichosanthes cucumerina</i>	Snake guard
11	<i>Vigna subterranea</i>	Bambara groundnut
12	<i>Vigna radiata</i>	Mung bean
13	<i>Vigna umbellate</i>	Rice bean
14	<i>Lens culinaris</i>	Lentil
15	<i>Macrotyloma uniflorum</i>	Horse gram
16	<i>Colocasia esculenta</i>	Taro
17	<i>Amorphophallus paeoniifolius</i>	Elephant foot yam
18	<i>Ipomoea batatas</i>	Sweet potato
19	<i>Dioscoria species</i>	Yams
20	<i>Artocarpus heterophyllus</i>	Jackfruit
21	<i>Syzygium cumini</i>	Jamun
22	<i>Annona species</i>	Custard apple
23	<i>Tamarindus indica</i>	Tamarind
24	<i>Ziziphus mourtiana</i>	Ber
25	<i>Mangifera indica</i>	Pickle mango
26	<i>Garcinia indica</i>	Kokum butter tree
27	<i>Nephelium lappaceum</i>	Rambutan

6 Mainstreaming Biodiversity Conservation and Sustainable Use for Improved Human Nutrition and Well-being, funded by BFN-UNEP-GEF for five years (2012 to 2017). The countries covered were Brazil, Kenya, Sri Lanka and Turkey. The project included studies of 40 wild edible grains, 70 native fruit species and moringa among others. It examined the importance of the nutritional value of agrobiodiversity, and its role in promoting healthy diets.

7 Promotion of neglected and indigenous vegetable crops for nutritional health in Eastern and Southern Africa funded by Germany from 2003 to 2006. In this project indigenous vegetable crops have been considered for detailed study for identification of potential species and new varieties.

- 8 Conservation and use of rare and diverse tropical fruit species with potential for enhanced use in Malaysia, undertaken from 2005 to 2009. Rare tropical fruit tree species were identified for enhanced food and nutrition. From this, a few rare tropical fruit species have been shortlisted for conservation and exploitation in the future.
- 9 The India UNEP Project (2016 to 2021) on mainstreaming agricultural biodiversity conservation and utilization in the agricultural sector to ensure ecosystem services and reduce vulnerability. This project covers five Indian states and is currently being implemented.
- 10 ICAR–Bioversity International collaborative programmes on the characterization and mainstreaming of minor fruits of tropical and subtropical fruits is being implemented in India from 2014 to 2019 with ICAR funding. The project is aimed at identifying potential minor fruit crops for mainstreaming to address the challenges of climate-change effects and malnutrition.

Many promising NUS have been identified through these projects (see Table 5.1) for mainstreaming and mitigating food and nutrition challenges, as well as potentially helping to overcome climate change effects. These identified crops are acclimatized to the local conditions; are already popular and being consumed by the local people, with producers making a good income and receiving support in the existing market. FAO (2017), in its Regional Expert Consultation, supported the identification of these crops as FSF.

### 5.5.2 Major interventions for mainstreaming/promoting NUS

Based on the criteria of mainstreaming, some minor millets, legumes, leaf vegetables and other NUS have been considered for further popularization in the food basket to diversify people's daily diets. Further, the authorities are concentrating on research and development programmes, nutritional profiling, and value-chain development for building the dietary image of these crops. The following are the important crops that have been successfully mainstreamed.

- 1 **Minor millets (finger millet, proso millet, Italian millet, little millet and kodo millet):** Research and development activities implemented by MSSRF Chennai, ICAR-AICRP, the University of Agricultural Sciences (UAS) Bengaluru in association with Bioversity International have successfully promoted minor millets as nutri-millets.

**Special attributes:** Minor millets are grains that are highly resistant to abiotic stress and can be cultivated on marginal lands with low fertility. They are rich in dietary fibre, proteins, minerals and amino acids providing nutrient-rich, anti-obese, anti-diabetic foods for humans, as well as nutrient-rich and palatable fodder for cattle. Minor millets are primarily organic in cultivation.

**Promotional interventions:** ICAR has established “All India-Coordinated Research Projects” (AICRP) with good networks for the promotion of these crops. AICRP is a network programme wherein research and development aspects of the selected/identified group of crops/concepts is conducted in different regions involving local research organizations. Women's self-help groups with all members trained on cultivation and processing, and supplied with quality seed material have been created, and small-scale processing mills have been established to improve efficiency. In addition, women have been trained in the development of value-added products, packaging and marketing, with numerous foods fairs organized to create awareness of and to popularize these products. Special incentives are provided to producers, and retail outlets have been opened for marketing. These crops are covered under social food supply systems. The value-added products have helped enhance production by farmers, and have a minimum support price established by the government for sustainable production.

- 2 **Legumes (Bambara groundnut, horse gram, lentil, mung bean and rice bean):** Legumes are consumed both as green pods and dried grains. They are good sources of essential vitamins, micronutrients and proteins. They also serve as a source of fodder for livestock, as well as fix atmospheric nitrogen. They are best suited to dryland farming systems due to their drought resistance and short growth duration.

**Promotional interventions:** ICAR's AICRP has established a community seed bank for the timely distribution of quality seeds. Organized producer's groups have been trained in cultural practices, post-harvest handling, and production of value-added consumer products as well as the establishment of a market chain. Since legumes are a cheap source of protein for vegetarians, they have been incorporated into the Mid-Day Meal Programme in primary schools to combat undernutrition and malnutrition of school children.

TABLE 5.2 Potential underutilized fruits for mainstreaming

Crops	Species	Varieties
<b>Jackfruit</b> ( <i>Artocarpus species</i> )	6	32
<b>Custard apple</b> ( <i>Annona species</i> )	7	24
<b>Ber</b> ( <i>Ziziphus species</i> )	3	8
<b>Jewish plum</b> ( <i>Syzygium species</i> )	9	17
<b>Drumstick</b> ( <i>Moringa oleifera</i> )	1	5
<b>Tamarind</b> ( <i>Tamarindus indica</i> )	1	5

### 3 Root and tuber crops (sweet potato, elephant foot yam, taro, yams/*dioscorea* etc.):

Tuber crops are the third-most important food source for people after cereals and grain legumes, and boast the versatility to adapt to varying altitudes, climate and edaphic conditions. Tuber crops have been a food source since ancient times. Most are grown organically and constitute a major component of indigenous food in tribal areas. Orange, yellow and pink-fleshed sweet potato, rich in vitamins A and C, and starch are recognized as a staple food in some African countries.

**Promotional interventions:** ICAR's AICRP has established producers' clubs that specifically involve women for production and processing. They have also opened primary processing units in a major cultivation areas as well as organized seed banks.

### 4 Vegetables (amaranth including leaf and grain, moringa or drumstick, bitter gourd, rosella, fenugreek and snake gourd):

Vegetables constitute the most significant portion of biodiversity and are a well-balanced food as they supply vitamins (such as C, A, B1, B6, B9, and E), minerals, dietary fibre and phytochemicals. Vegetables also have strong nutraceutical value and can help prevent some chronic diseases and gastrointestinal disorders. Most vegetables are short-duration crops that are adaptable to a variety of edaphic and climatic adversities. Therefore, they are common among rural tribal populations, with cucurbits and leafy vegetables prominent constituents of the daily diet.

**Promotional interventions:** Institutes with high levels of expertise have been established for researching gene to plate processes to promote vegetable consumption. Farmer producer companies/organizations have been formed. Consumer fairs for consumer awareness and popularization have been organized, and a seed production and a distribution network has been established.

### 5 Fruits (butter tree, custard apple, jackfruit, jamun, kokum, pickle mango, rambutan, tamarind):

Fruits are the cheapest and most accessible source of nutrients and are grown all over the world and eaten fresh without loss of nutritional value. Most are perineal in nature with wide adaptability to different agro-ecological regions. Bioversity International has completed three mega projects on the promotion of fruit crops for health and nutrition. As part of its mission, the Bangalore project office of Bioversity International has initiated a project on the collection, *ex-situ* conservation, and characterization of mainstream underutilized tropical and subtropical fruits. Through this effort, 227 accessions of 103 species belonging to 55 genera and 33 families have been collected from different custodian farmers, nurserymen and research organizations from different parts of India. These have been conserved in the *ex-situ* gene bank. Based on the preliminary studies of the species and varieties collected, six crops: ber, custard apple, drumstick, jackfruit, jamun (java plumb) and tamarind have been identified as potential crops for mainstreaming (see Table 5.2). In-depth studies have been initiated on the characterization of the available genetic variability along with landraces and wild relatives. Associated ethnobotanical and traditional knowledge, food and nutritional composition, local food preparation and recipes have been collected. In addition, information on the custodian farmers maintaining the germplasm of these species, and good cultivation practices, including propagation protocols, have been recorded. Currently, characterization, food-value composition and development of value-added product aspects of these fruits have been completed, which lays the foundation for future promotional interventions.

#### Jackfruit (*Artocarpus species*)

Jackfruit, which is native to Western Ghats of India, has been introduced into many countries because of its wide adaptability and rich nutritional composition.

Everything from the tender fruit to raw flakes, mature flakes and seeds are consumed, and the timber is highly valued. Jackfruit is rich in dietary fibre, which makes it a good bulk laxative. Fresh fruits have a small amount of vitamin A and flavonoid pigments such as caroten-B, xanthin, lutein and cryptoxanthin-B. It is a rare fruit rich in the B-complex group of vitamins. It contains good amounts of vitamin B6 (pyridoxine), niacin, riboflavin and folic acid. Fresh fruit is a good source of iron, manganese, magnesium and potassium. Potassium is an important component of cells and body fluids and helps to control heart rate and blood pressure.

#### **Custard apple (*Annona* species)**

In the genus *Annona*, six species produce edible fruits of high nutritional value. Food products such as ice cream, juice, mixed fruit jam, pastries and sweets are prepared from this species. *A. muricata* is a good source for medicines used for combatting cancer. The seeds and leaves of most species have insecticidal properties that can be used in the manufacture of bio-pesticides and the paste of the leaf is used to treat boils, abscesses and ulcers. Magnesium in custard apples is good for the prevention of strokes and heart attacks. All six species can grow on marginal lands with low fertility and are adaptable to biotic stress conditions.

#### **Jamun**

Jamun (*Syzygium cumini* Skeels) is an underexploited indigenous fruit tree of India. It produces dark purple, delicious fruit with prominent seeds. Variation exists between seedling strains in respect of fruit shape and size, pulp colour, total soluble solids, acidity and earliness. It is a pharmaceutically important fruit, adequately rich in antioxidants and phytochemicals, as well as containing some essential nutritional components. The fruit is a good source of carbohydrates, iron, minerals, protein and sugar. The seeds contain alkaloids namely, jambosin and a glycoside called jambolin or antimellin, which reduces the diastatic conversion of starch into sugars. The seed powder is extensively used to control diabetes.

#### **Ber**

The ber plant is highly drought resistant and perfectly adapted to arid regions. The fruit is eaten fresh and also processed for making *murraba* and candies. The fruit is rich in vitamins C, A and B-complex, and minerals. Ber fruits help in weight-loss and soothes the nervous system with its sedative properties. Recent research shows that ber fruit could help in the fight against Alzheimer's disease.

#### **Drumstick (*Moringa oleifera*)**

Drumstick is a perennial multipurpose tree. All parts of the tree have one or more nutritional elements. Leaves are a rich source of iron, fibre and vitamin A. Drumstick is a popular food for anaemic people, especially women and children. Pods are produced four times a year and used as a vegetable. Pods are a rich source of vitamins A and C, iron, calcium and potassium. Seeds are used for the extraction of high-value oil.

#### **Tamarind (*Tamarindus indica*)**

The species is highly drought tolerant and grown in marginal areas and wastelands. Tamarind is ideally suited for avenue planting as a roadside tree. Ripe fruits are a rich source of vitamin C and tartaric acid. Seeds are used for the extraction of starch, protein and oil. The acidic sourness of the fruit is due to tauric acid levels ranging from 12.2–23.8 percent but this is uncommon in other plant tissues. Tamarind seeds are an alternative source of protein and some essential amino acids. An *ex-situ* gene bank and nursery has been established to provide quality planting material.

## **5.6 Future Options for Mainstreaming FSF's for Food Security and Nutrition**

Based on these reports and evidence, many underutilized crops have the potential for helping attain food and health security; are resilient to changing climate and provide livelihood support in terms of research and development efforts, market value for sustainable income and policy issues. Many authors have suggested approaches to mainstreaming the potential crops in the future. Williams and Haq (2000), Padulosi *et al.* (2013), Arora (2014), Baldermann *et al.* (2016), and several others emphasized the importance of underutilized crops and recommended the next steps for their popularization. Bioversity International is making a multifaceted effort through a special programme called "Moving from orphan to high-potential crops" (unpublished Note No. EE/PO 1.2.1, Bioversity International). Based on the recommendations of the authors in earlier conferences and dialogues, important issues covering research and development activities, and value-chain and policy aspects which need attention at global, regional and national levels are listed on the following page:

- Create a common global platform to consolidate, share and exchange available information on the status of NUS crops.
- Prioritize potential crops at regional and national levels to address commonly accepted research issues.
- Document and exchange available information on ethnobotanical aspects and traditional knowledge worldwide.
- Initiate worldwide investigations on food and nutritional composition and analyse molecules of special interest/nature in these individual crops and their varieties, including beneficial health properties.
- Promote the concept of on-farm/*in-situ* conservation of the available genetic diversity through custodian farmers as well as the establishment of *ex-situ* gene banks.
- Develop sound seed systems including planting material banks for multiplication and distribution.
- Develop food value and marketing chains for better availability to consumers and better returns to growers.
- Build the capacity of all custodians, particularly women, for the consumption, cultivation and conservation of these crops.
- Establish a single global body to coordinate and promote promising NUS crops as FSF.
- Develop an acceptable model of benefit sharing that is more rewarding to all stakeholders.
- Provide communication and publicity highlighting the strengths and resilience of FSF.
- Convince policy-making bodies to include some of nutrient-rich underutilized crops in common/social food security programmes, such as midday meals, hospital menus, grains for work, etc.
- Create a level playing field for NUS crops on par with other major crops.
- Attract the attention of donors for liberal funding of research programmes aimed at popularizing and mainstreaming these crops.
- Initiate a long-term network programme for the overall development of FSF crops.

### 5.7 Conclusion

Biodiversity in general and agriculture biodiversity in particular are facing grave danger globally due to the combined effects of climate change and unabated anthropogenic activities to meet ever-increasing human needs. Cultivation of a few crops in large areas to meet the demand for food has resulted in the narrowing down of the food basket and, in turn, limited dietary options. Three crops: maize, rice and wheat, and the big five animal sources: cow, goat, pig, poultry and sheep meet the 60 percent of energy required for food and nutrition. Hence, large populations in general, and especially in Southeast Asia, are suffering from undernutrition and acute malnutrition, as well as mineral and vitamin deficiencies. Studies show that NUS crops hold promise to overcome the crises of undernutrition and malnutrition and also offer better climate adaptation. Bioversity International, Crops for the Future, ICUC, FA and GEF among others, have launched large-scale research and development programmes on scoping and shortlisting potential FSF crops for mainstreaming and policy support. Different groups of crops: leafy vegetables, legumes, root and tuber crops, and minor fruits are attracting attention because of their nutrition value, adaptability to changing climate and their potential for improved livelihood options.

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# 6 Bangladesh

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## 6.1 Introduction

### 6.1.1 About the country

Bangladesh lies in the northeastern part of South Asia between 20° 34' and 26° 38' north latitude and 88° 01' and 92° 41' east longitude. The country is bordered by India in the west, north and northeast, Myanmar in the southeast and the Bay of Bengal in the south. The area of the country is 147 570 sq. km. Except for some hilly regions in the northeast, southeast and some areas of higher land in the north, Bangladesh consists mainly of fertile plains irrigated by a network of rivers, the main ones being the Padma, the Jamuna, the Tista, the Brahmaputra, the Surma, the Meghna and the Karnaphuli. These rivers have 230 tributaries with a total length of about 24 140 km. Bangladesh's highly fertile, alluvial soil is, therefore, continuously enriched by silts and river deposits during the rainy season (BBS, 2016). Across the country's 30 agro-ecological zones (AEZs), the land can be classified as 79 percent floodplain, 12.6 percent hilly areas and 8.3 percent terrace soils. The pH of soil in Bangladesh ranges from 4.0 to 8.4.

#### Land-use system

The country has 8.20 million hectares of agricultural land, mostly used in three crop seasons for rice locally known as *aus* (April to July), *aman* (July to November) and *boro* (December to April). Growing seasons for non-rice crops are *rabi* (the cool dry season from November to May) and *kharif* (the season from April to October). *Kharif* can be divided into two growing periods: *kharif I*, which is hot and dry, and *kharif II*, which is hot and humid. The *rabi* and *boro* seasons are less vulnerable to natural hazards, so crop competition is very high during this season. From 2014-2015, the total cropped area in Bangladesh was 15.25 million hectares representing 7.93 million ha of the net cropped area, with a cropping intensity of 192 percent.

#### Agriculture

Due to its fertile land and favourable weather, Bangladesh is predominantly an agrarian country with many varieties of crops growing abundantly. The agricultural sector makes up about 17 percent of the country's gross domestic product (GDP) and employs more than 45 percent of the total labour force (BBS,

2016). The performance of the agriculture sector over the past decade is linked to the rapid growth of the food grain sector, with cereal production being the main driver of this expansion. The major challenges facing agriculture in Bangladesh are feeding a large and growing population (the country's growth rate is 1.14 percent) of 160 million people, land loss and degradation (1 percent a year), and increasing competition for water resources.

### 6.1.2 Agro-ecological zones (AEZ)

**AEZ 1: Old Himalayan Piedmont Plain:** This distinctive region is part of the Tista Alluvial fan which extends out from the Himalayas. Here, top soils range from very strongly acidic to the local sub-soils being moderately acidic and rich in weatherable sand minerals.

**AEZ 2: Active Tista Floodplain:** This region includes the active floodplains of the Tista, Dharla and Dudkumar rivers. Most of these areas are subject to shallow flooding with occasional deep floods during periods of heavy rain.

**AEZ 3: Tista Meander Floodplain:** This region occupies the major part of the Tista Floodplain as well as the floodplains of the Atrai, Little Jamuna, Keratoma, Dhaka and Dudhkumar rivers. Most areas have broad floodplain ridges and almost level basins.

**AEZ 4: Karatoya-Bangali Floodplain:** This floodplain comprises a mixture of the Tista and Brahmaputra sediments. Most areas have smooth, broad, floodplain ridges and almost level basins. The topsoils range from very strongly to slightly acidic and are slightly acidic through the rest of the profile.

**AEZ 5: Lower Atrai Basin:** This region comprises low-lying areas between the Barind Tract and the Ganges River Floodplain. Smooth basin land takes up most of the region and dark grey, heavy, acidic clays predominate.

**AEZ 6: Lower Purnabhaha Floodplain:** This region occupies basins and tracts separated by low floodplain ridges. Most of the region is moderately to deeply

flooded during the rainy season. Soils here are dark grey, mottled red and very strongly acidic with heavy clays found in both ridge and basin sites.

**AEZ 7: Active Brahmaputra-Jamuna Floodplain:**

This region is comprised of a belt of unstable alluvial land along the Brahmaputra-Jamuna rivers, where the landscape is constantly being formed and eroded by the shifting river channels. The area's soil profile includes sandy and silty alluvium, which is rich in weatherable minerals with strongly acidic to slightly alkaline reactions.

**AEZ 8: Young Brahmaputra and Jamuna Floodplain:**

This region is the area of Brahmaputra sediments. It is occupied by permeable silt loam and silt clay load soils on the ridges and impermeable clays in the basins. Soils are neutral to slightly acidic in reaction.

**AEZ 9: Old Brahmaputra Floodplain:** This region occupies a large area of Brahmaputra sediments built up before the river was diverted to its present Jamuna channel around 200 years ago. The region has broad ridges and basins. Soils of this area are predominantly silt to silty clay loams on the ridges and clay in the basins. Topsoils are very strongly acidic to neutral and sub-soils are neutral in reaction.

**AEZ 10: Active Ganges Floodplain:** This region occupies unstable alluvial land within and adjoining the Ganges River. The area has complex mixtures of calcareous sandy, silty and clayey alluvium. Soils are of low to medium in terms of organic matter and neutral to slightly alkaline in reaction.

**AEZ 11: High Ganges River Floodplain:** This region includes the western part of the Ganges River Floodplain which is predominantly high to medium high land. General soil types are predominantly calcareous. In general, topsoils are slightly acidic to slightly alkaline in reaction.

**AEZ 12: Low Ganges River Floodplain:** The region comprises the eastern half of the Ganges River Floodplain which is low-lying. The region has a typical meander floodplain landscape of broad ridges and basins. Soils are calcareous in nature and are neutral to alkaline in reaction.

**AEZ 13: Ganges Tidal Floodplain:** This region occupies an extensive area of tidal floodplain land in the southwest of the country. The greater part of this region has smooth relief with large areas of salinity. In general, most of the topsoils are acidic and subsoils are neutral to slightly alkaline.

**AEZ 14: Gopalganj-Khulna Bils:** The region occupies extensive low-lying areas between the Ganges River Floodplains and the Ganges Tidal Floodplains. Seasonally, the region is moderately deep to deeply flooded by clear water. Basin centres stay wet through the dry season.

**AEZ 15: Arial Bil:** This region occupies a low-lying basin between the Ganges and Dhaleshwari rivers south of Dhaka and northwest of Munshiganj districts. Topsoil ranges from slightly acidic to neutral.

**AEZ 16: Middle Meghna River Floodplain:** This region occupies an abandoned channel of the Brahmaputra River on the border between the greater Dhaka and Comilla districts. Soils are very strongly acidic to neutral in medium-low and lowland soils, and the subsoils are slightly acidic to slightly alkaline.

**AEZ 17: Lower Meghna River Floodplain:** This region occupies a transitional area between the Middle Meghna River Floodplain and the Young Meghna Estuarine Floodplain. Soils are non-calcareous and dark grey in floodplains and calcareous and more acidic in high land. In medium highland and medium lowland, soils range from slightly acidic to slightly alkaline, and the subsoils are neutral in reaction.

**AEZ 18: Young Meghna Estuarine Floodplain:** This region occupies young alluvial land in and adjoining the Meghna estuary. The soils in the south become saline in the dry season. Topsoils are slightly acidic to slightly alkaline and subsoils of the area are slightly alkaline.

**AEZ 19: Old Meghna Estuarine Floodplain:** This region occupies a large area, mainly low lying, between the south of the Surma-Kushiyara Floodplain and the northern edge of the Young Meghna Estuarine Floodplain. Topsoils are slightly acidic to slightly alkaline but subsoils are neutral in reaction.

**AEZ 20: Eastern Surma-Kushiyara Floodplain:** This region occupies the relatively higher parts of the Surma-Kushiyara Floodplain formed by sediments of the rivers draining into the Meghna catchment area from the hills. The area is mainly smooth, with broad ridges and basins. Soil reactions in the area range from very strongly acidic to neutral.

**AEZ 21: Sylhet Basin:** The region occupies the lower, western side of the Surma-Kushiyara Floodplain. Soils of the area are grey silty clay loams and clay loam in the higher parts that dry out seasonally. There is also grey clay in the wet basins. Soil reactions are mainly slightly acidic in topsoil.

**AEZ 22: Northern and Eastern Piedmont Plains:**

This is a discontinuous region occurring as a narrow strip of land at the foot of the northern and eastern hills. Soils of the area range from loams to clays in texture and have very strongly acidic to slightly acidic reactions.

**AEZ 23: Chittagong Coastal Plain:** This region occupies the plain land in the greater Chittagong district and the eastern part of the Feni district. It is a compound area of piedmont, river, tidal and estuarine floodplain landscapes. The major problem in these soils is high levels of salinity during the dry season (October to May).

**AEZ 24: Saint Martin's Coral Island:** This small but distinctive region occupies the whole of St. Martin's Island in the extreme south of the country. The area has very gently undulating old beach ridges and inter-ridge depressions, surrounded by sandy beaches.

**AEZ 25: Level Barind Tract:** This region is developed over Madhupur Clay. The landscape is almost level although locally irregular along river channels. Available moisture holding capacity is low and topsoils range from very strongly acidic to neutral in reaction.

**AEZ 26: High Barind Tract:** This area includes the southwestern part of the Barind Tract where the underlying Madhupur clay has been lifted and cut into by deep valleys. General fertility status is low and top soil reactions range from very strongly acidic to slightly alkaline.

**AEZ 27: North Eastern Barind Tract:** This region occupies several discontinuous areas along the northeastern margins of the Barind Tract. It stands slightly higher than the adjoining floodplain land. The soils here are mainly strongly acidic in reaction.

**AEZ 28: Madhupur Tract:** This is a region of complex relief and soils are developed over the Madhupur clay. Eleven general soil types exist in the area of which, deep red brown terrace, shallow red brown terrace soils, and acid basin clays predominate. The topsoils are mainly very strongly acidic in reaction.

**AEZ 29: Northern and Eastern Hills:** This region includes the country's hill areas. The major hill soils are yellow-brown to strong brown, permeable, friable and loamy. The soil profile here is mainly very strongly acidic and low in moisture holding capacity.

**AEZ 30: Akhaura Terrace:** This small region occupies the eastern border of Brahmanbaria and southwest corner of Habiganj district. In appearance, the region resembles Madhupur Tract with level uplands, dissected by mainly deep, broad valleys. The soils are strongly acidic to slightly acidic in reaction.

**Stress-prone ecosystems**

There are several stress-prone ecosystems in the country such as hill ecosystems, coastal ecosystems, drought, charland (land accreted inside and beside large rivers) and haor (swamp) ecosystems. Only abiotic stress-tolerant underutilized and neglected crops can be grown successfully in these ecosystems.

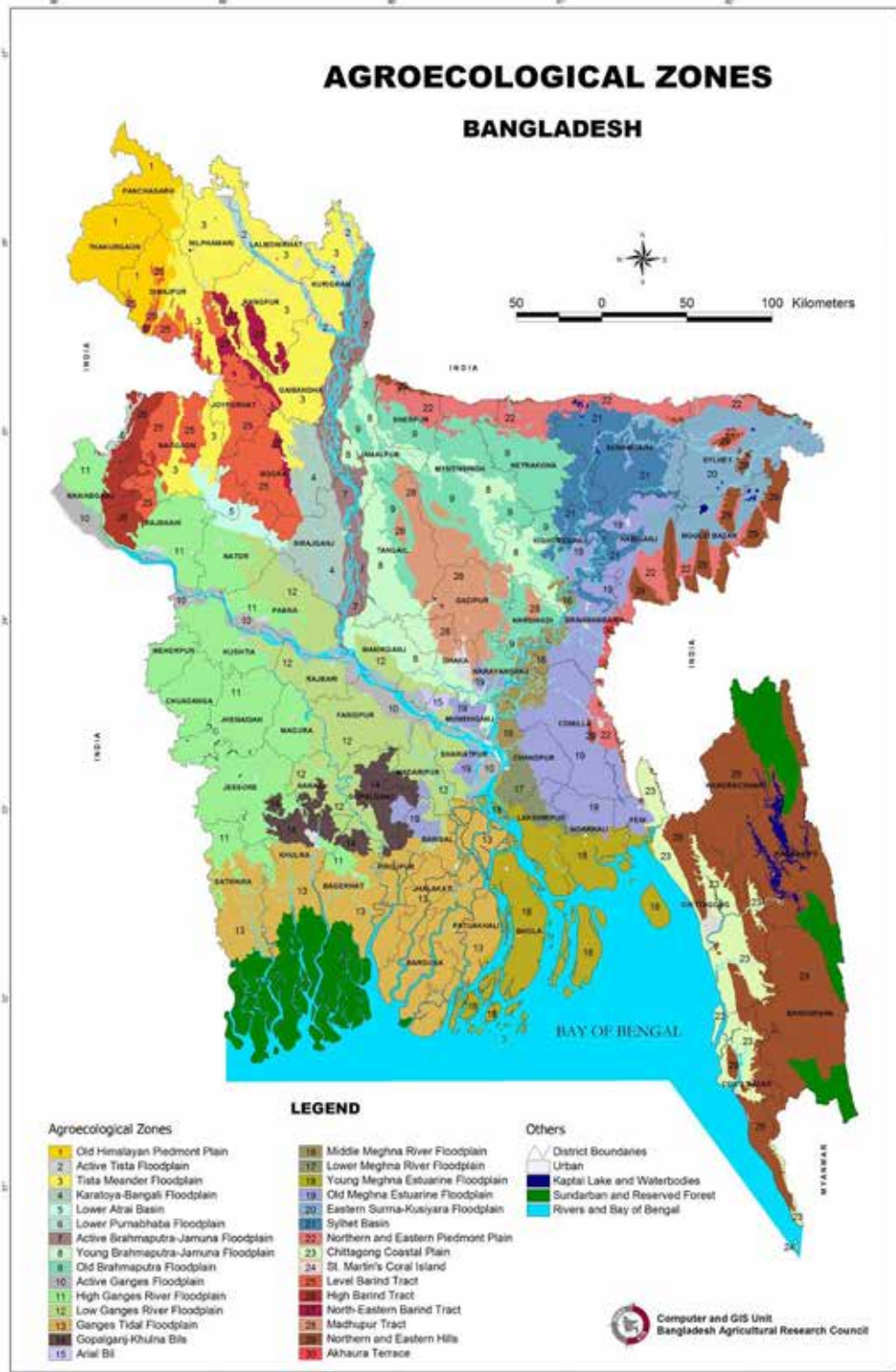
**Hill ecosystems:** The Hill Tract region of the country covers an area of about 13 191 sq. km., which is about 10 percent of the country's total land resources. Due to rugged topography and soil conditions, land available for field crops is scarce, but large areas are available for horticultural crops especially minor fruits like bael, custard apple, sapota, tamarind, wood apple, etc. (BARI, 2015).

**Coastal ecosystems:** Coastal areas in Bangladesh cover over 30 percent of the net cultivable area (2.85 million ha) of which 0.88 million ha is affected by different degrees of seasonal salinity. Schemes to increase production and utilize fallow land during the dry season include relay cropping of mustard and cowpea with transplanted aman (t. aman) rice and early sowing of mung bean, cowpea, soybean and sesame after of t. aman rice harvests. These schemes have showed profitability in saline areas (BARI, 2015).

**Drought stress:** Drought periods of different intensities occur in Bangladesh and severely affect about 2.3 million ha in the *kharif* season and 1.2 million ha in the dry (*rabi* and *pre-kharif*) seasons annually. Mung bean lines BMX-01015 showed tolerance to drought, with BMX-01007 and BMX-01013 showing moderate tolerance.

**Charland ecosystems:** Charland is known as a nutrient limitation stress ecosystem. The area under charland is estimated to be about 0.83 m ha. Charland soil is structureless with poor fertility. However, foxtail millet, grasspea, proso millet, mung bean, sweet potato and cucurbitaceous vegetables like bitter melon, pumpkin and snake melon can be grown successfully in such ecosystems.

FIGURE 6.1 Major crops, cultivation area and production in Bangladesh (BBS, 2016)



Source: Bangladesh Agricultural Research Council

**Haor areas:** Haors form unique ecosystems that remain inundated for 7-8 months each year, the haor basin covers about 25 000 square km. in seven districts of northeast Bangladesh. Haors are among the more poverty-prone areas in the country, because the land is single cropped (mainly planted with rice), and often damaged by the frequent flash floods. Short-duration

crops such as mung bean and garden pea perform better in *kanda* (periphery) areas.

To keep pace with population growth and shrinking land resources, food production needs to approximately double by the year 2050. With the rapid increase in population and the subsequent high pressure on land,

**TABLE 6.1** Major crops, cultivation area and production in Bangladesh

Crops	Area (million ha)	Production (million M. ton)	Total demand (million M. ton)	Deficit (million M ton)
Rice (3 cropping season)	11.42 (74.930%)	34.71 (58.320%)	26.28	–
Wheat	0.44 (2.890%)	1.35 (2.290%)	5.50	4.15 (75%)
Maize	0.33 (2.160%)	2.27 (3.810%)	3.40	1.13 (33%)
Minor cereals	0.002 (0.013%)	0.002 (0.003%)	–	–
Sugarcane (estimate of sugar)	0.11 (0.720%)	0.10 (0.160%)	1.50	1.40 (93%)
Pulses	0.41 (2.690%)	0.73 (1.230%)	2.50	1.77 (71%)
Oilseeds (estimate of oil)	0.83 (5.450%)	0.27 (0.450%)	1.05	0.78 (75%)
Vegetables	0.40 ((2.620%)	3.73 (6.270%)	11.68	7.95 (68%)
Fruits	0.13 (0.850%)	4.70 (7.900%)	11.68	6.98 (60%)
Spices	0.37 (2.420%)	2.41 (4.050%)	3.12	0.71 (23%)
Potato	0.47 (3.080%)	9.25 (15.540%)	7.00	–
<b>Total</b>	<b>15.25 (100.000%)</b>	<b>59.52 (100.000%)</b>		

Source: BBS, 2016

it is not possible to increase productivity of agriculture through traditional farming systems. So bringing stress-prone ecosystems under intensive cultivation with FSF crops could be vital when it comes to meeting these challenges.

### 6.1.3 Status of Bangladesh's food basket: the composition of crops, including staples

Currently, Bangladesh can boast a surplus in rice and potato production. But for other crops including fruit, maize, oilseeds, pulses, sugarcane, vegetables etc. there is still big gap between demand and production, and this accounts for much of the hidden hunger in the country. Bangladesh's major crops with their cultivation areas, production levels, demand and deficit can be seen in Table 6.1.

### 6.1.4 Crop diversity and major cropping patterns

Bangladesh can boast rich agro-biodiversity, a wide diversity of landraces and traditional species of agro-horticultural crops (Rahman, 2008). More than 300 crops are currently grown in Bangladesh and the country is home to around 7 000 species of vascular plants as well as being the secondary centre of origin for many types of crop plant (Irfanullah, 2013).

Over 300 indigenous species of plants have been identified which are wild relatives of cultivated Bangladesh crops. The major cropping patterns in different AEZs of the country are shown below:

- Potato-fallow-T. aman (AEZ-8,9)
- Mustard-boro-T. aman (AEZ-7, 8, 9)
- Fallow-fallow-T. aman (coastal areas)
- T. aman-fallow-ash gourd (AEZ-7, 8, 9)
- T. aus-T. aman-fallow (AEZ-20)
- Boro-fallow-T. aman (AEZ-11)
- T. aman-fallow-boro (AEZ-9)
- Fallow-jute-T. aman (AEZ-12, 13, 14)
- Mung bean-fallow-T. aman (AEZ-12, 13, 14)
- Mustard -boro-fallow-T. aman (AEZ-3)
- Wheat-fallow-T. aman (AEZ-26)

In almost all the AEZs, agricultural land use is dominated by maize, potato, rice or wheat during the *rabi* and *boro* seasons except in stress-prone areas such as coastal, hilly and charland regions. Scope for horizontal expansion of FSF crops during this season is limited. However, there is scope for intervention with FSF crops during the *kharij-I* and *kharij-II* seasons.

**TABLE 6.2** Hunger and malnutrition status in Bangladesh

Health index		Prevalence (%)	Health effects	World ranking (lowest to highest)
<b>Undernourishment</b>		26.33		–
<b>Stunting</b>		36.10		107
<b>Wasting</b>		14.30		117
<b>Underweight</b>		56.00		
<b>Micronutrient deficiencies (school age)</b>	Vitamin A	20.90	Night blindness	
	Vitamin B12	23.00	Beriberi	
	Vitamin C	92.00	Scurvy	
	Iron	9.50	Anaemia	
	Zinc	44.60	Diarrhoea, stunting	
	Iodine	40.00	Learning difficulties	
<b>Adult overweight and obesity</b>		18.10		7
<b>Adult obesity</b>		3.60	Diabetes	10
<b>Anaemia in women of reproductive age</b>		43.50		158
<b>Diabetes</b>		9.40		99
<b>Low birth weight</b>		20.00		
				<b>World ranking (highest to lowest)</b>
<b>Exclusive breast feeding (EBF rate)</b>		55.30		29

Source: Hussain *et al.*, 2015 and IFPRI, 2016

## 6.2 Situation and gap analysis

### 6.2.1 Hunger and malnutrition

Overpopulation, poverty and floods are persistent factors of life in Bangladesh and lead to population vulnerability, particularly malnutrition of women and children. The prevalence of malnutrition is among the highest in South and Southeast Asia. Millions suffer from one or more forms of malnutrition, including low birth weight, stunting, underweight, iodine, iron and vitamin-A deficiency disorders (UNICEF, 2006). The World Bank (2013) estimated the cost of undernutrition in Bangladesh to be USD 700 million annually as an indirect cost of lost productivity and expenses to health systems.

The problems of malnutrition are much higher in South Asia compared to Africa and other parts of the world (UNICEF, 1998; De Onis *et al.*, 2000.) In South Asia, the prevalence of underweight and stunting has been recorded as 46 and 44 percent, respectively (UNICEF, 2006). This is a 'very high' priority public health problem according to WHO (1995). Malnutrition is a major underlying cause of child morbidity and mortality. In Bangladesh, two-thirds of childhood deaths can be attributed to malnutrition (Pelletier *et al.*, 1995). A study

undertaken in the Matlab Thana region, found that about one-third of deaths among 6-36 month-old children were related to severe malnutrition (Fauveau *et al.*, 1990). Jahan and Hossain (1998) found that 77 percent of children aged 6-71 months were physically retarded in Bangladesh. The levels of severe stunting and severe underweight were 28 and 21 percent, respectively: the highest levels in the world (Mitra *et al.*, 1997).

One of the Millennium Development Goals (MDGs) called for a 50 percent reduction of stunting and underweight by 2015 as compared to that of 1990. The Government of Bangladesh has made substantial investments to improve nutrition, including the establishment of the National Nutrition Program (NNP), which provides comprehensive nutrition services to children and women at the community level. As a result, the country has made significant progress in eliminating some forms of malnutrition including vitamin-A and iodine deficiency (UNICEF, 2006). In rural Bangladesh, a steady decline in the prevalence of stunting (68.3 percent to 50 percent) and underweight (71 percent to 57 percent) have been reported for children aged 6-59 months between 1991 and 2001

(HKI/IPHN, 2002). The prevalence of stunting for children under 5 years old was 55 percent in 1996-97, which declined to 45 percent in 1999-2000 (NIPORT, 2001).

### 6.2.2 Climate change constraints

Bangladesh has a humid, warm subtropical climate. There are four prominent seasons: pre-monsoon (March-May), monsoon (June-early October), post-monsoon (late October to November) and winter (December-February). The mean annual rainfall varies widely across the country, ranging between 1 200 mm and 5 800 mm. Seasonal and spatial variation in surface temperature is also substantial.

The pre-monsoon period is hot, with an average maximum temperature of 36.7 °C, and high rates of evaporation and erratic but occasional heavy rainfall from March to June. In some places the temperature occasionally rises to 40.6 °C or more. The peak maximum temperatures are observed in April, the beginning of pre-monsoon season.

The monsoon period is hot and humid and brings heavy torrential rainfall throughout the season. About four-fifths (over 70 percent) of the mean annual rainfall occurs during monsoon. The mean monsoon temperatures are higher in the western region compared to rest of the country. Warm conditions generally prevail throughout the season, although cooler days are also observed during and following heavy downpours.

The post-monsoon period is short and the season is characterized by fewer and lighter rain showers and the gradual lowering of night-time minimum temperatures.

Winter is relatively cool and dry, with average temperatures ranging from a minimum of 7.2 to 12.8 °C and a maximum of 23.9 to 31.1 °C. The minimum temperature occasionally falls below 5 °C in the northern region though frost is extremely rare. There is a south to north thermal gradient in winter meaning that temperatures in the southern and southeastern districts are 5 °C warmer than in the northern districts.

**Temperature:** Analysis of long-term climatic data shows a fair degree of inter- and intra-seasonal variations in temperature changes in Bangladesh. Air temperature generally shows an increasing trend over the years. Studies conducted at SAARC Meteorological Research Centre reveal that mean temperatures in pre-monsoon season have decreased. But in other seasons of the year, temperatures have generally increased (Huq *et al.*, 2003). The average monsoon maximum and minimum

temperatures show an increasing trend annually at 0.05 °C and 0.03 °C, respectively. Maximum and minimum temperatures in winter season (December, January and February) show a decreasing and an increasing trend annually at 0.001 °C and 0.016 °C, respectively (Rahman and Alam, 2003).

**Temperature rises and crop production:** Increases in temperature could greatly affect the productivity of temperature sensitive crops, especially *rabi* crops in Bangladesh. The production of wheat might drop 32 percent by the year 2050 (IPCC, 2007). Under a severe climate change scenario (4 °C temperature rise), the potential shortfall in wheat and potato production could be as high as 50 percent and 70 percent, respectively (Karim, 1996). In addition, temperature increases would shorten the winter season in Bangladesh. Short winters would adversely affect the vegetative as well as the reproductive growth of most of the winter crops and so consequently reduce yields.

Changes in temperature, humidity and radiation, also have an impact on the incidence of insect pests, diseases and micro-organisms. For example, a change of 1 °C in air temperature, changes the virulence of some strains of wheat rust.

Bangladesh grows nearly 9.0 million tonnes of potato, 0.9 million tonnes of oilseed and 0.8 million tonnes of pulses (AIS, 2014). All these crops require temperatures between 18-25 °C. These crops are highly sensitive to fog, cloud and changes in humidity. The growing of these crops in Bangladesh is predicted to end if temperatures continue to rise.

**Rainfall:** The mean annual rainfall in the country is about 2 300 mm, but there exists a wide spatial and temporal variation in distribution. Annual rainfall ranges from 1 200 mm in the west to over 5 000 mm in the east and northeast (MPO, 1991). Analysis of long-term rainfall data fails to show any consistent trends. However, the most remarkable change in rainfall is the change in the duration of rainy season. The season has shortened, but the total annual rainfall has remained more or less the same. This suggests that heavy rainfall now occurs within a shorter period (June-early October), with around 72 percent of total rain falling during the monsoon.

**Drought:** The western and northwestern part of the country receives less rainfall, averaging some 1 400 mm compared with the national average of about 2 150 mm. As a consequence, the severity of droughts in the western districts is much higher than elsewhere. Based on the soil's physical and hydrological properties, water



holding capacity, infiltration etc., high prevalence of drought is observed in the districts of Rajshahi, Bogra, Pabna, Dinajpur, Rangpur and Kushtia. Droughts of different intensities in monsoon, dry and pre-monsoon seasons cause damage to 1.20 million ha of dry season upland crops annually. Droughts are associated with the delayed onset or the early recession of the monsoon rains and with intermittent dry spells coinciding with critical crop growth stages. Yield reductions due to droughts vary from 45-60 percent in rice and 50-70 percent in upland crops in very severe drought situations.

**Rise of sea levels and salinity intrusion:** The coastal belt of Bangladesh already suffers from high levels of salinity as a result of saltwater intrusion. Two-thirds of Bangladesh is less than 5 metres above sea level and, therefore, is susceptible to sea-level rises as well as tidal flooding during storms, which lead to losses in shelter and livelihoods. Recent studies (SRDI, 2010) indicate significant increases in salinity-affected areas, from 0.833 million ha to 1.056 million ha over the past four decades. Levels of salinity are predicted to rise further under various climate change scenarios as sea levels rise and saltwater intrusion becomes more common.

A rise in saline water intrusion up coastal rivers and into ground water aquifers will reduce the availability of fresh water. A World Bank study showed that a 10 cm, 25 cm and 1 m rise in sea levels by 2020, 2050 and 2100 in Bangladesh will impact 2 percent, 4 percent and 17.5 percent of the total land mass respectively. A 1 m rise in sea level would inundate 18 percent of Bangladesh's total land, which would directly threaten 11 percent of the country's total population. Based on the ground survey information on the dynamic coastal area of Bangladesh, Brammer (2014) suggests possible area-specific mitigation measures to counter these predicted rates of rises in sea level.

**Climate change and water resources:** Nearly three-fourths of the total surface of the earth is covered by water and ice; however, a tiny fraction (less than 0.8 percent) is fresh water, usable for agricultural, industrial and domestic consumption. This means that terrestrial water storage is vital for agricultural economies. Global demand for fresh water has been growing fast, as much as twice the rate of the global population (USCB, 2011). This essential resource, which is mostly stored as groundwater, is distributed unevenly around the world (UNEP GEAS, 2012). Aquifers in some of the major agricultural regions are now being exploited unsustainably. Mechanized pumping makes it possible to improve crop production, as in northern Bangladesh, but this has also led to over-exploitation of aquifers.

Problems worsen when abstraction of groundwater happens faster than it can be replenished by rainfall or surface water flows (Custodio, 2002; Tiwari *et al.*, 2009).

### Climate change impacts on agronomic management

**decisions:** Worldwide research into climate change impacts on agriculture have shown that changes in the climate represent a significant new source of risk and management challenges to food production (Kruger *et al.*, 2011). Our understanding of the underlying mechanisms means that some of the climatic variability is now predictable with fair degree of certainty.

A broad range of management options and technological interventions can be adopted for adapting agriculture to climatic variability and climate change. Options that can be considered include investment in flood protection; planting different crop types; development of crop varieties tolerant to drought, heat and salinity; agronomic management, such as early planting to avoid terminal drought; bed planting or growing crops on dykes to avoid tidal floods; integrating rice-fish culture; and early warning systems.

### 6.2.3 Market and economic constraints

Marketing systems for agricultural produce in Bangladesh are not well organized, especially for perishable goods. A recent study revealed that the producers' share of consumer prices for different vegetables types ranges from 25.8 percent to 48.5 percent (Matin *et al.*, 2016). This is an indicator of the problems farmers face when sending produce to market. Farmers generally sell their produce directly from the farm, or at nearby primary or secondary markets. Such primary markets are usually located around 1-2 km from the farming areas. This means that growers have to rely on different means of transportation with rickshaws, auto-vans and bicycles being most common. Trucks are generally only used by *bepari* and *paiker* (wholesale traders) to carry produce to more distant markets. Some other market and economic related constraints are listed below:

- Uncertain pricing
- The lack of short-term storage facilities
- High market fees
- Lack of access to credit
- Extended sales chains between farmers, intermediaries, retailers and consumers, (Martin *et al.*, 2008)
- Lack of market information
- Lack of modern transportation facilities

- High transportation costs
- Large disparities between farm gate prices and urban retail prices

### 6.2.4 Cultural relevance

Among the selected FSF crops, only bael has cultural significance to Bengali culture. As well as its many medicinal uses, the tree and its fruit are of religious importance. In Hinduism, bael leaves and fruit are used as offerings in prayer and religious rituals and the tree is seen as sacred, with many people growing them in their

gardens or near temples. The tree is especially important in the worship of Shiva, as the tri-lobate leaves symbolize the trident that the god holds in his right hand.

## 6.3 Scoping and prioritization of FSF

### 6.3.1 Scoping and availability of FSF

Considering their nutritive value, economic importance, public acceptance and scope of intervention, the following FSF crops have been prioritized for Bangladesh as shown in Table 6.3.

**TABLE 6.3** List of Future Smart Food (FSF) crops in Bangladesh and their priority

Sl.	English/Local name	Scientific name	Accessions	Priority
<b>Cereals</b>				
1	Foxtail millet	<i>Setaria italica</i>	546	1
2	Proso millet	<i>Panicum miliaceum</i>	199	
3	Barley	<i>Hordium vulgare</i>	62	
4	Buck wheat	<i>Fagopyrum esculentum</i>	6	
5	Finger millet	<i>Eleusine coracana</i>	2	
6	Sorghum	<i>Sorghum vulgare</i>	187	
7	Grain amaranth	<i>Amaranthus hypochondriacus</i>	3	
8	Oat	<i>Avena sp.</i>	1	
9	Pearl millet	<i>Pennisetum glaucum</i>	2	
10	Teff	<i>Eragrostis abyssinica</i>	2	
<b>Roots and tubers</b>				
1	Yam	<i>Dioscorea spp.</i>	60	
2	Taro ( <i>Mukhi kachu</i> and <i>panikachu</i> )	<i>Colocasia esculenta</i>	293	2
3	Giant taro ( <i>Man kachu</i> )	<i>Alocasia indica</i>	1	
4	Elephant foot yam ( <i>Ol kachu</i> )	<i>Ammorphophallus campanulatus</i>	2	
5	Yam bean ( <i>Keshore alu</i> )	<i>Pachyrhizustuberosus</i>	1	
6	Sweet potato	<i>Ipomoea batatas</i>	2	
7	Cassava	<i>Simal tarul</i>	–	
8	Aroids ( <i>Moulavikachu, dudhkachu, dastarikachu</i> )	<i>Alocasia spp.</i>	–	
<b>Nuts and pulses</b>				
1	Lentil	<i>Lens culinaris</i>	422	
2	Pigeon pea	<i>Cajanus cajan</i>	83	
3	Cowpea	<i>Vigna unguiculata</i>	37	
4	Grass pea	<i>Lathyrus sativus</i>	1 807	
5	Black gram	<i>Vigna mungo</i>	77	
6	Mung bean	<i>Vigna radiata</i>	114	3

Sl.	English/Local name	Scientific name	Accessions	Priority
7	Field pea	<i>Pisum sativum</i>	162	
8	Horse gram	<i>Macrotyloma uniflorum</i>	32	
9	Faba bean	<i>Vicia faba</i>	13	
10	Rice bean	<i>Vigna umbellata</i>	6	
11	Groundnut	<i>Arachis hypogaea</i>	23	
12	Soybean	<i>Glycine max</i>	50	
13	Winged bean	<i>Psophocarpus teragonolobus</i>	3	
14	Chickpea	<i>Cicer arietinum</i>	760	
<b>Horticulture</b>				
1	Snake gourd	<i>Tricosynthes anguina</i>	143	5
2	Amaranth	<i>Amaranthus sp.</i>	731	
3	Yard long bean	<i>Vigna sesquipedalis</i>	184	
4	French bean	<i>Phaseolus vulgaris</i>	32	
5	Ash gourd	<i>Benincasa hispida</i>	206	
6	Ridge gourd	<i>Luffa acutangula</i>	155	
7	Okra	<i>Abelmoschus esculentus</i>	225	
8	Pumpkin	<i>Cucurbita moschata</i>	478	4
9	Bitter gourd	<i>Momordica charantia</i>	47	
10	Custard apple	<i>Annona squamosa</i>	1	
11	Wood apple	<i>Feronia limonia</i>	2	
12	Sapota	<i>Achras zapota</i>	1	
13	Bael	<i>Aegle marmelos</i>	15	6
<b>Others</b>				
1	Black cumin	<i>Nigella sativa</i>	11	
2	Coriander	<i>Coriandrum sativum</i>	31	
3	Ajowan	<i>Trchyspermum ammi</i>	1	
4	Fenugreek	<i>Trigonella foenum graecum</i>	4	
5	Dill/Sulfa	<i>Peucedanum graveslens</i>	1	
6	Fennel	<i>Peniculum vulgare</i>	1	
7	Postodana	<i>Papaver somniferum</i>	1	
8	Celery	<i>Apium graveolens</i>	2	
9	Onion	<i>Allium cepa</i>	3	
10	Radish	<i>Raphanus sativus</i>	46	
11	Turmeric	<i>Curcuma longa</i>	27	
12	Garlic	<i>Allium sativum</i>	2	

### 6.3.2 Prioritization analysis

#### 1 Cereals

Bangladesh agriculture is predominantly rice based. Rice farming uses around 75 percent of the country's total cropped area during the three cropping seasons and represents over 58 percent of total crop production. Bangladesh achieved self-sufficiency in rice production between 2011-12 and in recent years has been listed as a rice exporting country.

Among other cereal crops, wheat and maize farming takes up substantial areas (2.89 and 2.16 percent, respectively) and contributes 2.29 and 3.81 percent to total crop production. Cultivation of minor cereals in Bangladesh is limited to stress-prone areas (charland and hilly areas) of the country requiring only minimum care. Their share in area and production is negligible (0.013 and 0.003 percent). Other minor cereals and pseudo-cereals like proso millet, barley, barnyard millet, finger millet, buckwheat etc. are so neglected that they are now often considered lost crops.

Among more minor cereals and pseudo-cereals, foxtail millet (*Setaria italica*) is the only crop that is still cultivated in different areas of the country and can be considered as fourth cereal crop after rice, wheat and maize. It is popular as it can be grown year round in marginal, low fertile and saline lands (BARI, 2015).

Diverse genetic resources for foxtail millet are still available at the farm level. A good number of diverse germplasms are also conserved in the BARI Genebank. Foxtail millet is a rich source of carbohydrate, vitamins (E, B 1, B 2, niacin, B 6, folate and pantothenic acid) and minerals (potassium, calcium, magnesium, phosphorus, iron, zinc and manganese). Foxtail millet also contains substantial quantities of dietary fibre. The popularity and market price of dehusked grain are also very high. In the retail markets of Bangladesh's Gazipur, district, dehusked foxtail millet is sold for BDT 90 per kg as against BDT 46 and BDT 35 per kg of fine and coarse rice respectively. BARI is currently conducting research on foxtail millet and barley on a limited scale, and has developed three improved varieties with high yield potential and tolerance to biotic and abiotic constraints.

#### 2 Roots and tubers

Systematic research and development work on potato (*Solanum tuberosum*) began in Bangladesh with the establishment of the Potato Research Centre (PRC) under BARI in 1977. In 1987, the PRC became the Tuber Crops Research Centre (TCRC) and was responsible for generating improved technologies for growing root and tuber crops to increase production and productivity. Aroids, cassava, potato, sweet potato, taro, yam, yam bean, etc. are crops now overseen by the TCRC. Potato is one of the mainstream (notified) crops in Bangladesh, and the country now produces a surplus crop and is listed as a potato exporting country. Taro and aroids are cultivated in about 23 000 ha of land, and total production is more than 0.20 million tonnes. Taro (*Colocasia esculenta*) is grown on around 85 percent of areas under taro and aroid cultivation.

There are two ecotypes of taro commonly grown in Bangladesh. The first is locally known as *panikachu* and grows in waterlogged conditions during the *kharif-I* season. Its tuberous roots, stolon, leaves and petioles can be eaten. The second ecotype is *mukhikachu*. This thrives in well-drained conditions during the *kharif-I* season, and only the corms and cormels are consumed. Taro is a rich source of major and minor nutrient elements, as shown in Table 6.4.

The suckers, or shoots, of *panikachu* and the *cormels* of *mukhikachu* are planted under rainfed conditions between February-March (Mondal *et al.*, 2014). The stolons are harvested periodically from April-May and this continues up to September-October. The corms and cormels are then harvested between August and September. Both corms and stolons of taro become available during the *kharif* season when Bangladesh faces a shortage of nutritious vegetables. This means that taro is increasingly popular and in demand across the country. Because taros are grown during *kharif-I* season, there is wide scope of horizontal expansion of the crop. BARI is currently undertaking a limited research programme on taro, and has developed two improved varieties of *mukhikachu* and five varieties of *panikachu*. The stolons of *Latiraj*, BARI *Panikachu-2* and BARI *Panikachu-3* are ideal for export and are characterized by higher yields in terms of both stolon and corm (BARI, 2015).

Yam (*Dioscorea*), sweet potato (*Ipomoea batatas*), elephant foot yam (*Ol kachu*) (*Ammorphophallus campanulatus*), giant taro (*Mankachu*) (*Alocasia indica*), yam bean (*Keshor alu* or *Pachyrhizus tuberosus*) are other root crops grown in Bangladesh.

**TABLE 6.4** Nutrient contents per 100 g of different edible portion of taro

Nutrient	Leaf	Petiole	Stolon	Tuber
Water (g)	92.00	86.50	92.00	–
Starch (g)	7.70	4.50	6.50	16.46
Protein (g)	0.15	4.00	0.50	1.50
Iron (mg)	3.70	0.50	1.12	0.55
β carotene (IU)	25 000.00	350.00	500.00	58.00
Vitamin B-1 (mg)	0.43	0.02	0.02	–
Vitamin C (mg)	115.00	5.00	6.00	4.50
Ca (mg)	316.00	59.00	38.00	43.00
Mg (mg)	–	–	–	33.00
K (mg)	–	–	–	591.00
Zn (mg)	–	–	–	0.23
Energy (kcal)	50.00	30.00	35.00	112.00

### 3 Nuts and pulses

In Bangladesh, pulses are generally grown as sole crops, or are mixed or relay with cereal and oilseed crops and grown in rice-based cropping patterns. More than a dozen pulse crop species grow successfully in Bangladesh thanks to the fertile alluvial soil. Most pulse crops such as chickpea, faba bean, field pea, grass pea and lentil are grown during the *rabi* season, when crop competition is very high. This means there is less scope for horizontal expansion. There is more scope for horizontal expansion for pulse crops such as black gram, cowpea, horse gram, mung bean, pigeon pea, rice bean and soybean, as these can be grown as sole crops or intercropped with maize or along roadsides during *khari*-I or *khari*-II seasons depending upon varieties and the AEZs. However, faba bean, horse gram and winged bean are so neglected that they are now treated as lost crops.

Systematic research and development activities on pulse crops in Bangladesh began when BARI and ICRISAT joined forces and implemented a pulses improvement project during the 1970s and 1980s. Later, in 1990, the improvement project emerged as Pulses Research Centre under BARI. A total of 64 improved varieties of 7 pulse crops have so far been developed by BARI. This includes 35 varieties of 7 pulse crops developed by the Bangladesh Institute of Nuclear Agriculture (BINA), and 27 varieties of 5 pulse crops developed by the Bangladesh Agricultural University (BAU).

A decline of 62 percent in production area for pulse crops has been observed in Bangladesh over the last two

decades (1994-2014). However, an increase in yields has lessened the impact of this decrease of production area (SAC, 2016). Pulses now take up only 2.69 percent of the total cropped area. Winter pulses are mainly cultivated during interim period between two rice crops (T. aman and boro) in a rice-rice cropping pattern in charland and drought prone areas or as relay crops with T. aman. These pulses are basically grown as rainfed crops in marginal land with minimum input. In Bangladesh, grass pea (*khesari*) is the number one pulse crop, both in terms of crop area and production volume (Mondal *et al.*, 2014). Lentil, however, is the most popular pulse crop in Bangladesh. As lentil is grown during *rabi* season and takes comparatively longer to grow (100-115 days), it is very difficult to fit in with rice-rice cropping pattern, which limits its horizontal expansion.

Mung bean is an emerging pulse crop in Bangladesh and the only one that is increasing in terms of area of production. Mung bean's advantages over other crops are its short growing time, wider adaptability, tolerance to biotic and abiotic (salinity, drought) stresses and existence of varieties for all the cropping seasons (*khari*-I, *khari*-II and *rabi*).

This rapid expansion of mung bean farming started with the introduction of BARI Mung-6, which is high yielding (1.5 tonne per ha), has a short growing duration (55-58 days) and bold seed (50-52 g per 1 000 kernels). BARI Mung-6 also has a long growing season and semi-determinate behaviour (almost all the pods mature at the same time). This means a crop can easily be planted between wheat or aus rice.

Chickpea is hugely popular in Bangladesh, especially during Ramadan when it is part of the *Iftar* or fast-breaking meal. Black gram ranks fourth in terms of production and represents 9-11 percent of the total pulse production in Bangladesh. A flat bread, locally known as *kalairoti*, made of black gram paste is very popular. A cowpea called *felon* is well known in the Chittagong region and some other coastal districts where fresh felon pods are eaten as vegetables.

#### 4 Horticulture

The fertile alluvial soil and subtropical climate of Bangladesh makes it ideal for growing a diverse range of horticultural crops. The Horticulture Research Centre (HRC) under BARI is responsible for overseeing the improvement of horticultural crops (fruits, vegetables, and flowers and ornamental plants). Ninety kinds of vegetables and 70 kinds of fruits are grown in the country (Hoque *et al.*, 2007), and are considered high value crops and a major source of the vitamins and minerals that are essential for human nutrition.

**Vegetables:** Common vegetables in Bangladesh during the *kharif* season include amaranth, ash gourd, bitter gourd, cucumber, eggplant, Indian spinach, long bean, okra, pointed gourd, pumpkin, ridge gourd and snake gourd. During the *rabi* season, common vegetables include bottle gourd, cabbage, cauliflower, eggplant, lablab bean, pumpkin, spinach, radish, red amaranth and tomato.

In recent years, off-season varieties and hybrids of both *rabi* and *kharif* vegetables have been developed, increasing the availability of these vegetables during lean periods or at other times of the year. Examples of these are summer tomatoes and bottle gourds.

Snake gourd (*Tricosynthes anguina*) is a nutritious *kharif* vegetable grown in Bangladesh. The total area under snake gourd cultivation is 7 177 ha and the production is 34 691 tonnes (BBS, 2016). Snake gourd is a good source of proteins, vitamins (vitamin A, B and C) and minerals (manganese, potassium, iron and iodine). Snake gourd also improves blood circulation and can help in detoxification.

Several private companies introduced hybrids that are well adapted to charland and coastal regions, and, inherently, snake gourd has excellent salinity tolerance. BARI has developed one variety of snake gourd, and there is wide scope for both vertical and horizontal expansion of the crop through dissemination of high yielding varieties and hybrids in stress-prone areas during the *kharif* season.

Pumpkin is another important cucurbitaceous vegetable that can be grown the year round. The total area under pumpkin cultivation is 27 126 ha and the total production is 218 000 tonnes. Pumpkin is an important source of protein, minerals (calcium, potassium and phosphorus), vitamins (especially vitamin A), and antioxidants (with abundant lutein and xanthin).

In recent years, with the development of stress-tolerant varieties and hybrids, areas under pumpkin cultivation are increasing. There is wide scope of intervention with this vegetable as it is tolerant to salinity, and the fertility and moisture constraints in stress-prone ecosystems (charland, coastal areas, hilly areas) can easily be overcome by managing only small areas of crop, rather than a whole field. BARI has developed an effective, eco-friendly and low-cost integrated pest management (IPM) package aimed at controlling fruit flies, which can cause serious damage to pumpkin crops (Mondal *et al.*, 2014). BARI has also developed three varieties (two open-pollinated and one hybrid variety) of pumpkin, and private seed companies have introduced a number of hybrid pumpkins that are becoming incredibly successful crops in charland and saline-prone coastal regions.

Amaranths (*Amaranthus spinosus*) are leafy vegetables similar to spinach and are widely cultivated in Bangladesh. The yard-long bean is a leguminous vegetable grown during the *kharif* season, while the French bean is another leguminous vegetable grown during *rabi* season. Ash gourd and ridge gourd are two moderately popular vegetables grown in Bangladesh during *kharif* season. Both these crops have the potential to thrive in stress-prone areas of charland. Bitter gourd is one of the most important vegetables in Bangladesh and there are two popular types: *karola*, which has large fruits and is grown during *kharif*, is well adapted to the charland; and *uchche*, which has small fruit, is grown during *rabi* and has a better taste and flavour. Bitter gourd is a good source of important nutrients including beta-carotene, folic acid, vitamin C, iron and potassium. Inherently bitter gourd has good salinity tolerance.

**Fruits:** Major tree fruits grown in Bangladesh include ber (*Ziziphus mauritiana*), coconut (*Cocos nucifera*), guava (*Psidium guajava*), jackfruit (*Artocarpus heterophyllus*), lychee (*Litchi chinensis*) and mango (*Mangifera indica*) among many others.

Most of the major fruits grown in the country become available between mid-May to mid-August. There is a glut of different fruits during this period, when the marketing of perishable fruits becomes more difficult. As a result, farmers do not get a proper return from

**TABLE 6.5** Prioritized FSF crops for Bangladesh, and possible intervention for improving them to promote as mainstream crop

Group	Prioritized crop	Possible intervention
Cereal	1 Foxtail millet	<ol style="list-style-type: none"> <li>1) Collection and conservation and utilization of PGR</li> <li>2) Public awareness development through print and electronic media regarding food value of FSF crops</li> <li>3) Incentives provided for FSF producers</li> <li>4) Growth areas expanded to marginal land (Char and Hill)</li> </ol>
Roots and tubers	2 Taro	<ol style="list-style-type: none"> <li>1) Collection and conservation and utilization of PGR</li> <li>2) Development of export oriented production programmes and arrangement of incentives for FSF growers and exporters</li> <li>3) Growth areas expanded</li> </ol>
Nuts and pulses	3 Mung bean	<ol style="list-style-type: none"> <li>1) Development of HYVs with tolerance to biotic and abiotic stresses</li> <li>2) Growth areas expanded to stress-prone ecosystems with adaptable varieties</li> <li>3) Development of short duration determinate varieties</li> <li>4) Promotion of processed products</li> </ol>
Horticulture	4 Pumpkin	<ol style="list-style-type: none"> <li>1) Collection and conservation and utilization of PGR</li> <li>2) Arrangement of incentives for FSF producers</li> <li>3) Growth areas expanded to marginal land (char, hill and coastal zones)</li> <li>4) Dissemination of technology on relay cropping with potato</li> </ol>
	5 Snake gourd	<ol style="list-style-type: none"> <li>1) Collection and conservation and utilization of PGR</li> <li>2) Provision of incentives for FSF producers</li> <li>3) Growth areas expanded to marginal land (char, hill and coastal zones)</li> </ol>
	6 Bael	<ol style="list-style-type: none"> <li>1) Collection and conservation of PGR</li> <li>2) Development of HYVs through selection and hybridization</li> <li>3) Establishment of a Foundation Mother Tree Orchard at research level and Elite Multiplication Block at extension level for ensuring the supply of quality planting materials (QPM)</li> <li>4) Growth areas expanded to marginal land (char, hill, coastal and drought prone zones) and homesteads</li> </ol>

their crops. On the other hand, there is acute shortage of nutritious fruits in the country during other seasons. Some of this shortage is made up for by importing fruits from neighbouring countries. But many neglected and underutilized species of fruit become available during lean periods and have the potential to tolerate abiotic stresses such as salinity, drought and moisture scarcity. These fruits can be grown successfully in stress-prone areas and are rich in nutrients, especially vitamins and minerals.

Bael (*Aegle marmelos*) is popular lean season fruit in Bangladesh. Demand for bael is high all over the country and the crop can demand high prices. In Bangladesh, bael is cultivated with minimum or no care, mainly in homestead boundaries, on roadsides and in school premises in rural areas. However, bael cultivation in horticultural gardens is limited. Total production of bael

in the country is 26 534 million tonnes, of which only 429 million tonnes are produced in gardens (BBS, 2016).

Bael is a delicious and nutritious fruit. It is also a rich source of carbohydrate, carotene, vitamin B complex, calcium and iron (Hossain *et al.*, 2011). For every 100 g of edible flesh, bael contains 62.5 g water, 1.8 g protein, 31.8 g carbohydrate, 0.39 g fat, 87 kilocalories of energy, 55 mg carotene, 0.13 mg thiamine, 1.19 mg riboflavin, 1.1 mg niacin, 38 mg calcium and 0.6 mg iron. It is, in general, a hardy plant and can be grown in stress-prone areas, especially drought areas with poor soil (Hossain *et al.*, 2011). If more research and development is undertaken, bael could become a major crop in Bangladesh. BARI has already developed one new variety of bael.

Custard apple (*Anona squamosa*), sapota (*Achras zapota*) and wood apple (*Feronia limonia*) are some of the important lean season minor fruits in Bangladesh.

## 5 Others

Other food crops in Bangladesh include oilseeds (for example groundnut, linseed, mustard, rapeseed, sesame, soybean etc.), spices (for example, black cumin, black pepper, chilli, coriander, fennel, fenugreek, garlic, ginger, onion, turmeric), coffee, tea and sugar crops (for example, date palm, palmyra palm and sugarcane). Except for its tea crop, Bangladesh is deficit in production of almost all these crops, up to 90 percent. Land scarcity is the main reason behind the deficit of these essential food crops.

### 6.3.3 Prioritization results

Foxtail millet from cereal crops; taro from roots and tubers; mung bean from pulses and nuts; pumpkin, snake gourd and bael from horticultural crops have been prioritized for Bangladesh as FSF, taking into account their nutritive value, public acceptance, stress tolerance, climate resilience, economic importance and scope of intervention.

### 6.3.4 Details on the prioritized FSF

#### Prioritized FSF 1

**Foxtail millet (*Kaon*) (*Setaria italic*, *Panicum italicum* L)**



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#### General characterization

- **Origin and distribution:** Foxtail millet is an annual grass with vertical, leafy stems that can grow to 120-200 cm. This is the second-most widely planted species of millet, and the most important in East Asia. It has the longest history of cultivation among the millets, having been grown in India since antiquity. According to recent research, it was first domesticated in China around 6 000 BC. It is the only crop among the millets still cultivated in Bangladesh in marginal soils of charland and hilly areas.
- **Life form and ecology:** Growth duration varies from 105-125 days during winter or *rabi* period, and 85-95 days during summer *kharif* seasons.
- **Yield:** Yield of foxtail millet varies according to the variety and growing season. Generally the *rabi* crop gives a higher yield (2.5-3.0 tonnes per ha) compared to the *kharif* season crops.

- **Ingredients and health benefits:** Foxtail millet is a good source of fibre and carbohydrates and can help control blood-sugar levels and reduce risk of heart attacks.

#### Prioritized FSF 2

**Taro (*Colocasia esculenta*)**



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#### General characterization

- **Origin and distribution:** Taro is a perennial, tropical plant primarily grown as a root vegetable for its edible starchy corm, and as a leaf vegetable. Taro is thought to be native to Southern India and Southeast Asia. It is a food staple in African, Oceanic and South Indian cultures, and is believed to have been one of the earliest cultivated plants. *Colocasia* is thought to have originated in the Indomalaya eco-zone, perhaps in East India, Nepal and Bangladesh.
- **Life form and ecology:** Taro plants need a lot of moisture with rainfall or irrigation of 1 500-2 000 mm required for optimum yields. Taro thrives best under wet or flooded conditions.
- **Uses and used parts:** In Bangladesh taro is a very popular vegetable known as *kachu* or *mukhi*. It is usually cooked with small prawns or the ilish fish into a curry, but some dishes are cooked with dried fish. Its green leaves (*kachu pata*) and stem (*kachu*) are also eaten. Taro stolons (*kachur loti*) are also favoured by Bangladeshis and cooked with shrimps, dried fish or the head of the ilish fish.
- **Yield:** Stolon 25-30 tonnes per ha. and 15-20 tonnes per ha.
- **Ingredients and health benefits:** Taro benefits include its many nutrients, including magnesium, iron, fibre, potassium, manganese, zinc, copper and phosphorus. It contains good amounts of antioxidants, as well as vitamins A, B6, C and E.



**Prioritized FSF 3****Mung bean (*Vigna radiata*)**

© Shutterstock/Valery Evlakhov



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**General characterization**

- **Origin and distribution:** Mung bean is a legume cultivated for its edible seeds and sprouts across Asia. It can reach a height of 1.25 m and produces seeds of various colours. The mung bean is thought to have originated from the Indian subcontinent where it was domesticated as early as 1500 BC.
- **Life form and ecology:** The mung bean is a fast-growing, warm-season legume. It reaches maturity very quickly (60-65 days) under tropical and subtropical conditions where optimal temperatures are about 28-30 °C and always above 15°C. It does not require large amounts of water (600-1,000 mm rainfall per year) and is tolerant of drought. The mung bean grows on a wide range of soils but grows best in well-drained loams or sandy loams, with a pH ranging from 5-8. It is somewhat tolerant of saline soils.
- **Uses and used parts:** The mature seeds provide an invaluable source of digestible protein for humans in places where meat is lacking or where people are mostly vegetarian. Mung beans are cooked fresh or dry. The mung plant makes valuable green manure and can be used as a cover crop.
- **Yield:** 1.0-5 tonnes per ha.
- **Ingredients and health benefits:** Mung beans are a rich source of nutrients including B vitamins, copper, foliate, manganese, magnesium and zinc. They are also a very filling food, high in protein, resistant starch and dietary fibre.

**Prioritized FSF 4****Pumpkin (*Cucurbita moschata*)**

© Shutterstock/Kentaro Foto



© Shutterstock/Chutima Chaimratana

**General characterization**

- **Origin and distribution:** Pumpkin is a squash plant that originated in North America and is now grown worldwide.
- **Life form and ecology:** An annual crop, pumpkins are tolerant of hot, humid weather and display a resistance to disease and insects. They can be intercropped and rotated with other plants.
- **Uses and used parts:** Most parts of the pumpkin is edible, including the fleshy shell, the seeds, the leaves, vines, and even the flowers.
- **Yield:** 16 tonnes per ha.
- **Ingredients and health benefits:** Pumpkin leaves are good source of Vitamin A, calcium, Vitamin C, iron and protein. They also contain a significant amount of antioxidants, tocopherols and carotenoids.

**Prioritized FSF 5****Snake gourd (*Trichosanthes cucumerina*)**

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**General characterization**

- **Origin and distribution:** A climbing herbaceous vine with 40-120 cm long beans. These beans are pale-green and orange when ripe. The wild species can be found in scrub, along forest edges and in open forest, up to 1 000 m or even 1 500 m in elevation. It adapts well to low elevations in the humid tropics. It does not tolerate dry soils and is sensitive to waterlogging.

- **Life form and ecology:** Snake gourd is an annual herb and young fruits may be harvested 50-70 days from sowing, continuing to 80-130 days.
- **Uses and used parts:** The immature fruit is boiled and eaten as a vegetable or in curries. The ripe fruit is fibrous and bitter. Young shoots and leaves are also edible.
- **Yield:** Yields may vary between 8-10 tonnes per ha.
- **Ingredients and health benefits:** Snake gourd possess vitamin A, vitamin B, vitamin C, as well as calcium, iodine, iron, manganese, magnesium, and potassium. It also contains a rich variety of nutrients and minerals that are essential for human health, including significant levels of dietary fibre, a low number of calories, and high levels of protein.

### Prioritized FSF 6

#### Bael (*Aegle marmelos*)



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### General characterization

- **Origin and distribution:** Bael is a species of tree native to Bangladesh and India. Its fruits are used in traditional medicine and as a food throughout its range.
- **Life form and ecology:** It copes with a wide range of soil conditions (pH range 5-10), is tolerant of water logging and has an unusually wide temperature tolerance (from -7 °C to 48 °C). It requires a pronounced dry season to bear fruit.
- **Uses and used parts:** The fruits can be eaten either freshly from trees or after being dried. It can be made into *sharbat*, a very popular summer drink across the country. The leaves provide fodder and have medicinal properties. The bark contains gum that is used as fish poison.
- **Yield:** The yield per tree is 200-400 fruits per year.
- **Ingredients and health benefits:** Bael is a good source of carbohydrates and provides minerals and vitamins including calcium, carotene, iron, phosphorus, riboflavin, thiamine and vitamin C. In dried form, the concentration of minerals and vitamins is increased.

## 6.4 Conclusion and recommendations

Bangladesh is very rich in plant genetic resources. But only a few of these have been exploited in crop-improvement programmes. Over recent decades, minor and underutilized crops were left out of development programmes because of the emphasis on major cereals such as rice and wheat. Crop competition is very high during winter (*rabi*) season. Scope of horizontal expansion for FSF crops is limited to stress-prone areas, and the summer and rainy (*kharif*) season. FSF crops can bring diversification in diet and minimize hidden hunger. Stress-prone ecosystems can be brought under intensive cultivation only with FSF crops, which will promote food and nutrition security. Scarcity of fresh fruit and vegetables during lean periods can also be mitigated by planting of FSF crops. FSF crops are generally more climate resilient, as they are tolerant to biotic and abiotic stresses, and require less water and agro-chemicals. Some FSF also play vital role in improving soil health.

The collection and conservation of germplasm of prioritized FSF crops should be strengthened, and genetic diversity should be exploited in breeding programmes for developing high yielding varieties with tolerance to biotic and abiotic stresses. The establishment of coordinated research and development projects needs to be undertaken with a view to promoting prioritized FSF as mainstream crops. In addition, FSF intake should be increased.

Political commitment is essential for promotion of FSF crops with a view to eradicating malnutrition and hidden hunger in Bangladesh. With this aim in mind, organized marketing systems should be developed to minimize the wide gap between farm gate and retail market prices of FSF crops, especially for more perishable crops. In addition, organized seed production systems for FSF crops should be put in place to ensure supplies of high-quality seed.

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# 7 Bhutan

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## 7.1 Introduction

### 7.1.1 About the country

Bhutan is a landlocked mountainous country with a rugged landscape in the eastern Himalayas situated between China (Tibet Autonomous Region) and India. It has an area of 38 394 sq km, with elevations ranging from 150 m to more than 7 000 m above sea level. More than 70 percent of the area is covered by forest and only around 2.9 percent is under cultivation. Although small, Bhutan has a wide range of agro-ecological zones and climates, ranging from subtropical to temperate and alpine, providing opportunities for broad crop and livestock farming. It also is recognized as a global biodiversity hotspot. The country's economy is largely based on agriculture, and 62 percent of the population are farmers who depend on crop production and livestock for their livelihood. Agriculture contributes up to 16.77 percent of the country's GDP and accounts for 4.3 percent of exports. The crop sector alone contributes 10.06 percent of GDP. Farming is predominantly subsistence in nature but is gradually gaining commercial momentum. The agriculture sector continues to play an essential role in reducing poverty and bringing prosperity to the Bhutanese people. Poverty is almost entirely a rural phenomenon with 12 percent of the population living under the poverty line of USD 28 per person per month.

### 7.1.2 Agro-ecological zones

Bhutan has six major agro-ecological zones with different altitudes and climatic conditions (see map, Figure 7.1). Table 7.1 provides an overview of the major agro-ecological zones along with the characteristic features of these zones in terms of farming practices adopted.

### 7.1.3 Status of Bhutan's food basket: the composition of crops, including staples

Based on the food availability, access and nutrition, Bhutan is modestly food secure. The Bhutanese diet consists mainly of rice, maize, wheat, barley, buckwheat, millet, oilseeds, grain legumes and a variety of vegetables, fruits and livestock products, such as meat, cheese, milk, eggs and fish. The estimated dietary energy consumption for the period from 2006-2010 was 3 019.32 calories per person per day which is above the FAO-WHO determined requirement of 2 200 calories per person per day to meet the basic nutrition needs. Of the total dietary energy consumed daily by an individual, approximately 68 percent of the energy comes from cereals mainly rice; 17 percent from oil; 6 percent from livestock products; 4 percent from vegetables; 3 percent from fruits and 2 percent from pulses. It is evident from the dietary energy contribution that the intake of nutrients is limited and the diversity of food composition is very poor.

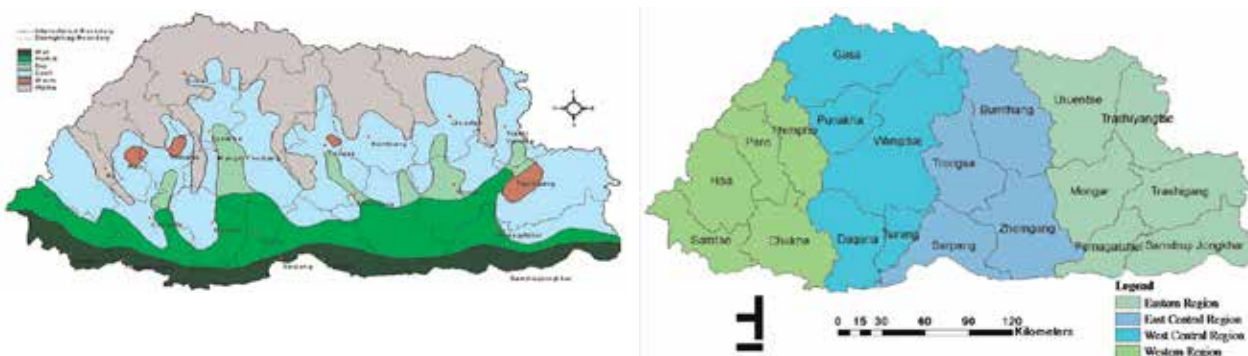
The domestic production of cereals in Bhutan is able to meet about 60 percent of total demand. Within cereals, the demand for maize and buckwheat is fulfilled by domestic production and the rest is met through imports. In 2010, Bhutan imported 50 percent of its rice, 20 percent of its millet and 64 percent of wheat and barley. Minor cereals, vegetables and non-wood forest products (NWFP) form an important source of household food and nutrition security with 41 percent of households earning income from the sale of NWFP. In 2015, total income from the sale of NWFP was USD 3.236 million, which was mainly earned from the sale of aromatic plants, cordyceps, medicinal plants and wild mushrooms.

Small landholdings compounded by the fragmentation of land are the most significant challenges when it comes to producing sufficient food commodities in Bhutan. The process of enhancing crop production is further constrained by a shortage of farm labour, lack of irrigation water and damage created by wild animals. Despite these challenges, there are still opportunities to

TABLE 7.1 Agro-ecological zones of Bhutan

Agro-ecological zone	Altitude (m asl)	Rainfall (mm/annum)	Mean temperature in Celsius	Farming systems, major crops agriculture produce and area (districts)
Alpine	3 600-4 600	Over 650	5.5	Semi-nomadic people, yak herding, dairy products, barley, buckwheat, mustard and vegetables  <b>Area:</b> Gasa and part of Bumthang, Thimphu, Wangdue, Paro, Trashigang and Trashi Yangtse
Cool temperate	2 600-3 600	650-850	9.9	Yaks, cattle, sheep and horses, dairy products, barley, wheat and potatoes on dryland, buckwheat and mustard under shifting cultivation; temperate fruits and vegetables  <b>Area:</b> Bumthang, Haa, and some part of Thimphu and Wangdue
Warm temperate	1 800-2 600	650-850	12.5	Rice on irrigated land, double cropping with wheat and mustard, barley and potatoes on dryland, temperate fruit trees, vegetables, cattle for draft and manure  <b>Area:</b> Paro, Thimphu and some part of Trongsa and Zhemgang
Dry subtropical	1 200-1 800	850-1 200	17.2	Maize, rice, millet, pulses, fruit trees and vegetables, wild lemon grass, cattle, pigs and poultry  <b>Area:</b> Punakha, Wangdue, Trongsa, Lhuentse, Trashigang, Trashi Yangtse, Mongar
Humid subtropical	600-1 200	1 200-2 500	19.5	Irrigated rice rotated with mustard, wheat, pulses and vegetables, tropical fruit trees  <b>Area:</b> Dagana, Tsirang, Zhemgang, Chhukha, Pemagatshel
Wet subtropical	150-600	2 500-5 500	23.6	Irrigated rice rotated with mustard, wheat, pulses and vegetables, tropical fruit trees  <b>Area:</b> Samtse, Samdrup Jongkhar, Sarpang, Dagana

FIGURE 7.1 Agro-ecological zones of Bhutan



Source: MoA/ISNAR, 1992

increase and diversify Bhutan's food production systems, especially considering the many and varied agro-climatic conditions found in the country.

#### 7.1.4 Major cropping patterns and crop diversity within agro-ecological zones

The alpine zone, covering the northern region, is characterized by alpine meadows and is dominated by livestock farming consisting mainly of yak and sheep. A few high-altitude crops such as barley, buckwheat, mustard and vegetables are grown on a small scale. In the cool temperate zones, rearing livestock is the most common way of living with some dryland farming. The main crops are barley, buckwheat, mustard, potato and wheat. The temperate zone has moderately warm temperatures except during winter when frosts occur. Here, agriculture is widely practiced in terraced irrigated lands and drylands. In the wetlands, rice is the main crop, and is rotated with potato, wheat, seasonal fodder and several kinds of vegetables.

The dry subtropical zone is warm with moderate rainfall allowing the cultivation of a wider range of crops. Barley, maize, mustard rice, different types of legumes and vegetables are cultivated here. The humid subtropical zone has a relatively higher rainfall and temperatures. The main crop cultivated in the terraced irrigated fields is rice, followed by wheat and mustard. The main cash crops are citrus (mandarin oranges) which grow in the lower altitudes and cardamom which grows in the higher elevations. In the dryland agricultural areas, the predominant crops are maize, millet, mustard, several types of legumes, ginger and vegetables.

The wet subtropical zone has agro-ecological conditions that favour intensive agriculture. Rice is the main crop grown in summer, which is rotated with wheat and mustard which are grown in winter, depending on irrigation. Irrigation sources are mostly rainfall dependent and tend to dry up during winter months. Large-scale winter cropping, although technically feasible, is normally not practiced due to the scarcity of water. In the dryland agricultural areas, maize and different types of millets are cultivated, and these are rotated with different types of legumes, mustard, ginger, tuber crops and vegetables.

## 7.2 Situation and gap analysis

### 7.2.1 Hunger and malnutrition

With the vision of being "a nation with the best health", the development of health and related services has always been a priority for the Government of Bhutan. Bhutan has made a remarkable progress towards achieving national, as well as regional and international goals and targets. Bhutan is also on track to addressing some of the nutrition indicators including reducing wasting and stunting in children under five and exclusive breast-feeding.

However, about 37 percent of farming households are not able to produce their annual food requirements, and this deficit is made up through off-farm earnings and the sale of livestock products. About 12 percent of the population of Bhutan lives below the national poverty line (USD 28 per person per month) and food diversity among rural households is less than urban households. Despite impressive progress, 21.2 percent of children under the age of 5 years are stunted and 9 percent are underweight (Table 7.2). Stunting is higher in rural areas and poorer households. The presence of stunting is high in the six eastern districts. Similarly, wasting in children under the age of 5 years is 4.3 percent at the national level. Iron deficiency (anaemia) is a serious problem among children and women, and occurs in 43.8 percent of children between 6 and 59 months and 34.9 percent of non-pregnant women. Vitamin A deficiency occurs in 22 percent of preschool children and 17 percent of pregnant woman in Bhutan. Most of these health issues are a result of acute malnutrition.

### 7.2.2 Climate change constraints

Bhutan is highly vulnerable to the effects of climate change due to its geographical features and the high economic dependency of the economy on climate-sensitive sectors such as agriculture, forestry and hydropower. This risk is acute, as the livelihoods of 62 percent of the population depend directly on agriculture and hydropower represents 13.4 percent of the national GDP.

In recent years, studies have identified increasing average temperatures, erratic rainfall patterns and other risks of climate related hazards in Bhutan. The Department of Agriculture reported that climate induced hazards such as flash floods, windstorms, hailstorms and droughts have caused massive losses and damage to crops. There is also evidence of new pests and disease outbreaks affecting crops.



TABLE 7.2 Nutritional status of children and women

Health Indicator	Prevalence %
Stunting	21.2
Underweight	9.0
Wasting	4.3
Anaemia in children (6-59 months)	43.8
Anaemia in non-pregnant women (15-49 years)	34.9
Overweight	4.7
Vitamin A deficiency (preschool children)	22.0
Vitamin A deficiency (pregnant women)	17.0

Soil fertility in Bhutan is decreasing due to soil erosion caused by high intensity rainfall. The frequency of floods (including flash floods and glacial lake outburst floods), windstorms, wild fires and landslides is increasing. The lack of irrigation water and the high incidence of pests and diseases discourage farmers from growing vegetables and other crops. The specific impacts of climate change on agriculture and related sectors include:

- Reduced availability of agricultural water (which increases fallow agricultural land).
- Increased incidence of pest and disease outbreaks (e.g. rice blast disease from 1995 to 1997; corn blight from 2006 to 2007; army worm outbreaks from 2013 and a giant African land snails (GALS) outbreak in Gyelposhing from 2006 to 2009).
- Loss of local or rare crop species due to extreme climatic events and disease epidemics (loss of indigenous rice varieties in Kanglung, Lungzampa, Thimphu and Paro).
- Loss of fields due to flash floods, landslides, and rill and gully formations. Soil nutrient loss through seepage.
- Crop-yield losses due to erratic and untimely rainfall, windstorms and hailstorms.
- Damage to road infrastructure (further impacting food security) – also related to natural disasters and the infrastructure sector.

### 7.2.3 Market and economic constraints

Although Bhutan's small economy has grown rapidly in recent years, it continues to be aid dependent, import driven and highly vulnerable, due to a narrow economic base reliant on hydropower exports to India and tourism.

Bhutan imports food commodities worth approximately BTN 7 billion (USD 108 million) annually. Rice is a major staple food in Bhutan, 50 percent of which is imported. In terms of vegetables, Bhutan is technically more than 95 percent self-sufficient with production higher during the summer season. As such, Bhutan exports vegetables to India during summer and imports food produce during winter months.

Due to difficult access to markets, high labour costs and low yields, the prices of domestic agricultural products are higher than imported ones. On the whole, the formal market for the agriculture sector in Bhutan is underdeveloped, with the trading of agricultural goods mostly taking place through intermediaries. The Food Corporation of Bhutan (FCB) facilitates the sale of a few agricultural commodities such as potato, vegetables and fruits but there is huge scope for it to expand its coverage and services. The government is investing in building infrastructure such as farm roads, cold stores, processing facilities and weekend markets to enhance domestic marketing and reduce reliance on imports. The government is also encouraging the establishment of farmers' groups and cooperatives to enhance the scale of production and increase farmers' bargaining power.

One of the major constraints affecting agriculture sector development is the break in interventions along the commodity value chain. Value-chain studies are available or are being developed for the mainstream agricultural commodities but are needed also for NUS crops that have the potential for food and nutritional security and commercialization.

### 7.2.4 Cultural relevance and local availability

Bhutanese people in general have no strong religious taboos regarding food consumption. However, there is an increasing trend of people becoming vegetarian. Their food culture is inclusive, with no discrimination between gender, age or caste or religion. Cereals account for 68 percent of diet and balance, 32 percent is derived from vegetables, pulses and livestock products. Of all the food consumed in Bhutan, 37 percent is by the urban population, with the remainder consumed in rural areas. Rice accounts for a larger share of the food consumed in rural households than in urban households, indicating potential risks for protein and micronutrient deficiencies, and poor nutrition status in rural households.

## 7.3 Scoping and prioritization of neglected and underutilized species

### 7.3.1 Availability of NUS

Available data shows that NUS crops, such as millet, buckwheat, barley and soybean, contribute a small

portion to the national food basket and play an important role in the household food and nutrition security of small and marginal farmers in rural areas. These foods are also culturally important for many communities. With the increasing awareness about health and nutrition, demand for NUS cereals is increasing among the urban population. However, the production volume of these cereals is quite low and production technologies are limited while investment in the research and development of minor cereals is negligible. So, considering the importance of such cereals for household food security, especially for rural poor farmers, there is a need to formulate a suitable policy and provide financial support to enhance the production of NUS crops.

Thirty-eight NUS crops (Table 7.3) belonging to various food groups were identified based on their availability, use and potential to address nutrition needs; their adaptation to climate change; and various economic and social concerns. The listed 38 have been reduced to six crops with maximum weightage given to nutrient content while also emphasizing these crops' adaptability to different climatic conditions.

**TABLE 7.3** List of Neglected and Underutilized Species (NUS)

Sl. No.	English/Local name	Scientific name	Priority
<b>Cereals</b>			
1	Finger millet	<i>Eleusine coracana</i>	3
2	Sweet buckwheat	<i>Fagopyrum esculentum</i>	1
3	Bitter buckwheat	<i>Fagopyrum tataricum</i>	4
4	Barley	<i>Hordeum vulgare L</i>	8
5	Quinoa	<i>Chenopodium quinoa</i>	2
6	Foxtail millet	<i>Setaria italica</i>	6
7	Amaranth	<i>Amaranthus spp</i>	5
8	Proso millet	<i>Pennisetum glaucum L</i>	7
<b>Roots and tubers</b>			
1	Tapioca	<i>Manihot esculentus</i>	2
2	Sweet potato	<i>Ipomoea batatas</i>	1
3	Greater yam	<i>Dioscorea alata</i>	3
4	Taro	<i>Colocasia</i>	4

Sl. No.	English/Local name	Scientific name	Priority
<b>Pulses</b>			
1	Kidney beans	<i>Phaseolus vulgaris</i>	3
2	Mung beans	<i>Vigna radiata</i>	5
3	Urd beans	<i>Vigna mungo</i>	4
4	Soybean	<i>Glycine max</i>	1
5	Lentil	<i>Len culinaris</i>	2
6	Horse gram	<i>Macrotyloma niflorum</i>	8
7	Rice beans	<i>Vigna umbellata</i>	7
8	Field pea	<i>Pisum sativum</i>	6
<b>Horticulture (Fruits and nuts)</b>			
1	Walnut	<i>Juglans regia</i>	2
2	Banana	<i>Musa spp.</i>	1
3	Jackfruit	<i>Artocarpus heterophyllus</i>	7
4	Amla	<i>Phyllanthus emblica</i>	6
5	Lime	<i>Citrus ourantifolia</i>	4
6	Persimmon	<i>Diospyros kaki</i>	5
7	Peach	<i>Prunus persica</i>	9
8	Pear	<i>Pyrus spp</i>	8
9	Passionfruit	<i>Passiflora edulis</i>	3
<b>Horticulture (Vegetables)</b>			
1	Drumstick (Moringa)	<i>Moringa oleifera</i>	1
2	Pumpkin	<i>Cucurbita spp</i>	4
3	Chayote squash	<i>Sechium edule</i>	9
4	Mustard green (Sag)	<i>Brassica juncea</i>	3
5	Chilli	<i>Capsicum annum</i>	7
6	Bitter gourd	<i>Momordica charantia</i>	6
7	Cucumber	<i>Cucumis sativus</i>	8
8	Stuffing cucumber (Slippery gourd)	<i>Cyclanthera pedata</i>	5
9	Amaranthus	<i>Amaranthus spp.</i>	2

### 7.3.2 Prioritization analysis

#### Nutrition

Hidden hunger, especially deficiencies in iron, vitamin A and zinc is a major concern in Bhutan. The prevalence of iron deficient anaemia is a major health issue in children aged 6-59 months and women of reproductive age (15-49 years old). As per the National Nutrition Survey 2015 Report, 43 percent of children between 6-59 months are anaemic along with 30.3 percent of

adolescents, 33.8 percent of non-pregnant women and 24.7 percent of pregnant women (according to the WHO, the prevalence of anaemia at levels of over 40 percent is categorized as a severe public health issue). Similarly, 22 percent of preschool children and 17 percent of pregnant women are vitamin A deficient in Bhutan. So the six identified NUS and FSF varieties (Table 7.4) are rich in iron, zinc and other micronutrients essential for good health.

TABLE 7.4 List of prioritized six FSF

Sl. No.	English Name/Local Name	Scientific Name	Reason for prioritization
1	Sweet buckwheat	<i>Fagopyrum esculentum</i>	Nutrition, economic, social
2	Quinoa	<i>Chenopodium quinoa</i>	Nutrition, economic
3	Soybean	<i>Glycine max</i>	Nutrition, adaptability, social
4	Lentil	<i>Len culinaris</i>	Nutrition, economic, social
5	Banana	<i>Musa spp</i>	Nutrition, economic, health, cultural and social
6	Drumstick	<i>Moringa oleifera</i>	Nutrition, adaptability, economic

### Adaptation to local environment and climate change

The six prioritized NUS and potential FSF are locally grown and available in the different agro-ecosystems of Bhutan. For example, buckwheat is cultivated in the alpine regions of up to 600 m to the subtropical regions of 300 m. Quinoa, recently introduced to Bhutan, is adapted to various altitude zones. Similarly, soybean, banana and moringa (drumstick) have the potential to be grown in many parts of the country, from warm temperate to subtropical regions. Lentils have a huge potential to be grown as a winter crop in warm temperate and subtropical zones, when large numbers of paddy fields are left fallow. Lentils can also be grown in dry conditions during the growing stage are known to add nutrients to the soil.

### Economic potential

As mentioned above, the economic and market potential of these crops were important criteria for prioritizing the six listed FSF. These crops have the potential to improve household income, address poverty and malnutrition concerns, and can contribute to export earnings. Quinoa is a good example of this, as there is a huge international market for the crop. The growing of FSF foods will also reduce reliance on imports. For example, Bhutan annually imports USD 2.6 million of lentils, which could more easily be grown within the country.

### Social and cultural potential

All six listed FSF are socially and culturally acceptable in Bhutan. Sweet buckwheat has cultural importance and is gaining popularity in modern cuisine as it is seen as a healthy food. Soybean is another crop that is consumed in various forms by Bhutanese people and has potential for value adding and product development. Lentils have become a common pulse consumed daily by many Bhutanese people, despite being a relative newcomer when compared to more traditional foods. Moringa (drumstick) is known for its health benefits thanks to

efforts to educate young school children via school agriculture programmes. Banana is a fruit that is socially and culturally important. It is used in religious ceremonies and at other important occasions.

## 7.3.3 Details on prioritized Future Smart Food

### Prioritized FSF 1

#### Sweet buckwheat (*Fagopyrum esculentum*)



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### General characterization

- **Origin and distribution:** Buckwheat is a pseudo cereal, which is related to knotweed, rhubarb and sorrel. It is thought to originate in China, though is now best known in Southeast Asia.
- **Life form and ecology:** Buckwheat is planted in spring (February–March) and grows up to 1 m tall. To enhance productivity, better genetic varieties and improved management practices are needed.
- **Uses and used parts:** The seeds are ground into flour and used to make pancakes or noodles. Young plants and tender shoots are used as vegetables.
- **Yield:** The yield is low and averages around 1 500 kg per ha.
- **Ingredients and health benefits:** It is gaining popularity as a health food among the urban population as it is rich in iron and zinc which are a major cause of hidden hunger.

**Prioritized FSF 2****Quinoa (*Chenopodium quinoa*)**

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**General characterization**

- **Origin and distribution:** Quinoa has only recently been introduced into Bhutan as a nutrient-rich food with export potential. Initial research has shown that it has wide range of adaptability (growing from 300-2 100 m).
- **Life form and ecology:** Quinoa is an annual herbaceous plant, measuring 0.2-0.3 m in height, depending on environmental conditions and genotype. The flowering panicles rise from the top of the plant or from leaf axils along the stem. The seeds are about 2 mm in diameter, with colours ranging from white to red or black, depending on the variety.
- **Uses and used parts:** The seeds are used in a similar way to other starchy grains.
- **Yield:** Potential of 750 -3 000 kg per ha (comparable to the global average).
- **Ingredients and health benefits:** Nutritionally, quinoa is rich in protein, iron, magnesium, zinc and many other minerals and vitamins. It also has high fibre and antioxidant content. Quinoa is considered good for controlling blood sugar.

**Prioritized FSF 3****Soybeans (*Glycine max*)**

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**General characterization**

- **Origin and distribution:** Soybean is an annual herbaceous annual plant grown for its edible seeds. Seed colour varies from yellow, green, brown, black to a mottled combination.

- **Life form and ecology:** Soybean is a short-day plant, requiring hot weather for optimum production. Plants are sensitive to waterlogging but are tolerant to drought conditions once established. Soybeans also fix approximately half of the nitrogen they require for growth within the soil.
- **Uses and used parts:** Soybean seeds are used to make flour and other products such as soya milk, tofu, margarine and yogurt. They are also a good source of edible oil. In Bhutan, soybean is mostly consumed as a snack after boiling or roasting. It is also used in curry after the seeds have been fermented.
- **Yield:** The average yield in Bhutan is 1 165 kg per ha.
- **Ingredients and health benefits:** Soybeans are an excellent source of essential foliates, nutrients (iron, manganese, phosphate, potassium, magnesium and zinc), and vitamins B and K. Soybeans are high in protein and dietary fibre.

**Prioritized FSF 4****Lentil (*Lens culinaris*)**

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**General characterization**

- **Origin and distribution:** Lentils originated in the Near East and spread to Egypt, central and southern Europe, the Mediterranean basin, Afghanistan, India, Pakistan, and China. The main lentil-growing countries include Bangladesh, Canada, China, India, Nepal and Turkey.
- **Life form and ecology:** Lentil is a bushy annual plant (40 cm tall) of the legume family grown for its edible seeds. Lentils are relatively tolerant to drought and are grown as winter crops after paddy rice with minimum irrigation and management practice. Crops mature within 100-120 days.
- **Uses and used parts:** Lentil seeds are eaten and commonly used in curries and stews.
- **Yield:** The average yield in Bhutan is 750-1 000 kg per ha.

- **Ingredients and health benefits:** According to the USDA nutrient database, 100 g of raw lentils provide 353 calories and the same weight of cooked lentils provides 116 kcal. Lentils have the second-highest ratio of protein per calorie of any legume, after soybeans.

#### Prioritized FSF 5

##### Banana (*Musa spp*)



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#### General characterization

- **Origin and distribution:** Bananas are one of the common fruits grown in Bhutan and are regarded as economically and culturally important. They are mainly found in subtropical and warm temperate zones. Though not grown on a commercial scale, almost every household in these zones grows a few banana plants for family consumption and to sell in local markets. On average, Bhutan imports USD 0.162 million worth of bananas each year.
- **Life form and ecology:** Bananas are a fruit produced by large herbaceous plant belonging to *Genus Musa*. Fruits are generally elongated and curved and popularly consumed as a dessert, but when raw, are also used for preparing curry.
- **Uses and used parts:** Both the skin and fruit can be used in a variety of ways, cooked and raw and as an ingredient in jams and many other dishes.
- **Yield:** The average yield per plant is 29 kg. There are no large-scale banana plantations.
- **Ingredients and health benefits:** Bananas are rich in essential minerals mainly potassium, which is good for maintaining proper heart function and regulating blood pressure by offsetting the effect of sodium (salt). They are also rich in vitamin B6, essential for creating hemoglobin and maintaining blood sugar levels. Besides potassium and vitamin B6, bananas carry many other health benefits and are a good source of instant energy.

#### Prioritized FSF 6

##### Moringa (*Drumstick*) (*Moringa oleifera*)



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#### General characterization

- **Origin and distribution:** This fast growing and generally drought resistant tree has its origins in the southern foothills of the Himalayas and is widely cultivated in tropical and subtropical areas.
- **Life form and ecology:** Moringa is a deciduous tree that can reach a height of 10–12 m with a 45 cm trunk diameter. The tree has an open crown of drooping, fragile branches. The fruits are green rod-shaped pods around 20–45 cm long. In cultivation, the tree is often cut back annually to 1–2 m and allowed to regrow so the pod and leaves remain within arm's reach. In Bhutan however, this practice less common. It can be grown successfully in tropical and subtropical climate receiving 250-3 000 mm annual rainfall annually.
- **Uses and used parts:** As well as the immature pod, which is used as a vegetable, leaves, flower, seeds, seed oils and roots are also consumed.
- **Yield:** The approximate yield per plant of drumstick is 5-7 kg. Harvesting of tender shoots and flower is not common.
- **Ingredients and health benefits:** The leaves are the most nutritious part of the plant, being a significant source of vitamins B, C and K, and are also rich in manganese, iron and protein.

## 7.4 Conclusions and recommendations

### 7.4.1 Conclusions

Bhutan offers a wide range of micro-climatic conditions and various agro-ecological zones providing opportunities for growing different kinds of food crops. About 62 percent of the population directly depends on agriculture for their livelihood. Based on food availability, access and nutrition, Bhutan is modestly food secure.

The agricultural production potential is challenged by low productivity due to issues such as difficult farm terrain, the subsistence nature of Bhutanese farming, a shortage of farm labour, lack of access to markets and climate change among many others.

Bhutan has made significant progress in the population's nutritional status, measured in terms of stunting prevalence in children, which declined from 37 percent in 2008 to 34.8 percent in 2010, and to 21.2 percent in 2015. Despite these promising figures, prevalence of stunting is still high, particularly in rural areas and among poor households. Another severe health concern are the high anaemia rates among children and women of reproductive age. Malnutrition is still a major problem in children, affecting their physical and intellectual development, which is directly related to poverty, poor nutrition and sanitation. Household food diversity is very low; rice is the preferred staple, and is often eaten three times daily. The consumption of vegetables, fruits and meat remains quite low.

Nutrient intake in Bhutan could increase with the incorporation of NUS into farming systems. Most NUS crops are locally grown in small quantities and, by nature, such crops have the potential to perform well under stressed climatic conditions and with minimal input and care.

### 7.4.2 Recommendations

NUS could play an important role in addressing household food demands and food security in Bhutan. As well as being highly nutritious and valued for medicinal properties, these crop species adapt well to being grown on marginal lands and can withstand harsh climatic conditions. Recognizing FSF production as a way of addressing the growing impact of climate

change on agriculture and nutritional deficiency in poor communities requires support and commitment from the government and development partners. It is important and timely that NUS crops are given due recognition as FSF and incorporated into mainstream agriculture to address the food and nutritional security in the poor and rural sections of the population of Bhutan.

In Bhutan, there needs to be an enhanced awareness of the importance of household food diversity with the inclusion of identified nutrient-rich FSF as a good source of iron, minerals and vitamins. Ongoing awareness programmes have to include school children as an important intervention entry point. Information about NUS crops and their benefits should be part of the agriculture educational curriculum in schools and colleges.

To enhance food and nutrition security, multi dimensional interventions need to involve different sectors. A national level taskforce should be considered to coordinate and monitor NUS and FSF programmes. In addition, production of FSF crops should be improved via varietal improvement and better agronomic management practices. It is also vital to build and develop human resources and infrastructure to promote FSF, and ensure that there is an exchange of technical expertise among the researchers at regional and international levels.

Land and climate suitability maps to promote and enhance production of FSF as nutritious and climate-smart food should be produced while product diversification should be an important strategy to promote consumption of FSF. There also needs to be full documentation of all NUS along with their value chain, adaptability, uses and health benefits.

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# 8 Cambodia

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## 8.1 Introduction

### 8.1.1 About the country

Cambodia is located in mainland Southeast Asia between 102° to 108° E and 10° to 15° N. The country is bordered in the northeast by Thailand, in the north by Lao PDR, in the south and east by Viet Nam and in the south by the Gulf of Thailand. Cambodia covers a geographical area of 181 035 sq km. (Fig. 8.1). The total population is about 15 million, with around 70 percent living in rural areas.

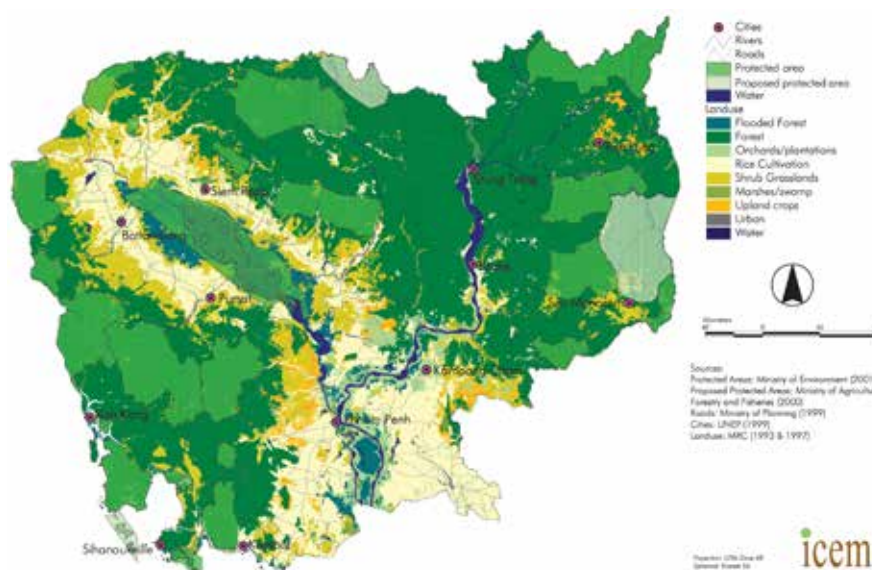
Cambodia is surrounded by mountains with a large central plain comprising the Great Lake (Tonle Sap Lake) and a river system. The Cardamom and Elephant Mountains are to the west and southwest, the Dangrek Mountains lie to the north along the Thai border, and the lower reaches of the Central Highlands of Viet Nam are to the east. The central plains are extremely flat, with an elevation difference of only 5-10 m between the southeastern portion of the country and the upper reaches of Tonle Sap in the northeast, a distance of more than 300 km. The plains are the result of long-term silt deposits originating from mountains within

Cambodia and sediments carried into the plain by the Mekong River.

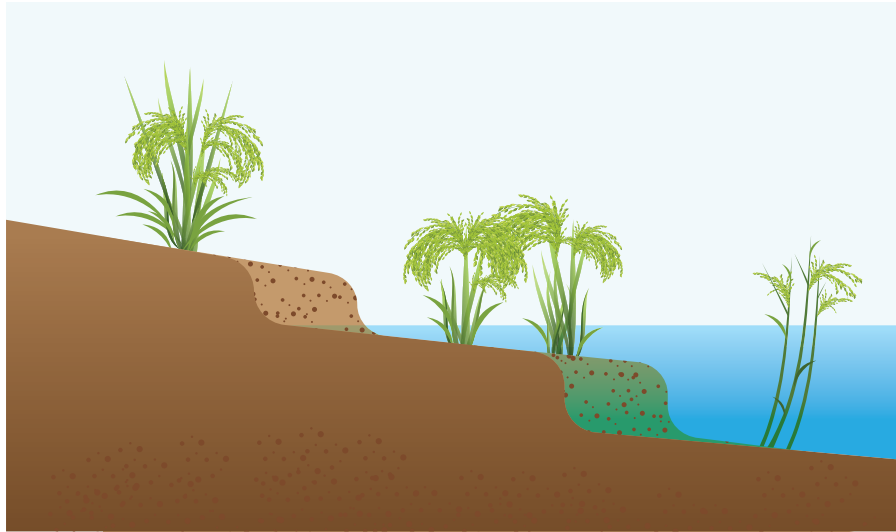
The Mekong River rises and falls approximately 9 m each year, the height of which is influenced by melting snow in the Himalayas and rainfall in China, Lao PDR, Myanmar, north Viet Nam and Thailand. In Cambodia, the river passes through the provinces of Stung Treng, Kratie, and Kampong Cham until it converges with the Tonle Sap Lake in Phnom Penh. When it reaches Phnom Penh, the water divides to flow down both the Mekong and Bassak Rivers to Viet Nam. As the river level rises, some water flows back in a northwesterly direction along the Tonle Sap River into Tonle Sap Lake. The lake can expand tenfold in area to approximately 25 000 sq km between May and November.

The south and southwest of the country comprise 443 km of coastline along the Gulf of Thailand, characterized by sizable mangrove marshes, sandy beaches, and headlands and bays. Cambodia's territorial waters encompass more than 50 islands. The highest peak in all of Cambodia is Phnom Aural, 1 810 m above sea level.

FIGURE 8.1 Map of Cambodia



Source: ICEM – International Centre for Environmental Management

**FIGURE 8.2** Agro-ecological pattern based on the rice ecosystem, Cambodia

Source: Men *et al.* 2007.

### 8.1.2 Agro-ecological zones

In Asia, Cambodia is a unique in terms of its various ecosystems under different natural selection pressures, such as drought, flooding and nutrient stresses (Javier, 1997). Its flat plains and mostly lowland areas have well-defined geographic regions. Three-quarters of the country encompass the Tonle Basin and Mekong Delta lowlands. Agricultural land and forest occupy 32 percent and 46 percent respectively, of the country's land area.

Day length varies from 11 h 29 min to 12 h 48 min without twilight, and the mean maximum and minimum temperatures range from 30 to 36°C and 21 to 25°C, respectively (Nesbitt, 1997). The average annual rainfall is 1 343 mm, which generally falls between May and November.

Cambodian soils, categorized under the FAO-UNESCO system, are gleyic luvisols, gleyic acrosols, ferrollic cambisols and eutric leysols. These ancient alluvial soils are low in organic matter, acidic, generally and poorly drained. They also have low pH buffering capacity and cation-exchange capacity (CEC).

The main crop in Cambodia is rice, which is cultivated on approximately three million hectares (MAFF, 2016). Cambodia ranks third in the world when it comes to rice consumption with each person eating on average 172 kg every year (Chaudhary, 1993). Based on the rainfall distribution and topography, rice ecosystems in Cambodia can be divided into three main categories: upland, rain-fed lowland and floating rice (Figure 8.2). Rice cultivation mainly occurs in the rain-fed lowland areas around Tonle Sap Lake, the Tonle-Bassac River and the Mekong River. The rain-fed lowland regions are subdivided into areas for early, medium and late varieties (Nesbitt, 1997).

### 8.1.3 Status of Cambodia's food basket: the composition of crops, including staples

In 2016, agriculture accounted for 26.3 percent of Cambodia's GDP and employed about 72 percent of the country's population. The total area given over to crops was about 4 million ha with around 75 percent of this area taken up by rice (Table 8.1 and Figure 8.4). Cambodia is not only self-sufficient in rice but has been an important exporter since 1995 (Figure 8.3). Cassava is the second major crop, mainly cultivated for starch and bioenergy production. Other crops such as maize and mung bean are important food crops in upland areas. In some more marginal areas, root crops such as sweet potato and local cassava are planted to generate income and to enhance food security and nutrition.

### 8.1.4 Crop diversity and major cropping patterns

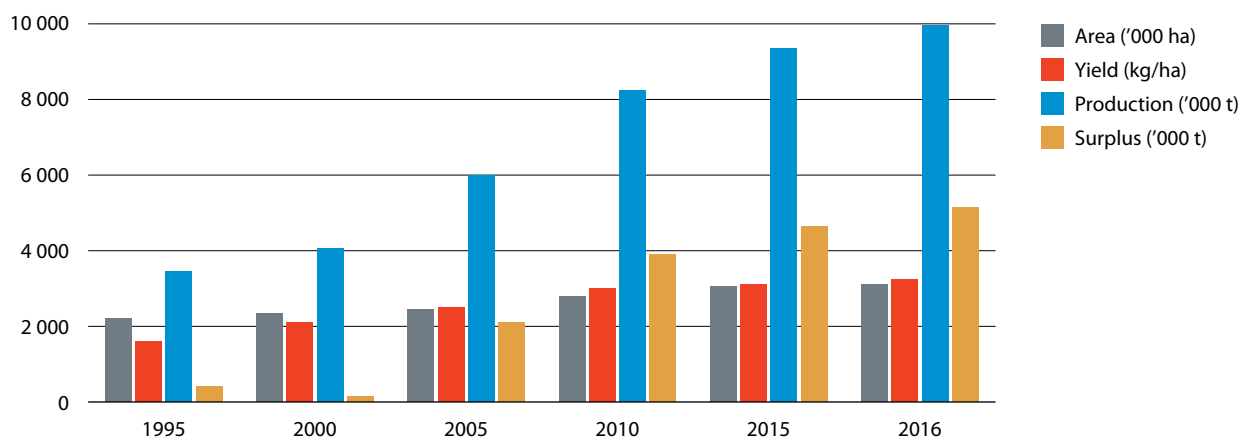
While Cambodia is a small country, it has varied ecosystems, which promote a high diversity of crop and animal species. According to Ashwell (1997):

Cambodians habitually utilized at least 931 species of Cambodia's 2 304 plant species. Of the 849 species for which life forms are described, 34.8 percent are trees of various sizes, followed by 21.7 percent herbs (including bamboo and bananas) and 15.1 percent shrubs. The remaining 28.4 percent include shrubs, palm trees, lianas and ferns... Habitats are known for 62.7 percent of these species. The main classes are the cultivated plants (23.6 percent), then species coming from primary evergreen (dense) forest (14.3 percent) and secondary formations habitats. Thus, wild plants appear to be at least as important

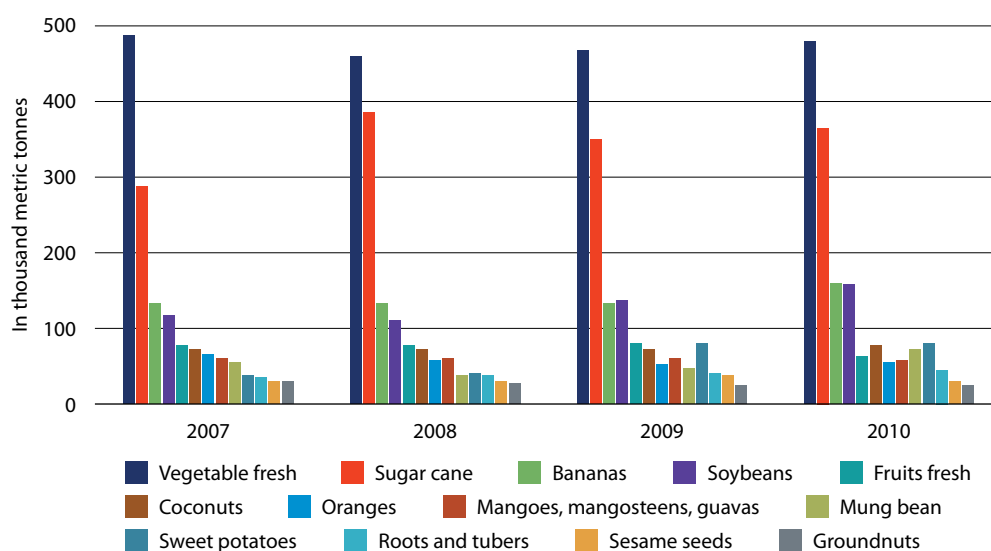
**TABLE 8.1** Crop production by area

Crop	Area (ha)
Rice	3 055 507
Cassava	521 459
Maize	143 517
Mung bean	53 294
Vegetable	51 637
Sugarcane	48 357
Sesame	28 170
Peanut	17 818
Tobacco	10 727
Jute	192
<b>Total</b>	<b>4 009 104</b>

Source: MAFF, 2016

**FIGURE 8.3** Rice production status from 1995 to 2016, Cambodia

Source: MAFF, 2016

**FIGURE 8.4** Total production of selected agrarian products, Cambodia, 2007–2010

Source: FAOSTAT, 2012

TABLE 8.2 Crop germplasm and conservation in Cambodian gene bank at CARDI

No.	Crop/plant	Scientific name	Accession/sample	Type of conservation
1	Rice (traditional)	<i>Oryza sativa</i> L.	3 545	Gene bank
	Rice (breeding line)	<i>Oryza sativa</i> L.	3 143	Gene bank
2	Wild rice	<i>Oryza rufipogon</i> Griff.	295	Gene bank
3	Wheat	<i>Triticum aestivum</i>	3	Gene bank
4	Maize	<i>Zea mays</i> L.	58	Gene bank
5	Sorghum	<i>Sorghum bicolor</i>	29	Gene bank
6	Okra	<i>Abelmoschus ficulneus</i>	5	Gene bank
7	Sesame	<i>Sesamum indicum</i>	13	Gene bank
8	Mung bean	<i>Vigna radiata</i>	14	Gene bank
9	Soybean	<i>Glycine max</i>	19	Gene bank
10	Peanut	<i>Arachis hypogaea</i>	16	Gene bank
11	Wild Vigna	<i>Vigna radiata</i>	137	Gene bank
12	Watermelon	<i>Citrullus lanatus</i>	43	Gene bank
13	Gourd	<i>Benincasa hispida</i>	27	Gene bank
14	Pumpkin	<i>Cucurbita maxima</i>	94	Gene bank
15	Cucumber	<i>Cucumis sativus</i>	195	Gene bank
16	Sing qua	<i>Luffa acutangula</i>	14	Gene bank
17	Seng qua	<i>Lagenaria siceraria</i>	3	Gene bank
18	Bitter Gourd	<i>Momordica charantia</i>	3	Gene bank
19	Winged bean	<i>Psophocarpus tetragonolobus</i>	3	Gene bank
20	Tomato	<i>Solanum lycopersicum</i>	37	Gene bank
21	Chili	<i>Capsicum annuum</i>	180	Gene bank
22	Eggplant	<i>Solanum melongena</i>	49	Gene bank
23	Mango	<i>Mangifera indica</i> L.	26	On-field
24	Fruit tree	<i>Fruit tree</i>	30	On-field
26	Cassava	<i>Manihot esculenta</i>	28	On-field
27	Sweet potato	<i>Ipomoea batatas</i>	36	On-field
28	Yam ( <i>Chheam Moan</i> )	<i>Oxalis tuberosa</i>	1	On-field
29	Yam ( <i>Dai Khla</i> )	<i>Dioscorea alata</i>	1	On-field
30	Potato	<i>Solanum tuberosum</i>	4	<i>In vitro</i>
31	Taro	<i>Colocasia esculenta</i>	7	On-field
32	Banana	<i>Musa spp.</i>	153	On-field and <i>in vitro</i>
33	Sugarcane	<i>Saccharum officinarum</i> L.	34	On-field
34	Wild sugarcane ( <i>Treng</i> )	<i>Saccharum spontaneum</i>	3	Gene bank
37	Lotus	<i>Nelumbo nucifera</i>	5	Gene bank
38	Ornamental plants	N/A	5	<i>In vitro</i>
	<b>Total</b>		<b>8 258</b>	

as cultivated plants. In addition, food plants constitute 37.9 percent (353 species) of the total number (2 304 species). These plants are used daily though dependency may be greater during months when there is food deficit in an area. Food plants include species of vegetables, fruits, nuts, leaves, flower, roots, tuber, etc.

Crops such as eggplant, glutinous maize, melon, mung bean, rice, sorghum, soybean, sweet potato, taro, tomato and wild vegetables including *sleuk bah* and *saom moav*, have high genetic variation that has long been utilized by local farmers. These crops species have also been cultivated in different ecosystems. However, most of them were observed in upland areas and are still consumed by farmers. Thirty-eight different crop species have been collected and conserved in the Cambodian gene bank for research and seed distribution (Table 8.2).

## 8.2 Situation and gap analysis

### 8.2.1 Hunger and malnutrition

In the 1980s, as the country emerged from decades of civil conflict, Cambodia ranked among the poorest nations in the world. The situation has since improved and the World Food Programme (WFP) noted that the country's poverty rate decreased from 35 percent in 2004 to 14 percent in 2014 (ADB, 2017).

Even though Cambodia has achieved more than two decades of strong economic growth and has moved closer to low-middle-income status, its people are still largely dependent on agriculture. Poverty in Cambodia is closely associated with a lack of food security and nutrition. Most people living in the north and some upland areas have low incomes that are strongly associated with high malnutrition levels.

In 2014, the Cambodia Demographic Health Survey (CDHS) reported that 32 percent of children under age five are stunted (short for their age), which is an 8 percent fall since the 2010 CDHS. Moreover, 9 percent of this age group are severely stunted. With regard to wasting (weight-for-height), the 2014 CDHS reported that 10 percent of children were wasted, compared to 11 percent in 2010. The percentage of underweight (weight-for-age) children improved marginally from 2010 to 2014. The prevalence of undernutrition was estimated by the World Bank (2011) to result in economic losses for Cambodia of USD 134 million annually. Cambodia has the third highest rice consumption in the world with an

average of 172 kg per person being consumed annually. The average diet consists of 70 percent starchy foods (Figure 8.5). Most children and adults in Cambodia eat three meals per day consisting of rice and vegetables. Fish, the most common protein source, is eaten less than once per day while meat is rarely consumed. The Tonle Sap Lake provides approximately two-thirds of the fish consumed annually in Cambodia.

The prevalence of malnutrition is strongly linked with the knowledge of caregivers and family income. Mothers often do not begin breastfeeding newborns until the second or third day after delivery (Jacobs and Roberts, 2004). Rather, babies are fed water (often unsanitary), sugar water, or honey. Rice porridge of minimal nutritional value is the only solid food given to children until the second year of life when protein and vegetables are introduced. This contributes to the high rate of infant mortality, 97 deaths per 1 000 live births, and the under-five mortality rate of 140 per 1 000 live births.

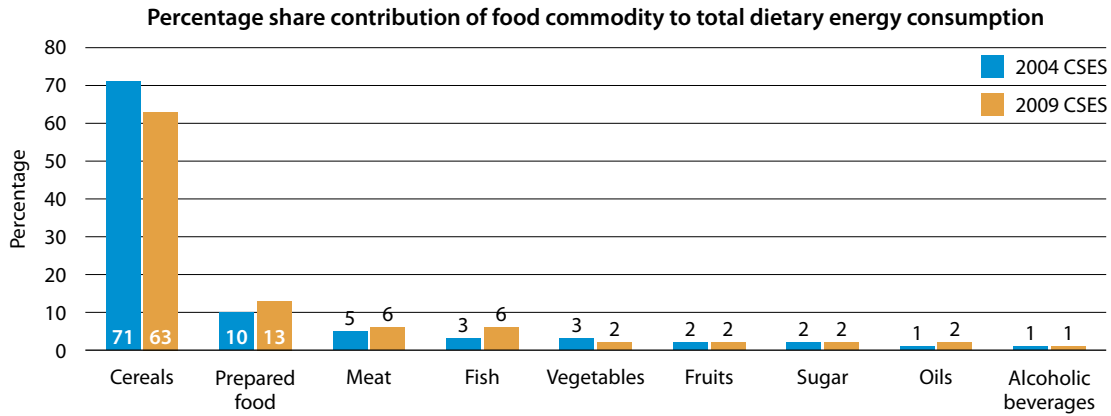
The Royal Government of Cambodia has established a National Action Plan to alleviate hunger and malnutrition by 2025, which is made up of five pillars:

- Pillar 1: 100 percent equitable access to adequate, nutritious and affordable food year-round
- Pillar 2: Zero stunting in children below two years of age
- Pillar 3: All food systems to be sustainable
- Pillar 4: A 100 percent increase in smallholder productivity and income
- Pillar 5: Zero loss and waste of food

### 8.2.2 Climate change constraints

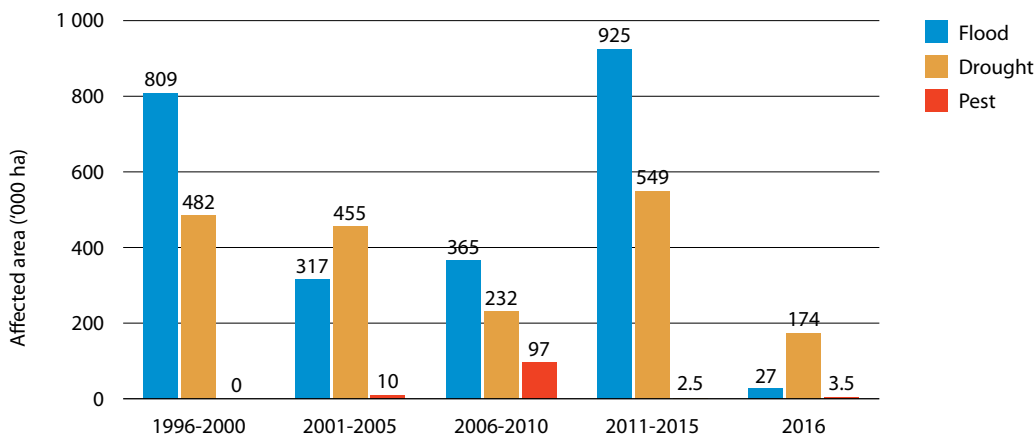
Cambodia is one of the countries most vulnerable to climate change. Scientists predict that a warming climate will profoundly affect Cambodia's coastal regions, ecosystems, and economy. It is predicted that mean annual rainfall in Cambodia could increase between 3 percent and 35 percent by 2100, most likely during the wet season and mostly affecting the lowlands (Heng Chan Theun 2015). Runoff in the Mekong Basin is projected to increase by 21 percent by 2030. By 2030, it is also estimated that climate change will raise the wet season levels of the Tonle Sap Lake by 2.3 m (Lauren 2012). Cambodia's high levels of poverty will make it harder for its population to adapt to these effects of climate change.

**FIGURE 8.5** Dietary energy pattern, Cambodia



Source: NIS, 2009

**FIGURE 8.6** Area affected by flood and drought in Cambodia from 1996-2016



Source: MAFF, 2016

Cambodians only have an average of seven years of education (NIS, 2009) making it hard for agricultural experts to share knowledge and skills on how to use high-tech equipment to improve agricultural practices. Since many Cambodian farmers still use traditional methods and tools to cultivate their land, they are highly sensitive to environmental changes, especially drought and flood. Five provinces along the Mekong River have

been identified as flood prone areas, while 80 percent of farmers live in drought prone areas. This is of great concern as irrigation schemes are limited in Cambodia. Based on assessments by the Ministry of Agriculture, Forestry and Fisheries (MAFF), flooding caused more serious damage than drought from 1996 to 2016 (Figure 8.6) (MAFF, 2016).

### 8.2.3 Market and economic constraints

Underutilized crops such as legumes, wild fruit and vegetables are grown in upland farms along stream banks or near water sources, and in-home gardens around farmers' houses. Due to poor market conditions, these species are grown in small quantities for local use only. In addition, local people do not have sufficient facilities and knowledge to process their agricultural products to meet market standards. Another problem is that public awareness of the benefits of NUS, such as nutritive value to consumers, is limited. As a result, some traditional underutilized crops are being displaced due to pressure from imported species, demography and changes in household structure. In contrast, where markets are available, underutilized crops play an important role in the lives of the rural poor because they contribute to livelihoods, poverty alleviation and sustainable environments. A case study conducted by (Thorng *et al.*, 2012) revealed that underutilized crops make a significant contribution to the diet of rural households, particularly during droughts, food crises and during the annual dry season. Ten of these NUS were classified as main contributors to income generation (Table 8.3).

### 8.2.4 Cultural relevance and local availability

Most underutilized crop species contribute to daily food intake and are important sources of nutrition for Cambodian people. Cambodian cuisine offers some unique dishes influenced by the traditions of local ethnic groups. As an example, *Samlor Korko* (stirring soup) is prepared from at least ten vegetables, most of which are underutilized crops. Traditionally, this recipe was prepared from 100 different vegetables and needed lots of stirring; it is often called 100-vegetable soup. In upland areas, foxtail millet is cooked with rice to increase energy levels and flavour, and is regularly used as an offering during religious or family ceremonies.

## 8.3 Scoping and prioritization of Future Smart Food

### 8.3.1 Scoping of availability of FSF

#### Cereal crops

Rice is the staple cereal crop in Cambodia. However, local varieties have been gradually abandoned by farmers due to their low productivity and quality, resulting in low market demand. Maize is the second most important crop after rice in terms of cultivated area and production. It is a good source of energy (360 kcal), vitamins (e.g., B1: 13 percent, B3: 12 percent, B6: 7 percent, vitamin C: 8 percent) and minerals (e.g. phosphorus: 13 percent, iron: 4 percent, magnesium: 10 percent). In Cambodia, many introduced varieties (hybrid seeds) are being planted while indigenous varieties are neglected and at risk of extinction.

Wild rice (*Oryza rufipogon* Griff.) was considered an abandoned species in Cambodia due to its poor agronomic traits and quality. Although wild rice varieties have lots of inferior traits in rice production, they still maintain beneficial alleles and nutritional advantages that can be utilized for breeding and food. However, due to population growth and infrastructure developments, some species of wild rice have now disappeared completely.

#### Roots and tubers

The yam is the best known member of the *Dioscoreaceae* family and there are over 600 recognized species found worldwide in temperate and tropical regions, with the highest diversity found in seasonally dry tropics including Indochina (Wilkin and Thapayai, 2009). Many *Dioscorea* species are good sources of food and medicine. The Phnong minority group experience food shortages throughout the year, especially during droughts when they rely on harvests of taro (*Dioscorea* such as *D. alata*, *D. esculenta*, *D. pentaphylla* and *D. brevipetiolata*). *Colocasia esculenta*, and sweet potato (*Ipomoea batatas*) from the wild and from small farms around the village (*Chamkar*). Taro and sweet potato are not only used as a food source but also to generate income in minority group communities (Table 8.4).

#### Wild vegetables

Most wild vegetables in Cambodia are leafy types that sprout and flourish after the annual rains. They generally mature within a short period (about two weeks) and include species such as Indian lilac (*Azadirachta indica*), ivy gourd (*Coccinia grandis*), scarlet-fruited gourd (*Cratoxylum formosum*), melientha (*Melientha suavi*) and water celery (*Oenanthe javanica*). People try, where possible, to add wild foods to local staple foods, or to mix them with other ingredients to enhance the fragrance and flavour.



**TABLE 8.3** The top ten underutilized crops that contribute to income generation, Cambodia

Rank	Underutilized crops	Scientific name	No. of households	Percentage (%)
1	Banana	<i>Musa spp.</i>	46	53.5
2	Papaya	<i>Carica papaya</i>	44	51.2
3	Sweet potato	<i>Ipomoea batatas</i>	42	48.8
4	Pumpkin	<i>Cucurbita moschata</i>	42	48.8
5	Winter melon	<i>Benincasa hispida</i>	38	44.2
6	Taro	<i>Colocasia esculenta</i>	36	41.9
7	Cucumber	<i>Cucumis sativus</i>	28	32.6
8	Long bean	<i>Vigna unguiculata</i>	25	29.1
9	Cow pea	<i>Vigna unguiculata</i>	22	25.6
10	Avocado	<i>Persea americana</i>	18	20.9

Source: Thorng *et al.*, 2012

**TABLE 8.4** List of wild root and tuber food plants, Cambodia

Scientific name	Family name	Common names	Local name (in Khmer)	Plant part used
<i>Alpinia galangal</i> L.	Zingiberaceae	Galangal	Rumdaeng prey	Root/tuber/ stem
<i>Dioscorea alata</i> L.	Dioscoreaceae	Purple yam White yam	Damloong chhiem Moen/damloong Phluk	Root/tuber
<i>Dioscorea brevipetiolata</i>	Dioscoreaceae	n/a	Damloongtien	Root/tuber
<i>Dioscorea esculenta</i>	Dioscoreaceae	Chinese yam Asiatic yam Lesser yam	Damloong sya Damloong dong Daloong chhvie Prey	Root/tuber
<i>Dioscorea pentaphylla</i> L.	Dioscoreaceae	n/a	Damloong tuk	Root/tuber
<i>Dioscorea hispida</i> Dennst.	Dioscoreaceae	n/a	Khuech	Root/tuber
<i>Kaempferia galangal</i> Linn.	Zingiberaceae	Wild ginger Sand ginger	Khnhy prey	Root/tuber
<i>Colocasia esculenta</i>	Araceae	Taro	Trarv	Root/tuber/ stem
<i>Dioscorea alata</i>	Dioscoreaceae	Winged yam Purple yam	Damloong Chheamorn	Root/tuber
<i>Ipomoea batatas</i>	Convolvulaceae	Sweet potato	Damloong Chhvea	Root/tuber/ whole
<i>Maranta arundinacea</i>	Marantaceae	Arrowroot	Kcheay	Root/tuber

A wide range of *Cucurbitaceae* species, such as waxy gourd, pumpkin, chayote and bitter gourd, are found in various parts of Cambodia, and most have multiple uses. However, the production area is small, and these plants

are usually grown in backyards or along river banks. The crops are well adapted to Cambodia's climate, particularly from November to February. These species are also rich in vitamins, minerals and carbohydrates.

**TABLE 8.5** List of wild vegetable species used for food in Cambodia

Scientific name	Family name	Common names	Local name (in Khmer)	Plant part used
<i>Azadirachta indica</i>	Meliaceae	Neem tree Indian lilac	<i>Phak sdau</i>	Flowers Young leaves Shoots
<i>Bambusa vulgaris</i> <i>Phyllostachys edulis</i>	Poaceae/ Bambusoideae	Bamboo	<i>Tumpuamng</i> <i>Russey</i>	Young shoots
<i>Coccinia grandis</i>	Cucubitaceae	Scarlet-fruited gourd Perennial cucumber	<i>Slerk bah</i>	Young leaves Shoots
<i>Calamus spp.</i>	Areaceae	Rattan	<i>Phdau</i>	Young shoots
<i>Cratoxylum formosum</i>	Guttiferae	n/a	<i>Longieng</i>	Young leaves Flowers
<i>Melientha suavis</i>	Opiliaceae	<i>Phak-wanpain</i> in Thai <i>Phak van</i> in Lao	<i>Slerk prich</i>	Fruit Young shoots
<i>Oenanthe javanica</i>	Umbelliferae	Water dropwort Water celery	<i>Phouv kangkep</i>	Entire plant
<i>Vigna minima</i>	Fabaceae	Wild cowpea	<i>Sanneak prey</i>	Young fruit Flowers

**TABLE 8.6** List of nuts and pulses found in upland areas of Cambodia

Scientific name	Family name	Common names	Local name (in Khmer)	Plant part used
<i>Arachis hypogaea</i>	Fabaceae	Groundnut	<i>Sandek Dei</i>	Grain/seeds
<i>Vigna radiata</i>	Fabaceae	Mung bean	<i>Sandek Bay</i>	Grain/seeds
<i>Vigna unguiculate</i>	Fabaceae	Cowpea	<i>Sandek Angkuy</i>	Fruit
<i>Vigna unguiculate</i>	Fabaceae	Yard-long bean	<i>Sandek Kour</i>	Fruit Grain/seeds

*Coccinia grandis*, locally known as *Slerk Bah*, is another vegetable grown on upland farms particularly in home gardens and is popular among Cambodians. *Slerk Bah* is a good source of nutrients, vitamins and minerals including iron (17 percent), vitamin B2 (6.15 percent), vitamin B1 (5.83 percent) and calcium (4 percent).

#### Nuts and pulses

Cowpea, black-eyed peas, mung bean, rice bean and yard-long beans are legumes grown on upland farms along stream banks or near a water source. Nuts and pulses are used as vegetable substitutes in many dishes while seeds are used in preparing sweet foods. Due to poor market demand, most of these species are grown in small quantities for local consumption, except for groundnut and mung bean which are grown on a larger scale.

#### Wild fruit species

Fruit and wild fruit trees are important for supplementing subsistence agriculture in developing countries such as Cambodia. Many wild food plants have been and still are underutilized. Wild mango, for example, has been abandoned without any conservation due to poor eating quality (fruits are often small and sour). However, wild mango can resist insects and diseases, and absorb water and nutrients when exposed to drought. Bael (*Aeglos marmelos*), Burmese grape (*Baccaurea ramiflora*) and amla fruit (*Embilica officinalis*) are good sources of vitamins and energy. However, the market for these fruits is small and these species have recently become threatened by deforestation and infrastructure development.

TABLE 8.7 List of wild fruit species, Cambodia

Scientific name	Family name	Common names	Local name (in Khmer)
<i>Acronychia pedunculata</i>	<i>Acronychia pedunculata</i>	n/a	
<i>Artocarpus rigidus</i>	<i>Artocarpus rigidus</i>	Monkey-jack	<i>Khnao prey</i>
<i>Baccaurea ramiflora</i>	<i>Baccaurea ramiflora</i>	Burmese grape	<i>Phnhiew</i>
<i>Dialium cochinchinensis</i>	<i>Dialium cochinchinensis</i>	Velvet tamarind	<i>Lralanh</i>
<i>Dillenia indica</i> L.	<i>Dillenia indica</i> L.	Elephant apple	<i>Dak chan</i> <i>Phlul vieng</i>
<i>Dillenia ovate</i>	<i>Dillenia ovate</i>	Ovate dillenia	<i>Phul thom</i>
<i>Diospyros hasseltii</i>	<i>Diospyros hasseltii</i>	n/a	<i>Tubloab prey</i>
<i>Garcinia cowa</i>	<i>Garcinia cowa</i>	n/a	<i>Tromoung</i> <i>Tromeng</i>
<i>Garcinia schomburgkiana</i>	<i>Garcinia schomburgkiana</i>	n/a	<i>Sandan prey</i>
<i>Mangifera duperreana</i>	<i>Mangifera duperreana</i>	Wild mango	<i>Svay prey</i>
<i>Nephelium hypoleucum</i>	<i>Nephelium hypoleucum</i>	Korlan	<i>Se moen</i>
<i>Passiflora foetida</i> L.	<i>Passiflora foetida</i> L.	Passion flower Wild water lemon	<i>Saou maou prey</i>
<i>Phyllanthus emblica</i> L.	<i>Phyllanthus emblica</i> L.	Indian gooseberry	<i>Kantuet prey</i>
<i>Spondias malayana</i>	<i>Spondias malayana</i>	n/a	<i>Mkak prey</i> <i>Puen</i>
<i>Syzygium</i> spp.	<i>Syzygium</i> spp.	Java plum, jambolan	<i>Pring dahs krabei</i>
<i>Terminalia chebula</i>	<i>Terminalia chebula</i>	Chebolic myrobalan	<i>Sramar</i>
<i>Willughbeia edulis</i> Roxb	<i>Willughbeia edulis</i> Roxb	Kuy (in Khmer) Gedraphol (in Thai)	<i>Kuy</i>

### 8.3.2 Prioritization results: proposed selected Future Smart Food

Based on nutritional value, cultural relevance, agricultural importance, and economic value, 16 crop species were selected for Future Smart Food development in Cambodia:

- **Grain crops:** wild vigna, mung bean, sorghum, foxy millet

- **Roots and tubers:** sweet potato, taro, yam
- **Nuts:** cashew and peanut
- **Horticulture:** bitter gourd
- **Others:** banana, mango, milk fruit, *Coccinia grandis* (*Sleuk Bah*), *Acacia pennata*, avocado, papaya

Of these 16 crops, six have been prioritized as FSF in Cambodia, and are detailed below.

**Prioritized FSF 1****Wild vigna (*Vigna umbellata*)**

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**General characterization**

- **Origin and distribution:** Annual form, mostly grown in upland areas, drought tolerant.
- **Plant part used:** Seeds for soup, glutinous rice cakes and desserts.
- **Nutrition and health benefits:** High protein content up to 293 g/kg, high sulfur amino acids (2.05–3.63 g per 16 g), high levels of resistant starch (64–75 percent). The presence of trypsin inhibitors could prevent cancer (Marconi *et al.*, 1997).

**Prioritized FSF 2****Sweet potato (*Ipomoea batatas*)**

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**General characterization**

- **Distribution and availability:** Perennial vine, drought tolerant, mostly planted in sandy soils in lowland areas.
- **Plant parts used:** Roots are boiled, fried or dried. Leaves can be used for cooking and animal feed.
- **Nutrition and health benefits:** High in energy and carbohydrates, high vitamin A, vitamin B6 and vitamin C. Good source of vitamin D, which helps build healthy bones. High magnesium levels help to fight stress.

**Prioritized FSF 3****Taro (*Colocasia esculenta*)**

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**General characterization**

- **Distribution and availability:** Grown in upland and lowland areas mostly around villages and next to paddy fields.
- **Plant parts used:** Roots and leaves.
- **Nutrition and health benefits:** Corm is rich in carbohydrates and the leaves are rich in calcium. Health benefits include the ability to improve digestion, skin protection, increased circulation, and lower blood sugar levels.

**Prioritized FSF 4****Peanut (*Arachis hypogaea*)**

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**General characterization**

- **Distribution and availability:** Mostly grown in upland areas. In lowland areas, they are grown after the wet season rice is harvested.
- **Plant parts used:** Seeds.
- **Nutrition and health benefits:** Rich in energy, fat, carbohydrate, protein and manganese, which can promote a healthier heart.

**Prioritized FSF 5****Ivy gourd/*Sleuk Bah* (*Coccinia grandis*)**

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**General characterization**

- **Distribution and availability:** Found among wild plants, near villages and growing along rural fences.
- **Plant parts used:** Leaves are used for soup or boiled for salad and eaten with fermented fish.
- **Nutrition and health benefits:** Rich in vitamins and minerals. Just 100 g of ivy gourd supplies 1.4 mg iron, 0.08 mg vitamin B2, 0.07 mg vitamin B1, 1.6 g total dietary fibre and 40 mg Calcium. May help to lower blood sugar levels, prevent obesity, prevent kidney stones, and lower the risk of heart disease and stroke.

**Prioritized FSF 6****Drumstick (*Moringa oleifera*)**

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Luis Echeverri Urrea**General characterization**

- **Distribution and availability:** Planted along fences in rural districts.
- **Plant parts used:** Leaves and seeds.
- **Nutrition and health benefits:** Rich in calcium, potassium, vitamin C and protein, highly nutritious profile and powerful anti-inflammatory, antioxidant and tissue-protective properties. Used to treat and prevent diseases such as diabetes, heart disease, anaemia, arthritis, liver disease, and respiratory, skin, and digestive disorders. It has become more popular thanks to its high value when used to make moringa powder (Kathryn, 2014).

**8.4 Conclusion and recommendations**

A diversity of underutilized crops are found growing in Cambodia. Farmers tend to keep to traditional practices in agriculture and maintain significant crop genetic diversity in their fields. Rice is the main crop followed by maize, cassava and cashew nuts. Crop production remains difficult in some areas due to drought, submergence and heat stress. Underutilized crops play an important role in food security, nutrition and income generation. Some crops have been rapidly replaced by newly-introduced varieties due to lack of seed sources (local maize) and are at risk of extinction.

Several recommendations need to be acted upon to ensure better use of NUS to sustain nutrition and food security in Cambodia. First, there needs to be germplasm collection of endangered species so that rare seeds can be conserved for future use. Documentation of all collected materials should be carried out for better utilization of crops in the future. At a farm level, it is important to diversify cropping systems to incorporate potential NUS into current production systems.

In addition, there needs to be more public awareness of the importance of NUS for their nutritional value and health benefits. Research should be undertaken to develop sustainable management practices for underutilized species and to improve marketing possibilities for all products.

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# 9 Lao PDR

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## 9.1 Introduction

### 9.1.1 About the country

Lao PDR is a landlocked country located in Southeast Asia, sharing borders with China to the north, Myanmar to the northwest, Thailand to the west, Cambodia to the south and Viet Nam to the east. It has a total area of 236 800 sq km, and is dominated by mountainous areas and alluvial plain regions. Around 70 percent of the country is mountainous and thickly forested, with elevations above 500 metres typically characterized by steep terrain, narrow river valleys, and low agricultural potential. This mountainous landscape extends across most of the north of the country.

Lao PDR has a typical monsoon climate, which is classified into two distinct seasons: the rainy season from May to October and the dry season from November to April. The southwest monsoon occurs from mid-May to early October. The average highest temperature range is between 35-38°C and lowest average temperature range is about 16-18°C. The maximum temperature is 40°C (in March to April, over low-lying land) and minimum temperature is 0°C (in December and January, over higher land, for example, in Xiengkhouang and Phongsaly provinces). Floods and drought are the main hazards in Lao PDR and both are dependent on the amount of rainfall. Tropical cyclones are not a direct hazard, as their force is normally diminished once they have reached Lao PDR from the South China Sea, but they can produce floods as a consequence of heavy rainfall. If the annual rainfall is less than 2 000 mm, drought sensitive areas are usually affected. Up to three cyclones hit the country annually, while flood, drought and landslides occur irregularly.

### 9.1.2 Agro-ecological zones

The alluvial plains and terraces of the Mekong and its tributaries cover about 20 percent of the land area. Broad alluvial plains, where much of the rice crop is grown, are found only in the south and west along Mekong River and its tributaries. The Vientiane plain is the most extensive.

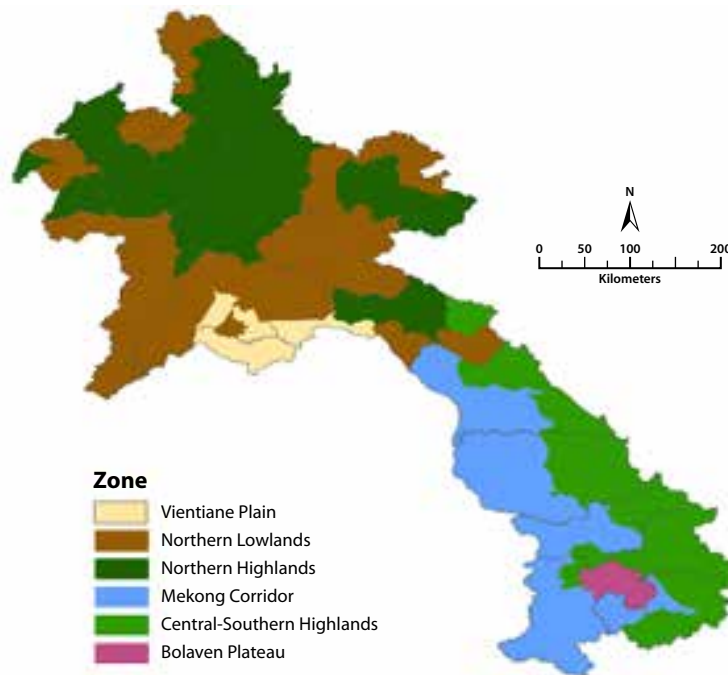
Lao PDR's rural landscape is characterized by six major agro-ecological zones with the following dominant features. The Mekong Corridor includes the banks and flood plains of the Mekong River and the lower alluvial valleys of its tributaries. The Central-Southern Highlands zone includes parts of Khammouane, Savannakhet, Salavan, Sekong and Attapeu provinces, and extends parallel to the Mekong covering the upper valleys of its tributaries and upland areas. The Northern Highlands zone covers the mountain areas of Phongsaly, Luangnamtha and Borkeo in the extreme northwest parts of Houaphanh and Xiengkhouang, and eastern parts of Bolikhamxay. The Northern Lowlands area comprises parts of Luang Prabang, Phongsaly, Oudomaxay and Sayabouly. The last zone is the Bolaven Plateau, which includes parts of Salavan, Sekong and Champasak provinces in the south. Because of good rainfall (2 500-3 000 mm) and rich soils, the Bolaven Plateau is ideal for a wide range of cropping.

The Vientiane Plain extends over Vientiane Capital, parts of Vientiane province, and Bolikhamxay province and covers the higher plains and lower slopes areas. The land is dominated by topography of middle mountain areas. Natural forests still exist but these have been impacted by shifting cultivation and illegal logging.

### 9.1.3 Status of Lao PDR's food basket: the composition of crops, including staples

Rice is life in Lao PDR. Rice is the key crop for national food and livelihood security. Lao people consume on average 165.5 kg of milled rice per person every year. Seventy three percent of the population is employed in the rice sector, which accounts for 25 percent of the national GDP (total agricultural GDP is 30.8 percent). Rice is culturally important for all ethnic groups and is used in many of the country's traditions and rituals. Lao PDR is also a centre of biodiversity for several glutinous rice varieties, and the primary centre of origin and domestication of Asian rice (*Oryza sativa* L.).



**FIGURE 9.1** Agro-Ecological Zones of Lao PDR

Source: WFP2013

A project to conserve and use genetic diversity for improving rice yields and quality was started prior to 1995 when the national gene bank (Under the Lao-IRRI project) was initiated. The Lao-IRRI project has now conserved more than 14 000 accessions of rice, 80 percent of the glutinous variety. Among the glutinous rice accessions, 55 percent are upland rice accessions and 45 percent are lowland rice accessions. Traditional glutinous rice varieties have a good aroma and eating quality, resistance to GM disease, drought and flood tolerance and pest and disease resistance.

Rice is grown throughout the country under diverse climatic conditions, including rain-fed and irrigated lowland, and rain-fed upland conditions. During the dry season lowland rice may be fully irrigated or supplementarily irrigated. Upland rice is grown in unbundled fields with irrigation coming from rainfall. Terraces for paddy cultivation on mountainsides may be seen in the northern regions of Lao PDR. Other crops include maize (glutinous for consumption and feed corn for selling), adlay millet (Job's Tears), which is mostly sold to traders, tuber crops (cassava, sweet potato and taro for home consumption), and vegetables grown in upland rice fields (integrated crops such as chilli, cucumber, local melon and others).

#### 9.1.4 Major cropping patterns and crop diversity

Food production systems in Lao PDR are currently transitioning from subsistence to more commercial production systems. Rice is the main staple food and the

country is currently sufficient in domestic production, which reduces the need for imports from neighbouring countries. Other potential commercial agricultural products are also increasing both in terms of production area and productivity. These include cassava, coffee, maize, rubber, sugarcane and tea. In order to add value to these products, manufacturing and processing industries are being established, which mainly produce goods for the export market. The processing and manufacturing industries recruit a number of workers in local areas, which contributes to employment opportunities and infrastructure development in rural areas.

Lao PDR is rich in plant species and genetic diversity, and these contribute to national and rural well-being. However, such natural resources are increasingly under threat from a variety of factors including deforestation, over-exploitation and the clearing of land for infrastructure development. Lao PDR has also seen the extension of farming systems into frontier zones, the mechanization of agriculture, and the adoption by farmers of new, high-yield crop varieties.

The change from a subsistence to an open market economy, and the availability of fertilizers and other inputs are contributing to genetic erosion in several crops such as rice, local vegetables and legumes. Farmers are also abandoning glutinous rice varieties, and replacing them with high-yield non-glutinous types. Wild rice species are at risk of being eroded or becoming extinct due to the conversion of their habitats.

Currently, there is insufficient information available on many crops and their associated biodiversity to ensure their improved use, development and conservation.

A survey of cultivated and wild *Vigna* in Lao PDR (Tomooka *et al.*, 2004) reported that cowpea (*Vigna unguiculata*) and rice bean (*Vigna umbellata*) are important legumes at the village level and landraces of these species are still commonly grown. These varieties have long been important genetic sources for breeding and it is necessary to collect more variations of this species in neighbouring countries. In Thailand for example, farmers prefer to grow improved varieties instead of landraces. It is vital to collect landraces and collate farmers' knowledge before these useful crops disappear for good.

## 9.2 Situation and gap analysis

### 9.2.1 Hunger and malnutrition

Despite the ongoing and rapid growth of the national economy, the problems of food insecurity and malnutrition, especially among vulnerable children under five years old, continue to pose a huge challenge to national development. Over the past two years, although GDP per capita in Lao PDR has almost tripled and poverty has been halved, malnutrition rates have reduced only slightly and progress remains slow.

In Lao PDR, chronic malnutrition affects 378 388 children under 5 years old, or 44 percent. This is one of the highest rates in Southeast Asia. Micronutrient deficiency rates are also high, with 41 percent of children under the age of 5 years and 59 percent of children under the age of 2 years suffering from anaemia, the latter figure being especially high. Although the underweight malnutrition rate among children under the age of 5 fell from 32 percent in 2006 to 27 percent in 2012, the wasting rate stood still at 6 percent. Moreover, the chronic and underweight malnutrition rates of the 6-24 month age group are markedly higher than those of other age groups. Malnutrition continues to have an impact on other vulnerable groups, including women of reproductive age, pregnant women and women who breastfeed, and this is related to infant and child care.

The percentage of children under five years old who were stunted in 2011/12 stood at 44.2 percent, though nutrition data indicates fewer stunted children in 2015 (35.6 percent). Around 13 provinces of Lao PDR had levels of stunting exceeding the WHO 40 percent threshold in 2011/2012, though this decreased to nine provinces in 2015. Of note is the significant reduction in stunting prevalence in Bolikhamxay and Vientiane

provinces. Whilst this is an encouraging sign of improvement, reducing stunting and malnutrition are vital criteria for a country when it comes to graduating from least developed country status.

Reducing malnutrition can also contribute to reducing associated losses caused by pressures on health systems and indirect loss of productivity, which was estimated by the World Bank (2014) to cost around USD 102 million annually.

Reducing the number of children who are stunted is one of the main international and national goals in Lao PDR. The National Nutrition Strategy 2025 sets out targets under different frameworks, such as the SDG agenda, World Health Assembly Targets, the ASEAN Integrated Food Security framework and the 8th National Socio-Economic Development Plan. What these all have in common is the goal of ensuring long-term food security and nutrition to improve the livelihoods of the citizens of Lao PDR, farmers in the ASEAN region, and of children across the globe.

### 9.2.2 Climate change constraints

Climate change is occurring globally and affects all countries. For Lao PDR, scientists predict that temperatures will continue to rise and that dry seasons will get longer. Rainfall, storms, droughts and floods will become more severe and frequent. Rainfall will become more erratic and weather events such as droughts or floods will become more extreme.

According to the National Disaster Management Office, for decades Lao PDR has been experiencing an increase in small-scale weather extremes, which affect over 10 percent of the population. Recurrent floods and droughts are considered to be the main natural hazards in addition to fires, landslides, erosion, tropical storms and disease epidemics. Floods mostly occur during the monsoon season from May-September. Dry spells are also increasing in duration in some parts of the country.

The immediacy of climate-change impacts became apparent in 2008 when the Mekong River rose and Vientiane suffered flooding levels not seen since the city was last inundated in 1966.

In 2009-2011, several typhoons struck Lao PDR, notably Ketsana, Haima and Nock-ten. They brought torrential rain, high winds and widespread flooding, which took the lives of many people. Furthermore, thousands of people were left homeless and large numbers of livestock died, while many hectares of crops were severely damaged.

### 9.2.3 Market and economic constraints

The marketing of agricultural products in Lao PDR tends to be regionally confined, resulting in significant variation in market prices from region to region. Such regionally unbalanced markets are created by formal and informal regulations which prevent free movement of goods; prohibitive fees and administrative costs; poor access roads and an underdeveloped farm-to-market network. Other factors are transportation shortages and high costs, and inter-regional transport fees and bureaucracy in Lao PDR.

Low technical expertise; limited access to domestic and international markets for import and export; lack of access to market information; constraints on inter-provincial and external trade; low domestic demand; and the dearth of local agribusinesses are other reasons why agricultural production continues to be inefficient.

In addition, limited human-resource capacity, poor agricultural support and delivery services and a lack of medium-term and short-term credit and other financial services hamper agricultural development.

**TABLE 9.1** Crop-related neglected and underutilized species, Lao PDR

Crop-related Neglected and Underutilized Species (NUS)			
Food group	English or local name	Scientific name	NUS classification
1 Cereals	Sorghum	<i>Sorghum bicolor</i>	Underutilized
	Adlay	<i>Coix lacryma-jobi</i>	Underutilized
	Waxy corn	<i>Zea mays</i>	Underutilized
	Rice landrace	<i>Oryza sativa</i>	Underutilized
	Finger millet	<i>Eleusine coracana</i>	
	Foxtail millet	<i>Setaria italica</i>	
2 Roots and tubers	Taro	<i>Colocasia sp.</i>	Neglected and Underutilized
	Greater yam	<i>Dioscorea alata L.</i>	Neglected and Underutilized
	Fancy yam	<i>Dioscorea esculenta Burk.</i>	Neglected and Underutilized
	Elephant foot yam	<i>Amorphophallus campanulatus</i>	Neglected and Underutilized
	Sweet potato	<i>Ipomoea batatas</i>	Underutilized
	Arrow root	<i>Maranta arundinacea</i>	Neglected and Underutilized
	Wild yam	<i>Dioscorea pentaphylla</i>	Neglected and Underutilized
	Yam	<i>Dioscorea hispida</i>	Neglected and Underutilized
	Wild ginger	<i>Kaempferia galanga</i>	Neglected and Underutilized
	Lotus	<i>Nelumbo nucifera</i>	Underutilized
3 Nuts and pulses	Mung bean	<i>Vigna radiata (L.) Wilczek</i>	Underutilized
	Rice bean	<i>Vigna umbellata (Thunberg) Ohwi and Ohashi</i>	Neglected and Underutilized
	Cowpea	<i>Vigna unguiculata (L.) Walp. subsp. unguiculata</i>	Underutilized
	Soybean	<i>Glycine Max (L.) Merrill</i>	
	Peanut	<i>Arachis hypogaea L</i>	
	Lablab	<i>Lablab purpureus</i>	
	Sword bean	<i>Canavalia gladiata</i>	
	Pigeon pea	<i>Cajanus cajan</i>	Underutilized
	Common bean	<i>Phaseolus vulgaris L</i>	Underutilized
	Azuki bean	<i>Vigna angularis</i>	

Crop-related Neglected and Underutilized Species (NUS)			
Food group	English or local name	Scientific name	NUS classification
4 Vegetable	Amaranthus	<i>Amaranthus viridis</i> L.	Underutilized
	Angled loofah	<i>Luffa acutangula</i> (Linn.)Roxb.	
	Bottle gourd	<i>Lagenaria siceraria</i>	
	Coriander	<i>Cucumis sativus</i> Linn	
	Dill	<i>Anethum stavus</i> L.	
	Sponge gourd	<i>Luffa cylindrical</i> (Linn.) M.J Roem	
	Small bitter guard Loofah	<i>Momordica charantia</i> L	
	Snake guard	<i>Trichosanthes cucumerina</i> L	
	Pumpkin	<i>Cucurbita moschata</i>	
	Sesame	<i>Sesamum indicum</i>	

To stimulate growth and to raise rural incomes, private-sector commercial strategies and initiatives, supported by a market-friendly legal and environmental policies, are needed to help subsistence and semi-commercial farmers move to more productive and diversified commercial agricultural production.

#### 9.2.4 Cultural relevance and local availability

The dominant religion in Lao PDR is Buddhism, mixed with elements of spirit worship and animism. One feature of daily life is the morning processions of Buddhist monks around towns, receiving offerings of food from the people. The daily event shows how important food is in the religious practices of the Lao people.

Traditional Lao food is dry and spicy with many dishes influenced by neighbouring countries and the culinary legacy of the French colonial period. One of the staples of Lao food is glutinous rice. This sticky rice is easily rolled into small balls for dipping into food. So a traditional everyday Lao meal is simple and normally consists of sticky rice, some natural vegetables and at least one kind of spicy sauce. Another national staple, eaten with nearly every dish is *padaek* (or *padek*), which is a paste made from cured, fermented fish. Other favourite dishes include *Laap*, a traditional food made from chopped meat, spices and broth mixed with uncooked rice grains that have been dry fried, and crushed. *Laap* is eaten with a plate of raw vegetables and sticky rice. *Tam Mak Houng* is a salad made from sliced raw papaya, garlic, chili, peanuts, sugar, fermented fish sauce and lime juice – it can be extremely spicy.

## 9.3 Scoping and prioritization of Future Smart Food

### 9.3.1 Scoping of availability of FSF

FSF crops that have been selected to study and promote are based on local production and consumption habits, nutritional value and market access.

### 9.3.2 Prioritization analysis

The prioritization analysis of NUS was based on:

- Nutritional value: Food composition and high nutrition
- Social value: Local acceptability, especially to children, and knowledge of how to process foods aimed at children
- Agricultural value: Seed availability, local knowledge on agronomy and environment requirements
- Commercial or market value: Quality of produce, access to markets and demand

### 1 Roots and tubers

Several roots and tubers species can be found in Lao PDR, but taro (*Colocasia esculenta*), greater yam (*Dioscorea alata*) and fancy yam (*Dioscorea esculenta*) are the most commonly consumed and grown in smallholdings. Generally, though, tubers are a neglected and underutilized crop, and most are only eaten as snacks or as a main ingredient in more remote areas when resources are low. Purple and fancy yams are rich in carbohydrates (over 97 percent) and other elements such as potassium, phosphorus, calcium and anthocyanin (which have excellent antioxidant properties). A few recent studies have been carried out

on *Colocasia esculenta*, *Dioscorea alata* L and *Dioscorea esculenta* and their germplasm and they've been identified as having excellent potential for food security and for fighting malnutrition.

## 2 Nuts and pulses

Grain legumes also known as pulses, are important when it comes to a protein-rich diet. In Lao PDR, such crops can help to fight malnutrition among the rural poor and subsistence farmers, and are nutritionally and economically important. The most widely cultivated of these crops in Lao PDR are cowpea (*Vigna unguiculata*), rice bean (*Vigna umbellata*) and sword bean (*Canavalia gladiata*), which are thought to have originally been domesticated in Southeast Asia where they have high genetic variation. The seeds of these three species have a protein content ranging from 20 to 25 percent (Shabnum *et al.*, 2012, Arora, 2014). Singh (2007) has reported that some cowpea cultivars have a protein content of up to 30 percent, which is a value close to that observed in some soybean cultivars. Cowpea leaves are also high in protein with a content of 22 percent for fresh leaves and 39 percent for dry (Chikwendu *et al.*, 2014). This means it has great potential as an animal feed.

### 9.3.3 Details on prioritized Future Smart Foods

#### Prioritized FSF 1

##### Taro (*Colocasia esculenta*)



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#### General characterization

- **Food group:** Roots and tubers.
- **Characteristics:** An annual plant that grows from a root or tuber stem.
- **Agro-ecological zone:** Taro can be grown both on wet and dry land and even in poor soil. They are often grown in swidden fields (those cleared by the slash and burn process) and are resilient to many diseases and pests. Taro has a growth cycle of around eight months.

#### Prioritized FSF 2

##### Greater yam (*Dioscorea alata*)



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#### General characterization

- **Food group:** Tubers.
- **Characteristics:** An annual plant that grows from a root or tuber stem.
- **Agro-ecological zone:** The greater yam thrives in both wet and dry land and can also be grown in poor soils. It is generally resistant to disease and blight and attracts relatively few pests.

#### Prioritized FSF 3

##### Fancy yam (*Dioscorea esculenta*)



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#### General characterization

- **Food group:** Tubers.
- **Characteristics:** It is an annual plant with edible roots.
- **Agro-ecological zone:** Like many yams, the fancy yam can be grown in wet and dry regions and in poor soil. It boasts good resistance to disease and pests.

**Prioritized FSF 4****Rice bean** (*Vigna umbellata*)

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**General characterization**

- **Food group:** Pulses.
- **Characteristics:** There is wide diversity in cultivated types of rice bean in terms of vine, shrub type, pod and seed size, and seed colour.
- **Agro-ecological zone:** Rice bean easily adapts to various soil types and weather conditions. As a cover crop, rice bean can help protect against soil erosion and can be grown in integrated systems with other crops such as corn.

**Prioritized FSF 5****Cowpea** (*Vigna unguiculata*)© Shutterstock/Vergani  
Fotografia

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**General characterization**

- **Food Group:** Pulses.
- **Characteristics:** Cowpea comes in wide variety in terms of shrub type, pod and seed size and seed colour.
- **Agro-ecological zone:** Cowpea is widely adapted to various soil types and conditions including the poor soils often found in drier regions.

**Prioritized FSF 6****Sword bean** (*Canavalia gladiate*)

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© Shutterstock/Peingjai  
Chiangmai**General characterization**

- **Food Group:** Pulses.
- **Characteristics:** Sword bean is a perennial legume mainly cultivated as an annual. It has a vigorous climbing or trailing habit and can be up to 10 m long. Its stems are woody. The leaves are alternate, large, trifoliolate. The fruits are long (20-40 cm), straight, rough-surfaced and slightly compressed dehiscent pods containing 8 to 16 seeds. The seeds are 1.5-3.5 cm -1.5-2 cm, oblong-ellipsoid in shape and very variable in colour.
- **Agro-ecological zone:** Sword bean adapts widely to various soil types and weather conditions in Lao PDR, including drier regions with poor soil. It is a good source of protein and vitamins, and can help to improve soil fertility. It grows in the warmer season and can be intercropped or rotated with other crops.

**9.4 Conclusion and recommendations**

Lao PDR is rich in plant species and genetic diversity. FSF have been chosen with a view to fighting malnutrition, and increasing household income and food security. FSF could also be introduced to improve agricultural diversification and sustainable development policies to help Lao PDR adapt to climate change.

The criteria that need to be considered regarding FSF selection are nutritional value (food composition and high nutrition), social value, (local acceptability especially for children), knowledge, (about processing these new crops), agricultural value (seed availability, knowledge on agronomy and environment requirements), and the commercial market value of FSF crops, including quality, access to markets and demand.

However, there currently is not much information about some FSF crops, particularly in regard to processing, marketing and research, as well as germplasm collection and crop improvement. Much of the knowledge in Lao PDR is indigenous and is passed on by word of mouth, often from generation to generation. This means that potentially vital information is scattered and unsystematic. In addition, many of the targeted FSF crops are not currently in demand. It is vital that they are promoted as future cash crops. This means improving cropping systems, seed processing and marketing.

The challenges facing FSF crops selected for research include the lack of resources and investment as well as limited human-resource capacity. As these crops are not yet regarded as commodity crops, there is little private backing for development. The establishment of nationally coordinated research and development programmes, which look at high-potential FSF crops and collect data and statistics and encourage consumption, should be a prime government aim.

There needs to be more investment in FSF in Lao PDR to ensure food nutritional security and safety. Multi-sector collaboration and partnerships at local and national levels between academics, farmers, civil society and the private sector is vital. This will enhance research and investment into FSF crops and products, and ensure more consumption as people become aware of the economic and nutritional value of these crops.

Documentation and case studies are needed to look into selected FSF in Lao PDR. It is important that all indigenous knowledge is collected and that the health benefits and climate resistance advantages of these crops are promoted to farmers and the public as well as traders, health professionals and researchers. This will mean preparing a range of informative educational materials. In addition, value-chain development for specific FSF crops needs to be established with increased funds for research, development and processing technologies.

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# 10 Myanmar

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## 10.1 Introduction

### 10.1.1 About the country

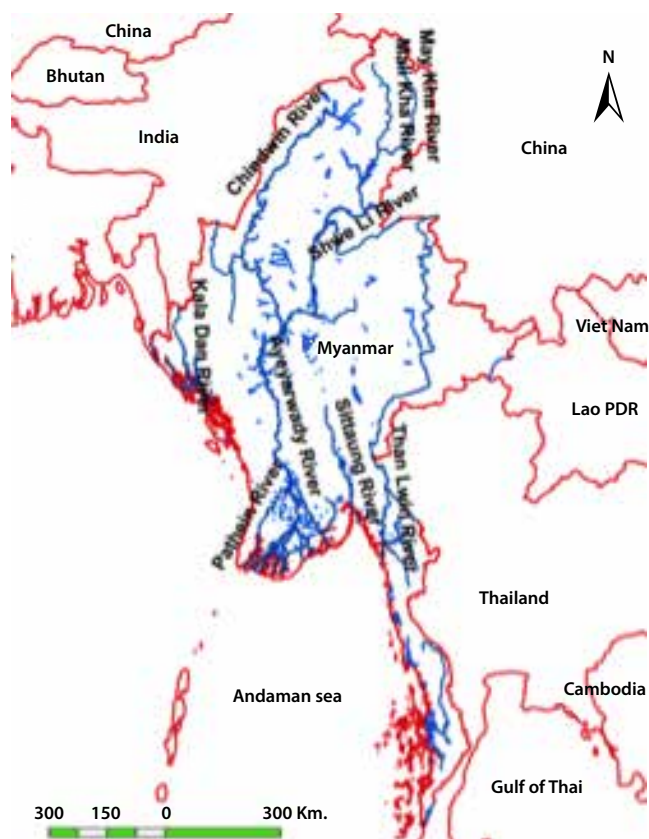
Myanmar is the largest country in mainland Southeast Asia with a total land area of 676 577 sq km, and is located between latitude 9° 32' and 28° 31' north and longitude 92° 10' and 101° 11' east. Myanmar shares borders with China, Lao PDR, Thailand, India and Bangladesh. Its estimated length is approximately 2 100 km from north to south while its width is 925 km from east to west. The population of Myanmar in 2014 was 51 701 000 with a population density of 76 people per sq km (DOP, 2015). The physical geography of Myanmar is structurally complex and diverse, having a topography of steeper mountain ranges, upland plateaus and hill valleys in the eastern, northern and northwestern regions. The undulated central dry zone is surrounded by the western coastal range and lowland

deltaic region in the lower part of the country and a narrow coastal strip is formed further south adjoining with peninsular Thailand. From the north to south, there are four major rivers: the Ayeyarwady, Chindwin, Sittaung and Thanlwin which are associated with the complex terrain formed by the large drainage systems and their wider tributary networks (NBSAP, 2011).

### 10.1.2 Agro-ecological zones

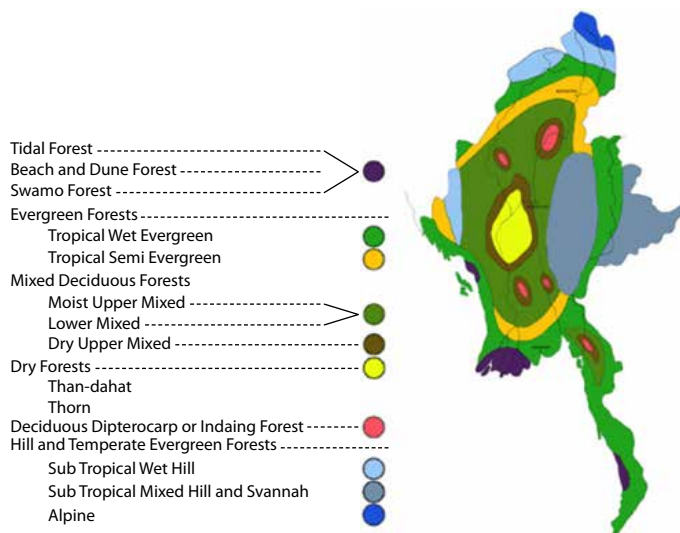
As part of the eastern Himalayan mountain range, the Hkakaborazi snow-capped mountain is located in the far north of the country with an altitude of 5 881 m and is considered to be the highest mountain in Myanmar and Southeast Asia. From the mouth of the Naff river in the far west to the southernmost point of Victoria Island, a long coastal line facing the Bay of Bengal and Andaman Sea forms 2 832 km of coastline. Other than

FIGURE 10.1 Major rivers of Myanmar



Source: Myanmar Information Management Unit

FIGURE 10.2 Major vegetation types of Myanmar



Source: NBSAP 2011

the highest uplands in the far north of the country, the climate of Myanmar may practically be classified as tropical monsoonal, although important regional variations occur within that overall category. Throughout the year, three seasons are defined; the dry (summer), the wet (monsoon) and the cooler season. Seasonally, temperatures in most parts of the country range between 32 °C and 38 °C during the dry season, 25 °C and 35 °C during the rainy season and 10 °C and 25 °C during the cooler season. Average annual rainfall is as high as 2 500 mm in some parts of the country, particularly in coastal regions but can be as low as 500 mm in the central dry zone.

### 10.1.3 Status of Myanmar’s food basket: the composition of crops, including staples

Myanmar boasts numerous agricultural resources with the Ayeyarwady Delta being the country’s rice bowl, while the plain and central dry zone areas are well known for production of oil and some other crops. The long coastal strip is perfect for plantation crops and fruit trees. As an agriculture-based country, more than 70 percent of the Myanmar people live in rural areas and rely on agriculture for their employment, income and livelihoods. Myanmar has diverse agro-ecosystems (Table 10.1) and offers high diversity of crops and useful plant species.

Rice is staple food and major crop, and Myanmar grows surplus rice for export. Other important food crops are fruits and vegetables, food legumes, maize, oilseeds, sugarcane and wheat. In the fiscal year 2014/15, the sown area under various crops was 21.37 million ha (Table 10.2). Mixed and multiple cropping areas

accounted for 13.36 million ha and 8.01 million ha, respectively. So, the cropping intensity percentage for the year 2014/15 was 159.9 percent.

Myanmar is one of the major pea and bean exporting countries in the world. However, the gap between production and demand is large, and this is one of the factors contributing to hidden hunger in the country. The crop areas and their production can be seen in Table 10.3.

Due to an increase in population and a decrease in cultivable land, food supply in the future will impact food security and food safety. Therefore, intensive cultivation of NUS is being examined as one of the solutions to food insecurity and malnutrition. NUS crops can be targeted to grow in adverse climatic conditions and should be considered as Myanmar’s FSF.

### 10.1.4 Major cropping patterns and diversity of crop species

Because of the wide variation in latitude, altitude and climates within the country, Myanmar supports a high diversity of habitats, and is rich in plant species. The country is located at the convergence of four major floristic regions: the Indian, Malesian (Sundaic), Sino-Himalayan and Indochinese. To date, more than 18 000 plant species have been recorded in Myanmar. However, there are huge research and information gaps for many species. More than 100 species of crops and their wild relatives are conserved in the Myanmar Seed Bank (Table 10.4). But, many local species are neglected and underutilized because planters see them as being less important than staple major crops. Although neglected, these underutilized species are potentially

**TABLE 10.1** Major agro-ecological zones of Myanmar (NBSAP 2011)

Name	Geographical description	Administrative unit	Crop
<b>A Bago, Kachin river-side land</b>	Upper Delta, Kachin plain, flat plain along the side of river Ayeyarwady and Sittaung, moderate rainfall 1 000 mm - 2 000 mm	Ayeyarwady, Sagaing, Mandalay, Bago Regions and Kachin State	Rice, pulses, oilseeds, cereals, sugarcane, jute
<b>B Central dry zone</b>	Central dry zone, rainfall less than 1 000 mm, high temperature in summer, flat plain, some areas with uneven topography	Magway, Mandalay, and Sagaing Regions	Oilseeds, pulses, cotton, other minor crops, irrigated rice
<b>C Delta and coastal lowland</b>	Delta, lowland and mouth of rivers in coastal area, heavy rainfall (over 2 500 mm)	Ayeyarwady, Yangon, Bago Taninthayi Regions, Mon, Kayin, and Rakhine States	Rice, pulses, oilseeds and Nipa palm, plantation crops
<b>D Kachin and coastal upland</b>	Mountainous, slope land, heavy rainfall (over 2 500 mm)	Kachin State, Rakhine State, Taninthayi Region, Mon State, Kayin State, Kayah State, Yangon Region and Bago Region	Orchard, plantation crops, fruit trees and other upland crops
<b>E North, East and West hills</b>	Hilly areas, uneven topography, moderate to heavy rainfall, slope land	Kachin, Chin and Shan States	Upland crops, several crop species in shifting cultivation and fruit trees
<b>F Upper, lower Myanmar and Shan plain</b>	Plain, upper and lower parts outside of central dry zone, plateau	Kachin and Shan State, Sagaing, Bago, Magway, Mandalay and Yangon Regions	Upland crops, oilseeds, pulses, vegetable and wheat

**TABLE 10.2** Sown area of crop group in 2014-2015 FY in Myanmar (DOP 2015)

Sr. No.	Crop group	Sown area ('000 ha)
1	Cereal crop	8 357
2	Oilseed crop	3 461
3	Pulse crop	4 554
4	Industrial crop	1 269
5	Culinary crop	350
6	Other	3 379
	<b>Total</b>	<b>21 370</b>

**PHOTO 10.1** Crop diversity from mixed cropping of traditional shifting cultivation offers a variety of new food options

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**TABLE 10.3** Sown area and production of some major crops in 2014-2015 FY in Myanmar

Sr. No.	Crop	Sown area ('000 ha)	Production ('000 mt)
1	Paddy	7 172	28 193
2	Wheat	99	185
3	Maize	459	1 721
4	Black gram	1 098	1 580
5	Green gram	1 173	1 536
6	Butter bean	64	86
7	Soy bean	151	229
8	Chickpea	378	580
9	Pigeon pea	619	841
10	Garden pea	54	71
11	Groundnut	949	1 525
12	Sesame	1 581	930
13	Sunflower	484	473
14	Oil palm	153	145
15	Sugarcane	181	11 307
16	Chili (dried)	112	123
17	Onion	78	1 265
18	Garlic	28	212
19	Potato	37	551

Source: Department of Agricultural Land Management and Statistics, MOALI

**TABLE 10.4** *Ex situ* conservation of crops and wild relatives in Myanmar Seed Bank, March, 2017

Sr. No.	Crop group	No. accession
1	Rice	7 757
2	Wild rice	180
3	Cereal	2 233
4	Oilseed	797
5	Pulse	1 578
6	Other	125
	<b>Total</b>	<b>12 670</b>

Source: Annual report of Myanmar Seed Bank (2016-2017)

a source of vitamins and micronutrients, and can be of high nutritional value. From the standpoint of the rural poor who depend on many of these species for food security, nutrition and incomes, the varieties are possible

FSFs. Therefore, scoping the availability of FSF, prioritizing and identifying those with high potential, and mapping the selected species for further development will become crucial in the near future.

## 10.2 Situation and gap analysis

### 10.2.1 Hunger and malnutrition

Hunger, food insecurity and malnutrition are major problems in many Asian countries including Myanmar. Agriculture and nutrition are strongly linked, and crop diversification serving sustainable agriculture can help diversify diets to reduce hunger and malnutrition. Despite most household expenditure being food related, dietary quality in Myanmar remains poor, with many people's diets being low on protein and vitamins and high in carbohydrates. Myanmar is making significant efforts to address the nutrition situation, and the country entered the global Scaling Up Nutrition movement in May 2013. Regarding dietary energy supply (DES) from 1990 to 2011, vegetable products increased 14 percent and remained the major DES source. Cereals remain the most important source of food energy (50 percent), but their contribution to overall DES has decreased. Consumption of animal products such as meat, milk and eggs has increased notably in recent years. Use of vegetable oils has also increased by 52 percent and this is also a significant contributor to DES.

As in much of Southeast Asia, the diet in Myanmar is rice based. Indeed, rice makes up 92 percent of cereals consumed, while cereals themselves represent 52 percent of the total food intake. When general inflation is taken into account, families spend more than 70 percent of their income on food. Food diversity is important for supplying micro-elements, protein and vitamins. According to FAO 2014, anaemia is a severe public health issue in Myanmar, with extremely high levels found among pregnant women (71 percent), and children under five (75 percent). It is also high among non-pregnant women (45 percent). Levels of stunting and underweight are more than twice as common among people in the poorest quintile as in the wealthiest. Severely high rates of vitamin A deficiencies (37 percent of preschoolers) indicate that vitamin A is generally lacking in the daily diet. Iron deficiency is also a considerable problem among children and women. This comes at a cost. Myanmar loses approximately USD 400 million annually from its GDP because of undernutrition (World Bank, 2010). It is clear that the lack of diversity in the food supply still plays a major role in Myanmar's high levels of malnutrition.

### 10.2.2 Climate change constraints

There are three seasons in Myanmar: summer (February-May), rainy season (June-September) and cold (October-January). As a result of the great variation in rainfall and temperature, the complex river systems and

topography, Myanmar offers several types of ecosystem: forest, mountain, dry and sub-humid land, estuarine mangroves, inland fresh water, grassland, marine and coastal as well as small island ecosystems. Among the ecosystems, forests are considered to be integral for stability of the environment in Myanmar. Although nearly half of Myanmar's total land area is forest (FAO, 2010), most forests are degraded. Forest cover in 1990 was 58.0 percent of total land area and it was reduced to 51.5 percent in 2000, 49.2 percent in 2005 and 47.0 percent in 2010.

Myanmar is likely to be faced with rising temperatures in several areas. According to a climate scenario analysis carried out as an initial national communication project under the UNFCCC, temperatures are going to increase by more than 1 °C in most parts of the country within the next 30 years. This change will affect agriculture, forestry, biodiversity and water resources, as well as contribute to natural disasters and have an impact on human health. In 2008, Cyclone Nargis hit lower Myanmar and many people were killed. Mangrove forests on the coast were also severely affected and biological balance in some areas was destroyed. Another result of this disaster was that the local rat population significantly increased and the damage of paddies by rat infestation further aggravated food insecurity in storm-affected villages.

Annual rainfall varies from 500 mm to 2 500 mm but if climate change affects precipitation it could change in the duration of the rainy season. A shorter or longer rainy period can affect crop productivity by causing droughts in some places and floods in others. A wide range of management options can be adopted for adapting agriculture to climatic variability and climate change. Crop diversification (inclusive of FSF in cropping patterns), and development of crop varieties tolerant to biotic and abiotic are possible interventions that can be made to ensure climate resiliency.

### 10.2.3 Market and economic constraints

Myanmar's leaders aim to attain food security for domestic consumption and higher nutritional values, to double the income of farmers and to improve their socio-economic status. There is also a goal to improve the quality and standards of agricultural products so that they can be sold in international markets. However, Myanmar does not have a well-organized marketing system for farm products. Harvested produce that is sold tends to fetch low prices. Farmers sell their produce at primary markets and only occasionally to secondary markets. The primary markets are located on average up to 10 km from the farms and have to be reached

TABLE 10.5 List of selected FSF crops in Myanmar

Sr. No	Common name	Scientific name	Group	Adaption	Crop nature
1	Aromatic rice	<i>Oryza sativa</i> L.	Cereals	Tropical	Annual
2	Specialty rice (Namathalay)	<i>Oryza sativa</i> L.	Cereals	Tropical	Annual
3	Sorghum	<i>Sorghum bicolor</i> (L.) Moench.	Cereals	Sub-tropical	Annual
4	Jack fruit	<i>Artocarpus heterophyllus</i> Lam.	Fruits	Tropical	Perennial
5	Custard apple	<i>Annona squamosa</i> L.	Fruits	Sub-tropical	Perennial
6	Wood apple	<i>Limonia acidissima</i> / <i>Ferronia elephantum</i>	Fruits	Sub-tropical	Perennial
7	Drumstick	<i>Moringa oleifera</i> Lam	Fruits	Sub-tropical	Perennial
8	Amla	<i>Phyllanthus emblica</i> L.	Fruits	Sub-tropical	Perennial
9	Cowpea	<i>Vigna unguiculata</i> (L.) Walp.	Pulses	Sub-tropical	Annual
10	Green gram	<i>Vigna radiata</i> (L.) R. Wilczek.	Pulses	Sub-tropical	Annual
11	Lablab bean	<i>Dolichos lablab</i> L.	Pulses	Sub-tropical	Annual
12	Sesame	<i>Sesamum indicum</i> L.	Oil seed	Sub-tropical	Annual
13	Groundnut	<i>Arachis hypogaea</i> L.	Oil seed	Sub-tropical	Annual
14	Sweet potato	<i>Ipomoea batatas</i> (L.) Lam.	Root/tuber	Sub-tropical	Annual
15	Cassava	<i>Manihot esculenta</i> Crantz.	Root/tuber	Tropical	Annual
16	Elephant foot yam	<i>Amorphophalus campanulatus</i> (Roxb) Bl.ex decne.	Root/tuber	Tropical	Annual
17	Bottle gourd	<i>Lagenaria siceraria</i> (Molina) Standley.	Vegetables	Sub-tropical	Annual
18	Roselle	<i>Hibiscus sabdariffa</i> L.	Leafy vegetable	Sub-tropical	Annual

using different means of transportation. There are other constraints for producers including weak links between farmers and consumers, the lack of a credit system, high transportation costs, no storage facilities, lack of market information and on-going price instability.

#### 10.2.4 Cultural relevance

Some plants and crop species in Myanmar have great cultural value. Among the proposed FSF crops, specialty rice (*Oryza sativa* L.), sometimes called *Namathalay*, is the most important to local people. This strain of rice has fine grains (two and half times smaller than normal rice). It has been cultivated in Myanmar for centuries, and, traditionally, farmers who grew it would first offer it to the king for feasting and then to the monks, before they could consume it themselves. As the grains are small, this rice is easy to digest and so is suitable for older people and children.

Another FSF crop that is culturally important is the Amla or Burmese gooseberry (*Phyllanthus embilica*), which is traditionally believed to repel snakes. The Drumstick tree (*Moringa oleifera*) has a range of traditional and pharmacological uses and can also be used for forage for livestock (Olson, 2002).

### 10.3 Scoping and prioritization of Future Smart Food

#### 10.3.1 Scoping and availability of FSF

After an examination of their agricultural importance, nutritional value, economic importance, public acceptance and scope of intervention, the following FSF crops (Table 10.5) have been selected in Myanmar.

**PHOTO 10.2** Specialty rice, *Namathalay*, is an ancient rice and easy to digest



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**PHOTO 10.3** Sorghum is a promising for food, feed, fodder and climate resilient crop



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### 10.3.2 Priority FSF in Myanmar

#### Cereals

**Specialty rice** (*Oryza sativa* L.), *Namathalay*: This rice is easy to digest and so suitable for older people and the ill to whom it is often marketed. It has abiotic stress tolerance ability and can thrive in waterlogged areas where many modern rice varieties cannot be grown. As the rice does not require much nitrogen fertilizer, it is considered a more environmentally friendly crop.

**Sorghum** (*Sorghum bicolor*): Sorghum as a semi-arid crop is an important crop and forage food in the central dry zone in Myanmar where there is limited pasture. Its sown area in 2014 was 226 000 ha (DAP 2014).

#### Roots and tubers

**Elephant foot yam** (*Amorphophallus campanulatus*): Called *Wa-U* in Myanmar, the yam is an indigenous plant found around the country and is often raised as a cash crop. Wild plants tend to prefer heavy soils, in the forest or towards the edge of forests on lowlands. Many edible forms are simply picked wild rather than grown in homes or on farms. To evaluate its use as FSF, this species needs to be studied to assess its germplasm and growing characteristics.

#### Horticulture

**Roselle** (*Hibiscus sabdariffa*): Roselle is likely to be native to Myanmar as it is often mentioned in works of ancient Burmese literature. Known locally as *Chin Paung*, roselle is generally cultivated in market gardens near big towns and in homesteads in rural areas. It can be procured at a cheap price everywhere. The leaves are generally eaten as vegetables and the calyx is used in cooking and to prepare a form of local jam. Exactly how much roselle is grown in Myanmar is unknown, but it's a major source of vitamin C for urban and rural people.



Nutrient composition (per 100 g of edible fresh weight)

Cereal	Water (g)	Energy (kcal)	Protein (g)	Fat (g)	CHO (g)	Crude Fibre (g)	Ash (g)	Ca (mg)	Fe (mg)	Mg (mg)	P (mg)
Sorghum	12.4	329.0	10.62	3.5	72.1	6.7	NA	13	3.36	165	289
Specialty rice	35.4	11.7	6.80	0.7	79.7	0.6	0.5	19	1.20	–	105

Cereal	K (mg)	Na (mg)	Zn (mg)	Cu (mg)	Vit. E (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B3 (mg)	Vit. B6 (mg)	Folate (µg)
Sorghum	363	2	1.67	NA	0.5	0.332	0.096	3.688	0.443	20
Specialty rice	71	27	0.50	0.1	–	0.100	0.040	2.600	–	–

PHOTO 10.4 Elephant foot yam, plant and tuber



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Nutrient composition of elephant foot yam (per 100 g of edible fresh weight)

Root and tuber	Protein (g)	Fat (g)	CHO (g)	Crude fibre (g)	Ash (g)
Elephant foot yam	12.5	0.98	75.2	3.67	4.42

PHOTO 10.5 Roselle, an underutilized leafy vegetable in Myanmar



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Nutrient composition (per 100 g of edible fresh weight)

Horticulture	Water (g)	Energy (kcal)	Protein (g)	Fat (g)	CHO (g)	Ash (g)	Ca (mg)	P (mg)	$\beta$ carotene ( $\mu$ g)	Vit. C (mg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B3 (mg)
Roselle	85.6	57	1.7	0.1	12.4	0.2	9	4	797	44	0.11	0.24	4.5

**PHOTO 10.6** Drumstick is used for food and medicinal purposes



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**Drumstick** (*Moringa oleifera*): Drumstick is a fast-growing plant with a high fruit production and has been cultivated in Myanmar since ancient times. The tender fruits are eaten in curry and the young leaves are added to soup for flavour. The leaves are also said to lower blood pressure (Watanabe, 1999). Although the area under cultivation for drumstick has not been surveyed, the plant grows in all states and in all regions of the country.

Drumstick is an important food which is eaten all over the tropics and sub-tropics (Opare-Obuobi, 2012). It is rich in the macronutrients and micronutrients that are essential for health and daily nutrition (Anwar *et al.*, 2007). The nutritional composition of drumstick compares satisfactorily with other crops, such as beans, cassava leaves, cowpea, maranth leaves, pumpkin leaves, turnip and even essential nutrients from other non-plant sources (CSIR, 1962; Palmer and Pitman, 1972; Maroyi, 2006). As there is a problem with malnutrition in Myanmar, drumstick could be a good potential source of calcium, phosphorus, potassium, protein and vitamins.

In addition, the seeds have been shown to be an effective primary coagulant for water treatment in rural communities.

Despite the clear benefits of drumstick as a crop, there has not been much research into this plant and information about its properties is scarce in Myanmar. So work needs to be done to help conserve plant stocks and use the germplasms.

The plant thrives in the humid tropics or hot dry lands and can survive in poor destitute soils and drought conditions. Drumstick also does well in wet conditions and can cope with rainfall from 250 mm to over 3 000 mm and a pH range of 5-9 (Palada and Chang, 2003). Propagation is carried out via seed planting or by taking cuttings. (Saini *et al.*, 2012).

**Amla or Burmese gooseberry** (*Phyllanthus emblica* or *Emblia officinalis*): Known locally as *Zee Phyuthis*, this fruit is a rich source of natural ascorbic acid (Thu, 2015) and is a good source of vitamin C for the rural poor. In Thailand such embolic myrobalan fruits are traditionally

Nutrient composition of Drumstick (per 100 g of edible fresh weight)

Material status	Moisture (%)	Calories (Kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Fibre (g)
Pod	86.8	26	2.5	0.1	3.7	4.8
Fresh leaves	75.0	92	6.7	1.7	13.4	0.9
Dried leaves	7.5	205	27.1	2.3	38.2	19.2

Source: <http://www.edlagman.com/moringa/moringa-fresh-leaf-vs-dried-leaf.pdf>

PHOTO 10.7 Amla or Burmese gooseberry, *Zee Phyu*



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Nutrient composition (per 100 g of edible fresh weight)

Other	Water (g)	Energy (kcal)	Protein (g)	Fat (g)	CHO (g)	Crude Fibre (g)	Ash (g)	Ca (mg)	Fe (mg)	P (mg)	βcarotene equ. (µg)	Vit. C (mg)	Vit. B1 (mg)	Vit. B3 (mg)
Amla	82.2	66	0.38	0.1	14.82	2.1	0.4	18	0.5	4	21	243	0.02	0.8

used as an expectorants and for their antipyretic, diuretic, antidiarrheal and antiscurvy properties (Subhadrabambhu, 2001). It is rarely cultivated in orchard gardens and most people gather it as a wild crop. However, the species' natural habitat in Myanmar's tropical forest is threatened due to ongoing deforestation.

### 10.3.3 Prioritization analysis

#### Cereal

Rice is a national crop and staple food in Myanmar where it is often eaten three times a day in rural areas. Specialty rice or *Namathalay* is no longer a mainstay crop but some farmers want to reintroduce it using seeds from the Myanmar Seed Bank, as it could fetch a premium price due to its high quality and close associations with Burmese culture.

There are a variety of cereal crops grown in Myanmar, including maize, sorghum and wheat, as well as minor cereals like adlay millet, finger millet, foxtail millet, little millet and pearl millet. Sorghum is seen as an important FSF as it could adapt well to climate change, and can be used as both food for humans and feed for animals in the dry zones of Myanmar. However, sorghum could face problems with degradation by out-crossing and some negative effects of mutation may already occur in the existing varieties. Therefore, outstanding varieties are needed.

**TABLE 10.6** Priority for improving some of the target FSF in Myanmar

Group	Crop	Possible intervention
<b>FSF</b>	To be FSF species	Inventory, preparing checklists, etc.
<b>Cereal</b>	1) Specialty rice 2) Sorghum	1) Evaluation of conserved collection and reintroduction to farmers, and market improvement 2) Participatory varietal selection
<b>Roots and tuber</b>	Elephant foot yam	Germplasm collection and identifying promising genotypes
<b>Horticulture</b>	1) Roselle 2) Drumstick	1) Varietal improvement 2) Incorporating the crop into homestead and improving processing, value added, etc.
<b>Others</b>	Amla	Domestication and pilot establishment of orchards

### Roots and tubers

Casava, sweet potato, taro, winged beans and yam are all grown in Myanmar. Elephant foot yam is a rich source of starch, vitamins and minerals. It is usually collected as a wild food from the forest and eaten domestically or exported as a raw tuber. There is a worry that over exploitation could mean that elephant foot yam becomes an endangered species. Therefore, domestication and identification of elite genotypes for cultivation as a FSF becomes crucial.

### Horticulture

Roselle is a local plant most often grown in kitchen gardens and is a great source of vitamin C for both urban and rural people in Myanmar.

Based on the need to prioritize FSF in Myanmar, possible interventions are as shown in Table 10.6.

## 10.4 Conclusion

Dietary quality in Myanmar remains poor. The diet is low on protein and vitamins, with too much emphasis on consumption of high carbohydrates. Most household expenditures are related to food. Poor diet quality has contributed to high levels of stunting and underweight, along with high levels of anaemia, iodine and vitamin A deficiencies. In addition, a lack of diversity in the food supply also plays a large role in the country's malnutrition problems.

Myanmar is rich in useful plant species and crops. Some species, which are currently neglected and underutilized can help to bring more diversification to diets and help to fight hunger and malnutrition. These FSFs will also benefit agriculture in Myanmar as a whole by helping prepare for climate change, and through their contributions to the country's culture and socio-economic status.

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# 11 Nepal

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## 11.1 Introduction

### 11.1.1 About the country

Nepal is situated from 26° 22' N to 30° 27' N and 80° 04' E to 88° 12' E and covers 141 181 sq km. The country is divided into five physiographic zones extending from east to west: High Himalaya, High Mountain (or High Hill), Middle Mountain (or Mid Hill), Siwalik and Lower Belt (*Tarai*) (Figure 11.1). The altitude ranges from 60 m above sea level in the *Tarai* plain to up 8 848 m at the peak of Mount Everest. The climate of Nepal is mainly characterized by altitude, topography and seasonal atmospheric circulations. As a result, climate types range from tropical to alpine in a south-north span of about 200 km.

The High Himalaya zone lies above 5 000 m in the northernmost part of the country and has a dry climate and winter snowfall. Above 5 500 m, the Himalayas are covered with perpetual snow with no tree vegetation. This area includes some dry inner-Himalayan valleys and treeless plateaus (such as the Dolpa, Manang and Mustang districts). The High Mountain zone is characterized by high steep slopes and deep gorges comprising subalpine and alpine climates and the associated vegetation types. The Middle Mountain region is physiographically the most diverse and has a subtropical to temperate monsoon climate. The Siwalik zone mainly comprises steep hills of unstable geomorphology. This region also provides ecosystem services, for example, prevention of soil erosion, the recharging of groundwater, and contributes to

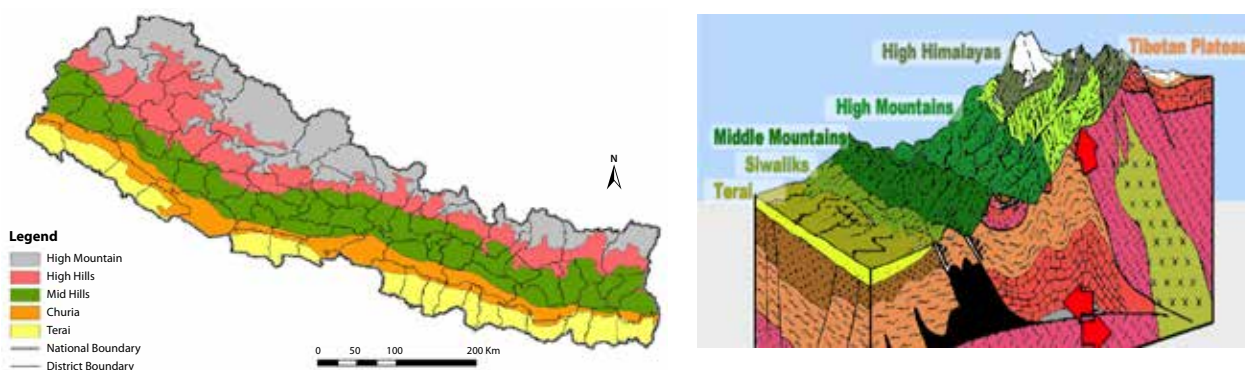
preventing natural disasters such as flash floods.

The *Tarai* comprises a narrow belt of flat and fertile land in the southernmost region of the country with an elevation below 500 m. Soil types found in Nepal range from alluvial and fine-to-medium textured in the *Tarai*, sedimentary rocks with a sandy texture in the Siwalik, medium-to-light textured with a predominance of coarse-grained sand and gravel in the mid-hill to shallow, and stony and glacial in the High Mountain zone (MoFSC, 2002).

### 11.1.2 Agro-ecological zones

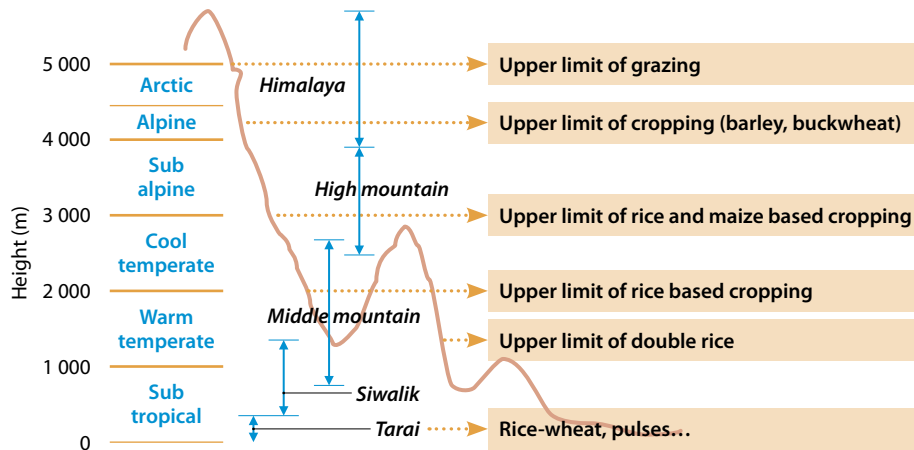
Nepal has a high degree of agro-ecological diversity, particularly in the hills and mountains owing to variations in topography, slope, aspect and altitude that allow for a range of biological environments, climatic regimes and varied ecosystems. Agricultural land and forests occupy about 30 percent and 39 percent, respectively, of the total geographical area of the country (Uddin *et al.*, 2015). Three major agro-ecological belts: High Hill, Mid Hill and *Tarai* occupy 43 percent, 45 percent and 12 percent of the agricultural area, respectively (Uddin *et al.*, 2015). There are four seasons in Nepal: pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February). The average annual rainfall is about 1 600 mm, but total rainfall differs in each eco-climatic zone. The north-central part near the Tibetan plateau records the lowest levels of rainfall of above 250 mm, while the southern slopes of the Annapurna range in central Nepal record the highest

FIGURE 11.1 Physiographic zones and topographical cross-section of Nepal



Source: WWF 2005



**FIGURE 11.2** The diversity of agroecological zones and farming systems in Nepal

Source: Joshi (2017b)

**TABLE 11.1** Crops grown in different agroecological zones of Nepal

Ecological region	Climate	Altitude (m)	Annual rainfall (mm)	Crops/livestock
<b>High Himalaya</b>	Arctic	Over 5 000	Snow	No tree vegetation, dry inner-Himalayan valleys
<b>High Hill</b>	Sub alpine and cold climate	2 000-5 000	150-200	<i>Agro-pastoral</i> : Almond, apple, apricot, barley, buckwheat, pear, plum, potato, radish walnut; sheep and yaks
<b>Mid Hill</b>	Cool temperate and sub tropical	1 000-2 000	275-2 300	<i>Agro-pastoral</i> : Sheep and yaks, potato, buckwheat, barley, apple, walnut, almond, pear, plum, apricot, radish <i>Gentle slopes and mountain valleys</i> : Apple, cardamom, citrus, ginger, potato, tea and vegetables <i>Steep highland/hillslope forests</i> : Maize, millet, mustard, pear, plum, potato, wheat; buffalo, cattle and goats <i>Fertile terrace, river basin, valleys and flat plains</i> : Banana, cauliflower, cucumber, coriander, eggplant, garlic, guava, ladies finger, mango, onion, papaya, persimmon and rice
<b>Siwalik</b>	Tropical	500-1 000	1 100-3 000	<i>Fertile river basin, valleys and flat plains</i> : Banana, coriander, eggplant, garlic, grape, guava, jackfruit, ladies finger, lentils, litchi, mango, mustard, onion, papaya, pineapple, potato, rice, tomato, wheat; buffalo, cattle and goat
<b>Lower belt</b>		Over 500		

Source: MoFSC 2002, 2014, Gauchan and Yokohama 1999, Upadhyay and Joshi 2003.

with around 5 000 mm. About 80 percent of precipitation falls in the summer monsoon during June-September (NARC and AFACI, 2016). Temperatures vary with topography in a south-north direction, decreasing from south to north (Figure 11.2). In *Tarai* regions the average maximum and minimum temperatures range from 7-23°C in winter to as high as 40°C in summer. In the Middle Mountain region, average temperatures range from 12-16°C (MoFSC, 2002). In general, for every 100 m rise in altitude, the mean annual temperature drops by 0.5°C.

A huge range of food crops can be grown in Nepal due to its varied agro-ecological zones (Table 11.1). The elevation and soil moisture availability determine the crop species and intensity of cropping systems (Figure 11.2). In the southern plain, adjacent to India, with its tropical climate, two to three crops are grown per year depending upon irrigation facilities. The cropping intensity decreases with increasing altitude.

### 11.1.3 Status of Nepal's food basket: the composition of crops, including staples

Agriculture, including forestry and fishery, is the principal economic activity in Nepal, employing about 66 percent of the population and providing 32.7 percent of the gross domestic product (GDP) and 60 percent of export earnings (ABPSD, 2015). The total cultivated area of agricultural land is 3 091 000 ha while the uncultivated area is 1 030 000 ha. According to the 2011 population census, there are 542 702 households with a total population of 26 494 504 and a population growth rate of 1.35 percent per annum. Agriculture is basically subsistence, where crops, livestock and forests are the three major components of the complex farming system (Khadka, 1987). Cereal crops, including rice, maize and wheat are the main crops, followed by lentils and potato (Table 11.2). In the lowlands, rice is the major staple crop followed by wheat, while maize is the most important food crop in the Mid Hill area (Sharma, 2001). In the High Hill area, potato is the main food crop followed by maize, buckwheat (Joshi, 2008) and barley. Rice is the major source of energy for most Nepali people. The altitude of crop cultivation ranges from 60 m (Kechana Kalan, Jhapa) to 4 700 m (Khumbu, Solukhumbu) (Joshi, 2017a). Production and productivity of the five selected FSF crop species are currently very low (Figure 11.3).

### 11.1.4 Crop diversity and major cropping patterns

Nepal's diverse agro-ecology suits a range of genetic diversity and farming systems including crops (Joshi and Gauchan 2017), cropping patterns and animal husbandry. Nepal has 790 plant species, including forage species, with food value, of which 577 are cultivated (Joshi, 2017a; MoFSC, 2002). The estimated number of crop landraces is 30 000. Diversity and food insecurity zones are indicated in Figure 11.4. Three broad groups of agricultural plant genetic resources (APGRs) are agronomic crops, horticultural crops and forage species with 64 145 and 275 known species, respectively (Figure 11.5) (Joshi *et al.*, 2017a).

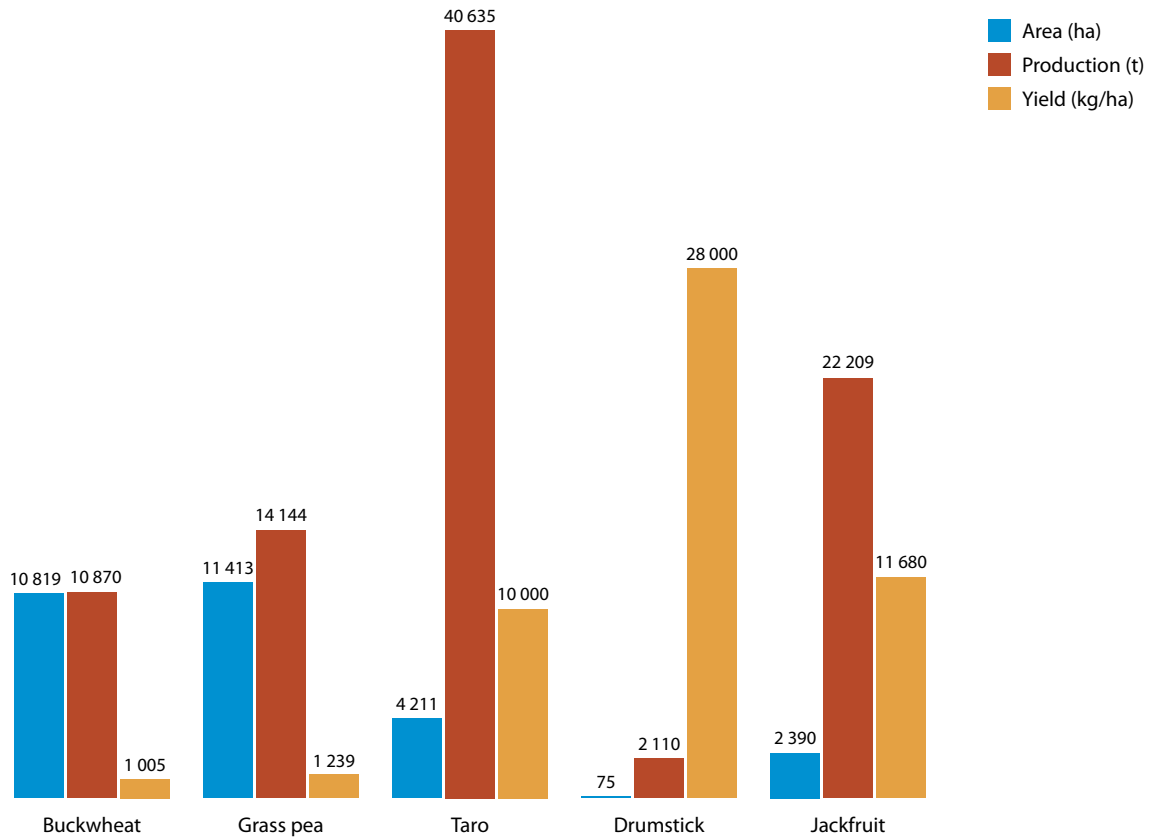
Farming systems in Nepal are based predominantly on cereal crop production to secure and sustain food security. Crops such as buckwheat, citrus, eggplant, foxtail millet, mango, rice, rice bean and underutilized food crops have a high genetic diversity that has been maintained through traditional farming systems and wild relatives in proximity (Joshi *et al.*, 2016b). Several fruit and vegetable species, with varieties including avocado, coffee, grape, macadamia nut, olive and strawberry, have been introduced into Nepal (MoFSC, 2002). A range of crop species is grown in different agro-ecological zones depending on the agro-climate (altitude, slope, aspect, topography, etc.), local food habits, and socio-economic status (Table 11.3 and Table 11.4). Some crop diversity has been conserved through various methods (Joshi *et al.*, 2016a).

**TABLE 11.2** Area and production of major crops in Nepal, 2015

Sl. No.	Crop	Area (ha)	Production (t)	Yield (kg/ha)
1	Rice	1 425 346	4 788 612	3 360
2	Maize	882 395	2 145 291	2 431
3	Millet	268 050	308 488	1 151
4	Wheat	762 373	1 975 625	2 591
5	Barley	28 053	37 354	1 332
6	Buckwheat	10 819	10 870	1 005
7	Oilseed	233 041	209 612	899
8	Potato	197 037	2 586 287	13 126
9	Lentil	204 475	227 492	1 113
10	Horse gram	6 188	5 678	918
11	Black gram	23 147	19 439	840
12	Citrus (mandarin, sweet orange, lime, and lemon)	24 236	216 125	8 918
13	Vegetables	266 937	3 580 085	31 412

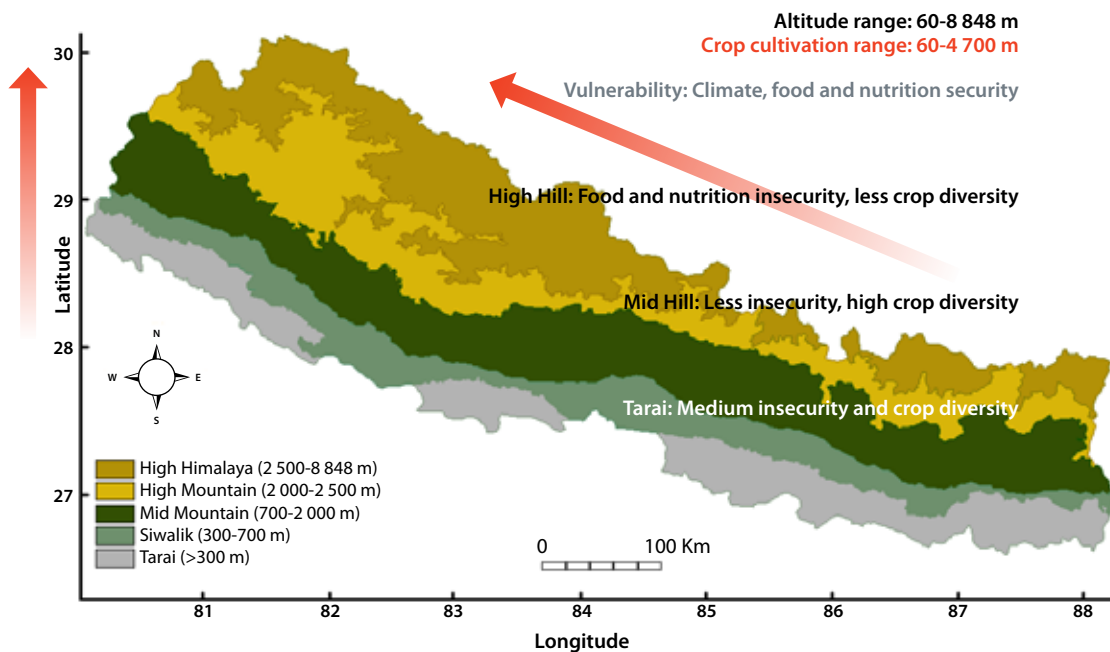
Source: ABPSD (2015).

**FIGURE 11.3** Area, production and productivity of the five major FSF crops grown in Nepal



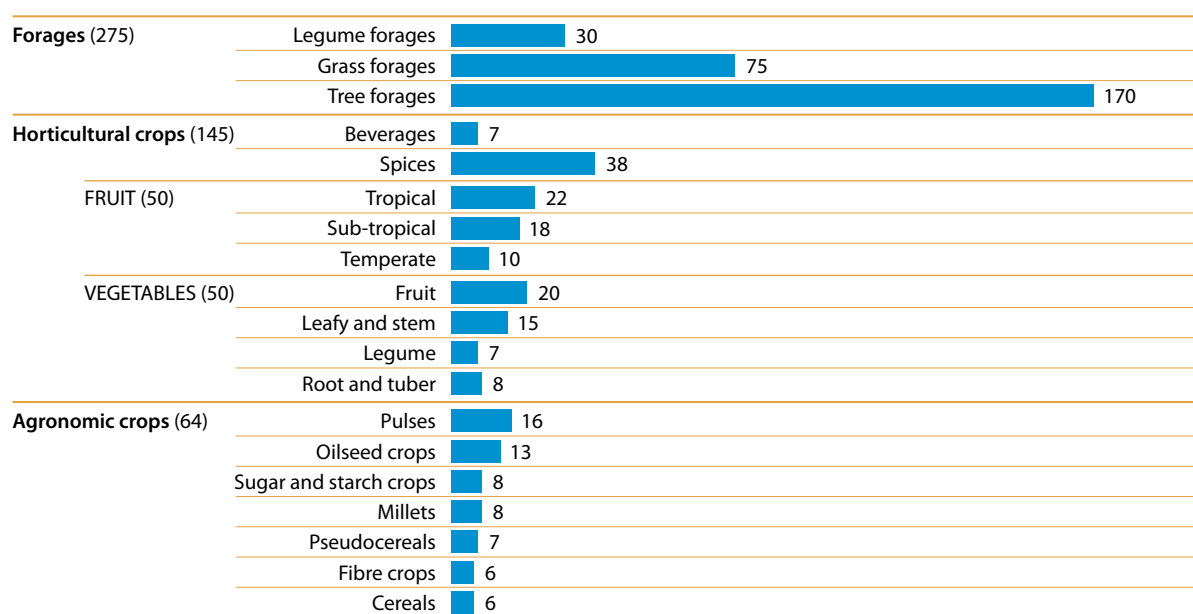
Source: MoAD 2015.

**FIGURE 11.4** Location of diversity-rich areas, and food and nutrition insecurity areas, Nepal



Source: World Food Programme

**FIGURE 11.5** The number of available species in various crop groups in Nepal (excluding ornamental plant species)



Source: Adapted from Joshi (2017a).

**TABLE 11.3** Crop diversity in selected ecological regions of Nepal

Ecological region	Climate	Crop diversity
<b>Siwalik and Tarai</b>	Hot, humid and dry	<i>Brassica</i> species, chickpea, eggplant, jackfruit, jute, kodo millet, lentil, mango, niger, okra, perilla, pigeon pea, rice, sesame, wild relatives of rice
<b>Eastern and Central Himalaya</b>	Cool and humid	Barley, black gram, <i>brassica</i> species, buckwheat, citrus fruit, field peas, finger millet, foxtail millet, maize, niger, perilla, pigeon pea, rice, sesame, soybean, wild relatives of buckwheat
<b>Western and Far-Western Himalaya</b>	Cool and dry	Amaranths, black gram, <i>brassica</i> species, buckwheat, chenopods, cold tolerant rice, field peas, maize, naked barley, niger, perilla, proso millet, radish, rice bean, sesame, soybean, walnut, wheat, wild apple, wild pear

Source: MoFSC (2002); Upadhyay and Joshi (2003).

## 11.2 Situation and gap analysis

### 11.2.1 Hunger and malnutrition

Nepal ranks 157th out of 187 countries on UNDP's Human Development Index, with 25 percent of its population living below the poverty line (Chaparro *et al.*, 2014). Slow economic growth and human development, political instability, high susceptibility to climate change, vulnerability to earthquakes, and weak governance are some of the challenges facing Nepal.

Food access and availability, healthcare, and socio-economic and political issues are the major issues that influence malnutrition in vulnerable women and children. The distribution of malnutrition varies geographically by ecological zone, and rural and urban residences. The Nepal Demographic and Health Survey (2011) reported that the prevalence of stunting and severe stunting in children less than five years old was

41 percent and 16 percent, respectively (Tiwari *et al.*, 2014). Higher rates of stunting occur in rural children (42 percent) than urban children (27 percent). The High Hill has higher rates of stunting (53 percent), wasting (11 percent) and underweight (36 percent) than the Tarai (37 percent stunting, 11 percent wasting and 29 percent underweight) and the Mid Hill (42 percent stunting, 11 percent wasting and 27 percent underweight) (Joshi, 2012). Micronutrient deficiencies are widespread, with almost half of pregnant women and children under five years old, and 35 percent of women of reproductive age being anaemic. The poorest households and prolonged breastfeeding (over 12 months) showed an increased risk of stunting and severe stunting among Nepalese children (Tiwari *et al.*, 2014). The prevalence of anaemia is high in the Tarai (50 percent), followed by 41 percent in the Hills and 48 percent in the mountains. Anaemia is also common

TABLE 11.4 Major cropping patterns in each ecological region of Nepal

Ecological region	Land type	Cropping patterns	
Tarai	Irrigated lowland	Rice–Wheat–Maize Rice–Wheat–Mung bean Rice–Potato–Vegetables Rice–Potato–Maize Rice–Potato–Potato Rice–Potato–Jute Rice–Peas–Rice	Rice–Mustard/Peas–Vegetables Rice–Rice–Wheat Rice–Rice–Maize Rice–Rice/Legumes Rice–Vegetables–Maize–Mustard–Fallow Rice–Berseem
	Rainfed	Rice–Wheat–Fallow Rice–Mustard/Peas–Fallow Rice/Lentil–Fallow Rice–Lentil+Chickpea+Linseed Rice–Sugarcane–Sugarcane (ratoon) Rice+Pigeon pea (on bunds)–Mustard or Lentil	Rice/Lathyrus+Lentil or Linseed Maize–Buckwheat–Fallow Maize+Soybean–Mustard–Fallow Maize/Finger millet–Wheat Maize+Upland rice (Ghaiya)–Wheat Maize–Wheat–Fallow Rice–Wheat+Pea
	Upland	Maize–Mustard–Fallow Maize–Lentil or Chickpea Maize–Lentil+Mustard Maize+Pigeon pea–Fallow Maize/Pigeon pea–Fallow Pigeon pea+Sesame–Fallow	Pigeonpea+Sorghum (fodder)–Fallow <i>Siwalik</i> and <i>Tar</i> (plain area in river basin zone) areas: Upland rice+Maize Sandy soils: Pigeon pea+Groundnut Light sandy soils: Groundnut–Fallow
Mid Hill	Irrigated lowland	Rice–Wheat–Maize Rice–Potato–Maize Rice–Wheat–Vegetables Rice–Lentil–Vegetables Rice–Vegetables–Rice	Rice–Wheat Rice–Barley Rice–Potato Rice–Vegetable crop Maize–Wheat Maize–Vegetable–Fallow
	Upland	Maize+Millet–Black gram–Fallow Maize–Millet–Vegetables Maize/Finger millet–Fallow Maize+Legumes–Potato–Fallow Maize+Upland rice–Vegetables–Fallow Maize–Black gram+Niger Upland rice–Legumes–Fallow Upland rice–Black gram Maize+Ginger–Fallow Maize+Soybean–Mustard/Fallow Maize–Wheat	Maize+Upland rice–Wheat or Lentil or Fallow Maize+Soybean–Mustard Potato–Fallow Maize+Potato–Winter crops Maize/Potato–Fallow Maize/Pea or Maize–Pea Maize+Ricebean (terrace risers) Maize–Ricebean Maize/Soybean (river basins)
	River basin	Rice–Wheat–Mung bean (irrigated) Maize/Soybean–Fallow Upland rice–Black gram	Maize/Black gram–Fallow Maize+Ghaiya–Fallow Maize–Black gram+Niger (rainfed)

Definitions of table symbols: – = followed by, / = relay, + = intercropping or mix cropping.

Source: Sharma 2001, MoFSC 2002.

among children aged 6–59 months (MoHP, 2015) (Table 11.5). In rural areas, the prevalence of night blindness is 5 percent, while it is 1 percent in urban areas. The Nepal Iodine Deficiency Disorders Status

Survey (2005) indicated an overall iodine insufficiency among rural children and an excess iodine intake among urban children.

Ecological region	Land type	Cropping patterns	
High Hill	Irrigated	Rice–Naked barley, Rice–Wheat, Potato–Buckwheat or Mustard or Vegetables	Bean–Barley Maize–Vegetables–Fallow Potato–Potato–Fallow Bean–Buckwheat
	Rainfed	Potato–Fallow Naked barley–Fallow Maize–Wheat Maize–Wheat+Finger millet Maize–Naked barley–Finger millet	Niger–Potato–Fallow Maize–Fallow–Fallow Wheat–Fallow

Definitions of table symbols: – = followed by, / = relay, + = intercropping or mix cropping.

Source: Sharma 2001, MoFSC 2002.

**TABLE 11.5** Status of malnutrition in Nepal and the world in 2014

Indicator	Prevalence (%)			Health effects
	Nepal	World	Nepal rank in world	
<b>Stunting</b> (height for age)	37.4	23.8*	109	Weakened immune system, high risk of death
<b>Wasting</b> (weight for height)	11.3	7.5*	111	
<b>Overweight</b> (under five years)	2.1	6.1	17	
<b>Anaemia in women of reproductive age</b>	36.1	29	146	
<b>Exclusive breastfeeding rate</b>	56.9	39	25	
<b>Adult overweight</b>	18.0**	39	6	Risk of chronic illness (diabetes)
<b>Adult obesity</b>	3.3	13	7	
<b>Adult diabetes</b>	–	9	–	
<b>Micronutrient deficiencies</b>	Vitamin A: 6-59 months	5.5	–	Night blindness, serum retinol
	Women			
	Iron	36.1	–	Anaemia, worm infestations, malaria, genetic blood disorders
<b>Women of reproductive age with chronic energy deficiency</b> (measured as low BMI)	18.0	–	–	Stillbirth, underweight childbirth

\* Children under five years, \*\* Overweight and obesity.

Source: FAO, IFAD and WFP 2015, IFPRI 2016, Rudert 2014, MoHP 2015.

There is a positive association between household food consumption score and a lower prevalence of stunting, underweight and wasting. Maternal education for low socio-economic status intervention is needed to reduce preventable deaths caused by malnutrition in Nepal. Undernutrition in Nepal is estimated to cost the country USD 190 million annually (World Bank, 2011).

The government of Nepal is focused on solving the issue of undernutrition in children and women of reproductive age through its Agriculture Development

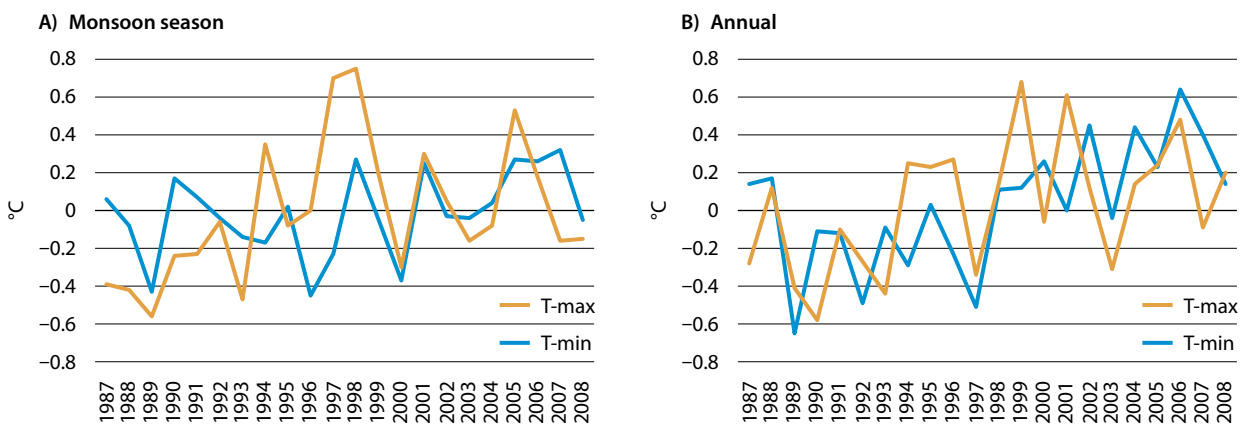
Strategy (ADS) 2015–2035. The nutritional status indicators and targets set by the ADS can be seen in Table 11.6.

### 11.2.2 Climate-change constraints

Nepal is ranked the fourth-most vulnerable country of 170 in the world when it comes to vulnerability to the impacts of climate change over the next 30 years. Nepal's geo-climatic conditions (23 percent of the total area is above the permanent snowline and 3.6 percent of the total area covered by glaciers), poverty, food

**TABLE 11.6** Indicators and targets of food and nutrition security in the Agriculture Development Strategy 2015-2035 for Nepal

Indicator	Current situation (2010)	Target		
		Short term (5 years)	Medium term (10 years)	Long term (20 years)
<b>Food poverty</b>	24.0%	16%	11%	5%
<b>Stunting</b> (children under 5)	41.5%	29%	20%	8%
<b>Underweight</b> (children under 5)	31.1%	20%	13%	5%
<b>Wasting</b> (children under 5)	13.7%	5%	2%	1%
<b>Women of reproductive age with chronic energy deficiency</b> (measured as low BMI)	18.0%	15%	13%	5%

**FIGURE 11.6** Maximum and minimum temperatures from 1987-2008 in Nepal

Source: MoSTE 2009.

insecurity, natural-resource-based livelihoods and economy (agriculture and tourism based), and political conflicts make it vulnerable to the many affects of climate change (Dahal, 2014; MoAD DNA). The impact of climate change in Nepal is evident in the increased melting of glaciers, warmer days and nights, erratic monsoons (drought and flood), increased numbers of rainy days with more than 100 mm per day, and extreme foggy and cold periods in the *Tarai* (NARC and AFACI, 2016).

The predominantly rain-fed agriculture in Nepal is highly vulnerable to changes in climatic variables. Weather data from 1975 to 2009 shows that temperatures have increased by around 1.5 °C (Figure 11.6), mostly during the dry season (December to March), and particularly in the Himalaya region (Krishnamurthy *et al.*, 2013). The Global Climate Model Projection indicated a 0.5 °C to 2 °C increase in temperature by 2030 with frequent heat waves and less frost, and a wide range of precipitation changes, especially during the monsoon from a decrease of 14 percent to an increase of 40 percent by the 2030s, and from a decrease of 52 percent to an increase of 135 percent by the 2090s (NCVST, 2009). Annual average

temperatures are expected to increase by around 0.06 °C (NCVST, 2009). A crop simulation model predicted that rice yields would increase with elevated CO<sub>2</sub> and a 4 °C rise in temperature in the *Tarai*, but wheat and maize yields would decline (NARC and AFACI, 2016). A recent study showed that increases in maximum temperature during the ripening phase (30.8 °C base average maximum temperature from 1999 to 2008) would increase rice yields up to a critical threshold of 29.9 °C, beyond which rice yields will decline (Karn, 2014). Climate change also changes pest insect and disease dynamics; for example, the prevalence of disease in chayote and insect pest in drumstick has increased. Farmers are reluctant to cultivate drumstick near their homesteads due to the increased prevalence of hairy caterpillars that can infest homes and buildings.

### 11.2.3 Market and economic constraints

Around half of the population in Nepal lives in rural mountain areas with fragile topography, where agricultural productivity is very low. In recent years, these areas have been temporarily abandoned primarily due to labour scarcity caused by the migration of young people

seeking off-farm and foreign employment. Subsistence farming is a major concern for household food security and nutrition.

The FAO food deprivation data (2005-2007) for Nepal showed that 4.5 million people are undernourished (FAO, 2011). Cereal crops are the staple food and contribute a major share in area and production. About 21 percent (3.2 million ha) of the total land area of Nepal is used for cultivation, with the major crops being rice (46 percent), maize (29 percent), wheat (25 percent), followed by pulses (10.5 percent), millet (8.7 percent), oilseeds (7.5 percent), potato (6.4 percent), sugarcane (2.2 percent), jute (0.3 percent), barley (0.9 percent), vegetables (8.6 percent) and fruits (3.6 percent) (ABPSD, 2015). The major constraints for markets are low-volume production in scattered areas, lack of processing facilities, and lack of knowledge about processing, product diversification, nutritive value of FSF commodities to consumers, and production in localized areas.

#### 11.2.4 Cultural relevance and local availability

Most of the FSF selected for cultivation in Nepal are considered socio-culturally inferior, including millet, grass pea, and colocasia, despite being nutritionally rich commodities. Most FSF are consumed by poor people and the lower castes (e.g. dalit, *kami*, *damaï*). Many FSF are localized and maintained by individual castes. At the local level, there is much diversity in FSF, but they are not grown widely by many households. Among the agricultural species, crops such as amaranth, buckwheat, citrus fruits, eggplant, foxtail millet, horse gram, mango, proso millet, rice, rice bean, soybean, sweet potato, taro and yam; and tropical fruit species, such as black plum, jackfruit, jujube and litchi, have high genetic diversity relative to other food crops (MoFSC, 2014).

### 11.3 Scoping and prioritization of Future Smart Food

#### 11.3.1 Scoping of availability of FSF

A team of scientists from the Nepal Agricultural Research Council (NARC) discussed the status of crops and farming in Nepal along with criteria to define neglected and underutilized crop species (NUS) and FSF in early 2017 in Kathmandu. NUS are crop species that have no released or registered varieties. FSF are NUS that have high potential for food and nutritional security, and are considered highly adaptable. Of the 484 cultivated indigenous crop species in Nepal, the team identified more than 200 NUS with 50 considered as potential FSF crop species, most of which are listed in Table 11.7.

#### 11.3.2 Prioritization analysis

Agricultural scientists from NARC reviewed relevant documents for prioritizing the FSF crop species of Nepal. There were five focus group sessions and seven email discussions to generate information on the prioritization of FSF. After listing the FSF crops, the team generated information on each crop based on the steps listed below:

##### Step 1: Nutrition

- Buckwheat, rich in rutin
- Grass pea, rich in protein
- Chiuri, for flavour, essential oils, vitamins, sulfur
- Moringa, a very nutritious vegetable
- Taro, rich in vitamin A
- Jackfruit, rich in energy and minerals

##### Step 2: Production and ecology (climate change)

- Buckwheat, short-duration crop grown in low rainfall areas on marginal land
- Grass pea, hardy crop requiring little care, irrigation and management, can be grown on degraded land
- Chiuri, drought tolerant and easily grown on marginal land
- Moringa, grown in the *Tarai* as a rain-fed crop
- Taro, adapted to a wide range of areas
- Jackfruit, high yield in lower belt of Nepal

##### Step 3: Economic potential

- Buckwheat, potential export commodity
- Grass pea, has market potential if low in the neurotoxin ODAP ( $\beta$ -N-oxalyl-L- $\alpha$ -diamino propionic-acid)
- Chiuri, high demand for oil and fresh seed. The seeds are also used for making soaps, and beekeepers pay chiuri tree owners to allow their bees to graze their trees
- Moringa, popular vegetable with medicinal value
- Taro, multipurpose vegetable with high market value
- Jackfruit, high market value



TABLE 11.7 List of potential future smart food crop species in Nepal identified in group discussions

Sl. No.	English name	Local/Nepali name	Scientific name	Accession	Priority
<b>Cereals/pseudo-cereals</b>					
1	Tartary buckwheat	<i>Tite Phaper</i>	<i>Fagopyrum tataricum</i> (L.) Gaertn.	400	1
2	Sorghum	<i>Junelo</i>	<i>Sorghum bicolor</i> (L.) Moench	100	
3	Prince's feather	<i>Latte dana</i>	<i>Amaranthus hypochondriacus</i> L.	70	
4	Foxtail millet	<i>Kaguno</i>	<i>Setaria italica</i> (L.) P.Beauv.	50	2
5	Proso millet	<i>Chino</i>	<i>Panicum miliaceum</i> L.	50	3
6	Foxtail amaranth	<i>Jhule Latte</i>	<i>Amaranthus caudatus</i> L.	40	4
7	Blood/ Red amaranth	<i>Rato Latte</i>	<i>Amaranthus cruentus</i> L.	30	
8	Pearl millet	<i>Bajra</i>	<i>Pennisetum glaucum</i> (L.) R.Br.	0	
<b>Root and tubers</b>					
1	Taro	<i>Pindalu</i>	<i>Colocasia esculenta</i> (L.) Schott	30	1
2	Greater yam, White yam	<i>Tarul, GharTarul</i>	<i>Dioscorea alata</i> L.	5	3
3	Elephant foot yam	<i>OI</i>	<i>Amorphophallus paeoniifolius</i> (Dennst.) Nicolson	0	4
4	Deltoid yam	<i>Vhyakur</i>	<i>Dioscorea nepalensis</i> (Jacquem. ex Prain and Burkill) Sweet ex Bernardi	2	2
5	Topioca, cassava	<i>SimalTarul</i>	<i>Manihot esculenta</i> Crantz	0	
<b>Pulses</b>					
1	Rice bean	<i>Mashyang/ Jhilinge/Siltung</i>	<i>Vigna umbellata</i> (Thunb.) Ohwi and H. Ohashi	80	3
2	Horse gram	<i>Gahat</i>	<i>Macrotyloma uniflorum</i> (Lam.) Verdc.	30	4
3	Grass pea	<i>Khesari</i>	<i>Lathyrus sativus</i> L.	50	1
4	Small pea, Field pea	<i>Sano Kerau</i>	<i>Pisum sativum</i> L. var. <i>arvense</i> L.	30	4
5	Faba bean	<i>Bakulla</i>	<i>Vicia faba</i> L.	20	2
6	Swordbean	<i>Tarbare simi</i>	<i>Canavalia gladiata</i> (Jacq.) DC.	1	
7	Velvet bean, Horse eye bean	<i>Kause Simi</i>	<i>Mucuna pruriens</i> (L.) DC.	2	
8	Cluster bean	<i>Juppe simi</i>	<i>Cyamopsis tetragonoloba</i> (L.) Taub.,		
<b>Fruit vegetables</b>					
1	Chayote	<i>Iskush</i>	<i>Sechium edule</i> (Jacq.) Sw.	15	2
2	Balsam apple	<i>Barella</i>	<i>Momordica balsamina</i> L.	20	
3	Drumstick	<i>Sahinjan/Sital Chini</i>	<i>Moringa oleifera</i> Lam.	0	1
4	Ash gourd, Wax gourd	<i>Kubhindo</i>	<i>Benincasa hispida</i> (Thunb.) Cogn.	10	
5	Chathel gourd	<i>Chattel, Chuche Karela</i>	<i>Momordica cochinchinensis</i> (Lour.) Spreng.	0	

Sl. No.	English name	Local/Nepali name	Scientific name	Accession	Priority
<b>Leafy vegetables</b>					
1	Fenugreek	<i>Methi</i>	<i>Trigonella foenum-graecum L.</i>	10	1
2	Dill	<i>Soup</i>	<i>Anethum graveolens L.</i>	4	
3	Lamb's quarter	<i>Bethe</i>	<i>Chenopodium album L.</i>	2	3
4	Water cress	<i>SimSaag</i>	<i>Nasturtium officinale R.Br.</i>	0	
5	Green pigweed, Green amaranth	<i>Lunde</i>	<i>Amaranthus gracilis Desf.</i>	2	2
6	Sweet belladonna, Indian poke	<i>Jaringo</i>	<i>Phytolacca acinosa Roxb.</i>	2	4
<b>Fruits</b>					
1	Walnut	<i>Okhar</i>	<i>Juglans regia L.</i>	0	
2	Jackfruit	<i>RukhKatahar</i>	<i>Artocarpus heterophyllus Lam.</i>	0	2
3	Wood apple, Bael tree, Bengal quince	<i>Bel</i>	<i>Aegle marmelos (L.) Correa</i>	1	3
4	Nepalese hog plum	<i>Lapsi</i>	<i>Choerospondias axillaris (Roxb.) B.L.Burtt and A.W.Hill</i>	1	
5	Lemon	<i>Nibuwa</i>	<i>Citrus limon (L.) Osbeck</i>	0	
6	Pummelo, Shaddock	<i>Bhogate</i>	<i>Citrus grandis (L.) Osbeck</i>	2	
7	Indian gooseberry, Embelicmyrobolan	<i>Amala</i>	<i>Emblica officinalis Gaertn.</i>	1	2
8	Custard apple	<i>Saripha, Sitaphal</i>	<i>Annona squamosa L.</i>	0	4
9	Rough lemon	<i>Jyamir</i>	<i>Citrus junos Siebold ex Tanaka</i>	0	
10	Tamarind, Indian date	<i>Imli</i>	<i>Tamarindus indica L.</i>	0	
11	Java plum, Surinam cherry, Black plum	<i>Jamun</i>	<i>Syzygium cumini (L.) Skeels</i>	0	
<b>Oilseeds</b>					
1	Linseed	<i>Aalash</i>	<i>Linum usitatissimum L.</i>	5	1
2	Nepali butter tree	<i>Chiuri, Mahuwaa</i>	<i>Bassia latifolia Roxb.</i>	0	2
3	Himalayan cherry	<i>Dhatelo</i>	<i>Prinsepia utilis Royle</i>	0	3
<b>Spices</b>					
1	Perilla	<i>Silam</i>	<i>Perilla frutescens (L.) Britton</i>	20	1
2	Nepal pepper, Prickly ash, Toothache tree	<i>Timur</i>	<i>Zanthoxylum armatum DC.</i>	1	2
3	Caraway, Ajowan, Ammi	<i>Jowano</i>	<i>Trachyspermum ammi (L.) Sprague</i>	0	4
4	Black cumin	<i>Himali Jira, Kalo Jira</i>	<i>Bunium persicum (Boiss.) B. Fedtsch.</i>	0	3

#### Step 4: Social and cultural potential

- Buckwheat is considered a healthy food among urban population
- Grass pea soup is a delicacy, and the tender shoots of grass pea are also eaten
- Chiuri (butter tree), considered a private resource and multipurpose tree in the Chepang community and is given as gift to daughters when they get married
- Moringa, is a highly popular vegetable
- Taro is a culturally valued commodity
- Jackfruit has cultural uses when combined with with other items, e.g. milk, ghee

### 11.3.3 Details on the prioritized FSF

#### Prioritized FSF 1

##### Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.)



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#### General characterization

- **Origin and distribution:** Tartary buckwheat self pollinates and is predominant in the High Hills.
- **Life form and ecology:** Annual and adapted to mountain ecosystems. It is a short-duration crop grown on marginal land.
- **Uses and used parts:** Grain can be consumed after grinding as pancakes or porridge, tender leaves and tips are eaten as leafy vegetables. The grain itself can be cooked like rice (*Bhate Phaper*).
- **Yield:** 983 kg per ha.
- **Ingredients and health benefits:** Tartary buckwheat grain contains 13.3 percent protein, 1.3 percent minerals, 3.4 percent fat, 71.5 percent carbohydrates and is a good source of rutin (which reduces cholesterol in the blood) and dietary fibre. It is seen as a healthy food by urban dwellers.
- **Problems:** It is difficult to process with low yields and small grains. It is also susceptible to waterlogging and frost, damping off, powdery mildew and rust.

#### Prioritized FSF 2

##### Grass pea (*Vicia sativa* L.)



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#### General characterization

- **Origin and distribution:** Grown in rice-based cropping systems in the Indo Gangetic plains in the 1970s, grass pea was the number one pulse in terms of area and production in Nepal. However, the sown area declined drastically due to a huge decline in consumption following a health scare.
- **Life form and ecology:** This annual plant is grown in sub-tropical areas, mainly in the *Tarai*. Often grown as a relay crop in rice, it is drought and waterlogging tolerant relative to other pulses.
- **Uses and used parts:** Young leaves are consumed as green vegetables, also rolled and dried for off-season use. The fodder is used as a valuable livestock feed. Grain is used in vegetable soup. It is cheaper than other grain legumes and mostly consumed by the rural poor.
- **Yield:** Fresh biomass yields 5–6 tonnes per ha, grain yields 1.2 tonnes per ha.
- **Ingredients and health benefits:** Rich in protein.
- **Problems:** The grass pea is low yielding and can contain oxalyldiaminopropionic acid (ODAP) in levels from 0.6 percent to 0.8 percent in local grass pea. Regular intake of grain is believed to cause the neurological disorder lathyrism. A ban has been imposed since 1991/1992 on marketing grass pea. This led to a huge reduction in sown area (after being the number one pulse in terms of area and production in the 1970s).

**Prioritized FSF 3****Taro** (*Colocasia esculenta* (L.) Schott)

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**Prioritized FSF 4****Drumstick** (*Moringa oleifera* Lam.)

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**General characterization**

- **Origin and distribution:** Taro is grown in the Mid Hill and Tarai districts and distributed widely across the country.
- **Life form and ecology:** An annual plant, cultivated on 4 040 ha, sown April–May as a rain-fed crop in the *Tarai* and Mid Hill regions and harvested Nov–Jan. A common cropping pattern is taro–maize–legume vegetable, while intercropping with maize, ginger or turmeric and other summer crops.
- **Uses and used parts:** The corms, petioles (*gaaba*) and leaves (*karkalo*) are edible after cooking. The tubers are used as a root vegetable, steamed, fried or cooked with black gram in the preparation of some soups. It is never eaten raw because it causes an itchy, stinging, and very irritating sensation to the throat. Leaves are also dried and stored. Tubers are also consumed during festivals.
- **Yield:** 10 tonnes per ha.
- **Ingredients and health benefits:** Corms are rich in carbohydrates, and the leaves have high levels of calcium and vitamin A.
- **Problems:** Crops can be attacked by white grub, are subject to wilting and have a poor cooking quality.

**General characterization**

- **Origin and distribution:** Drumstick is a fast-growing drought-resistant tree, widely cultivated in tropical and subtropical areas.
- **Life form and ecology:** In seasonally cool regions, flowering occurs once a year between April and June. With more constant seasonal temperatures and rainfall, flowering can occur twice or even year-round.
- **Uses and used parts:** Young seeds, pods and leaves are used as vegetables or as low-cost feed for animals. The seeds have a cooling effect when eaten.
- **Yield:** 40 tonnes per ha of green pods.
- **Ingredients and health benefits:** Used for water purification, hand washing and herbal medicine. It is a nutritious vegetable and rich in vitamin A.
- **Problems:** It can be a difficult plant to propagate in Nepal and attracts hairy caterpillars. Being tall, it is difficult to harvest and produces low yields. It is also relatively expensive to produce.

**Prioritized FSF 5****Jackfruit** (*Artocarpus heterophyllus* Lam.)

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**General characterization**

- **Origin and distribution:** Grown in tropical to subtropical regions.
- **Life form and ecology:** Flowering from February-March, available in markets from April-May as tender fruits and from July-August as ripe fruits.
- **Uses and used parts:** The unripe fruit is used as a vegetable and is popular in urban areas. Ripe fruit is eaten fresh. Mature seeds are used as vegetables, roasted and boiled. The jackfruit's wood is used to make *theke*, the pots in which ghee is churned.
- **Yield:** 11.6 tonnes per ha and so has high yield potential.
- **Ingredients and health benefits:** Useful for treating dysentery and diarrhoea. The fruit is nutritious, rich in calcium, carbohydrates, potassium, protein and vitamins A, B and C.
- **Problems:** The amount of fruit that can be consumed in proportion to the weight is low. In addition, jackfruit is difficult to process and propagate and trees do not bear fruit for several years. Jackfruit also tends to attract borers, pink disease, leaf spot, collar rot and rust.

**Prioritized FSF 6****Nepal butter tree** (*Bassia latifolia* Roxb.)

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**General characterization**

- **Origin and distribution:** Grown in sub-Himalayan regions at elevations from 400-1 400 m. The butter tree or *chiuri* is a popular crop among hill tribes such as the Chepang community.
- **Life form and ecology:** The tree produces flowers from November-January and fruits are available from April-June. The tree offers good protection from soil erosion.
- **Uses and used parts:** It is estimated that 35-40 percent of oil can be extracted from fully ripe, dried seeds. Products are used in confectionery, pharmaceuticals, vegetable ghee production, candle manufacturing and soap making. It is also used as an additive in animal ghee. Ghee is the main source of edible oil used to cook vegetables and roti in Nepal. Chiuri juice is also consumed to quench thirst. The cake produced after processing is used as fertilizer on paddy fields for its pesticide properties.
- **Yield:** 100-800 kg per ha (around 1-14 kg per tree).
- **Ingredients and health benefit:** Seed oils are used in head massages and can be highly effective in the relief of rheumatism.
- **Problems:** Processing requires a substantial amount of fuelwood which contributes to deforestation. Oil extraction rates are low when using a traditional oil expeller (*Chepuwa*), with only 38 percent recovery. The taste may seem unfamiliar and so off-putting to potential consumers.

**FIGURE 11.7** Potential sites for field surveys on FSF crops, Nepal

Source: Nepal Agricultural Research Council (NARC)

**TABLE 11.8** Collaborators from NARC for research and development of FSF

Sl. No.	Crop	Lead organization	Collaborators
1	Tartary buckwheat	HCRP, Dolakha	ARS Jumla, ARS Dailekh, RARS Lumle, FRD Khumaltar, Genebank Khumaltar, SARPoD Khumaltar (6)
2	Grass pea	GLRP, Banke	RARS Parwanipur, NORP Nawalpur, FRD Khumaltar, Genebank Khumaltar, RARS Doti, SARPoD Khumaltar (6)
3	Taro	HRD, Khumaltar	FRD Khumal, Genebank Khumal, SARPoD Khumal, HRS Malepatan, GRP Kapurkot, CRP Gulmi, RARS Nepalgunj (7)
4	Drumstick	HRD, Khumaltar	RARS Tarahara, ARS Belachapi, FRD Khumal, Genebank Khumal, SARPoD Khumal, ARS Pakharibas (6)
5	Jackfruit	HRD, Khumaltar	FRD Khumal, Genebank Khumal, SARPoD Khumal, RARS Tarahara, RARS Nepalgunj (5)

### 11.3.4 Sites for surveys and collaborators

Of the six potential FSF, the team of scientists considered five for further research and development. These five crops: buckwheat, drumstick, grass pea, jackfruit and taro are available across Nepal. Based on the diversity and economic value in particular locations of these crops, potential sites for field surveys were identified (Figure 11.7). NARC is the leading body for agricultural research in Nepal, with 61 branch offices across the country. The potential collaborators for each FSF crop species are listed in Table 11.8.

## 11.4 Conclusion and recommendations

Nepal is rich in agro-biodiversity as a result of extreme variation in altitude, ecology, farming systems and sociocultural values. Most of the population relies on three main crops for their food supply: rice, wheat, and maize. However, minor millets are an integral part of subsistence farming in the Mid Hills and High Hills, and contribute to food and nutritional security to some extent.

Many NUS crops have medicinal, religious and industrial significance for various tribal groups, and have a high potential for export value. Climate change will impact considerably the hill ecosystem of Nepal. Research and development are needed in the conservation, evaluation and utilization of NUS crops, which are more nutritious, climate resilient and better adapted to marginalized areas. Recommendations for better utilization of NUS and FSF for nutrition and food security in Nepal include the following:

- There needs to be **status and gap analysis** to document the information available on the dependency of households on certain crops, and the contribution that NUS and FSF make towards both household and national food and nutrition security, income generation, health security and the role of NUS and FSF in subsistence farming.
- To further advance NUS and FSF, a **baseline survey** should be carried out focusing on food, nutrition, health and climate change, and assessing crop status and diversity across the country. This needs to explore medicinal, religious, industrial and nutritional values along with different food recipes using NUS to expand cultivation areas, increase consumer numbers, and encourage researchers and policymakers to consider NUS and FSF as priority crops. As many NUS and FSF crops are adapted to different farming systems, cultures and climates, more value-added opportunities are needed to make them popular in different parts of the country.
- To protect these plants and ensure that they benefit future generations, **conservation, pre-breeding, exchange and utilization of NUS and FSF plants and seeds** should be initiated across Nepal. Processing techniques should be advanced, and recipes need to be diversified. Currently there is only limited information on the nutrient composition of NUS and FSF, which needs to be analysed and linked to respective health benefits.
- NUS and FSF crop species are more climate resilient than many current species and they could be vital in future sustainable production. More research is needed to identify climate-resilient varieties and varieties more tolerant to abiotic and biotic stresses. Priority should be given to **genetic and husbandry improvement** of NUS and FSF.
- To make NUS and FSF an export commodity, **strong market links should be established and programmes implemented**. Some NUS and FSF have geo-linked traits that can be marketed as geographical indicators (Joshi *et al.*, 2017b).

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# 12 Viet Nam

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## 12.1 Introduction

### 12.1.1 About the country

Viet Nam is in Southeast Asia, located between longitude 102° 09' and 109° 30' East, and latitude 8° 30' and 23° 30' North. The country has a total land area of 330 541 sq km, and borders China, Lao PDR and Cambodia. Viet Nam covers the length of the Indochinese peninsula and extends along the southeastern coastline of Asia for 3 260 km. The country's territory includes a vast sea area with various islands and covers a large section of continental shelf.

The country has considerable diversity in terms of landscape and can be divided into four physiographic regions. The northernmost region consists of rugged and heavily forested mountains and contains the country's highest point: the 3 143m peak of Fan Si Pan. The Red River Delta region is a triangular alluvial plain that stretches along the Gulf of Tonkin. The Annam Highlands region including the Central Highlands, lies to the south of the delta and forms the backbone of Viet Nam.

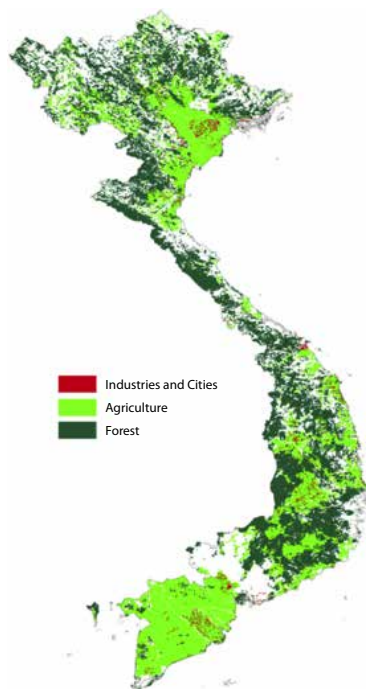
The southernmost region is the Mekong Delta, which extends from the southern edge of the Central Highlands to the mangrove swamps of the Ca Mau peninsula in the south (Figure 12.1).

Viet Nam's climate is generally hot and humid. North Viet Nam is located in the tropical zone, but has cold winters due to the influence of monsoons. The climate has subtropical features while the high mountainous areas are of a more temperate character. The north of the country is characterized by big differences in temperature between summer and winter, while the south of the country sees big differences in humidity between the rainy and dry seasons.

Rainfall is plentiful throughout the country, although precipitation in southern and central Viet Nam is heaviest during the summer months when monsoon winds sweep in from the sea. The average annual rainfall is about 1 680 mm in the Red River Delta, 1 650 mm along the central coast, and 1 980 mm in the Mekong Delta. Typhoons periodically strike the central coast, and some of these have caused considerable loss of life and major destruction of cropland.



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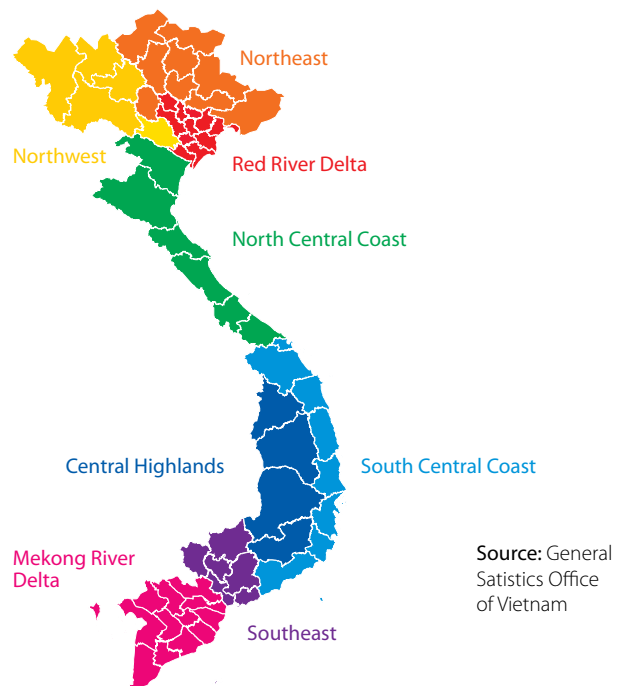
**FIGURE 12.1** Land cover map, Viet Nam

### 12.1.2 Agro-ecological zones

The total natural area of the country is 33 123 077 hectares, of which 31 000 035 hectares has been used for agricultural and non-agricultural purposes, accounting for 93.59 percent of the total area nature. The agricultural land area is 27 302 206 hectares, accounting for 82.43 percent of the total natural area. Soil classifications have been carried out nationwide (Figure 12.2) and Viet Nam can be divided into eight eco-agricultural zones (Figure 12.3) based on topography, climate soil patterns and agro-economics. Each ecological sub-region can be regarded as a basic unit because of the relative homogeneity of climate, geology, geomorphology and soil conditions. It also reflects major characteristics of agro-forest ecosystems (Phuong *et al.*, 2012). The share of agriculture in Viet Nam's GDP has shrunk from about 25 percent in 2000 to 17 percent in 2016 (World Bank, 2016). Viet Nam's traditional farming base is an integrated system of rice and other crops.

### 12.1.3 Status of Viet Nam's food basket: the composition of crops, including staples

Food consumption in Viet Nam is influenced by regional, cultural and ethnic concerns, as well as the country's differing incomes and agricultural production processes. Cereals are the main source of energy in the Vietnamese diet providing 78 percent of total energy. The main food is rice, which is considered the soul of every meal. Average consumption of rice per person is around 400 g a day across the country. Depending on

**FIGURE 12.2** Map of agro-ecological zones, Viet Nam

Source: General Statistics Office of Vietnam

the region, other staple foods in Viet Nam include corn and cassava in mountainous and plateau regions, sweet potatoes on the plains and roots and tubers in midland and mountainous regions (FAO, IFAD and WFP, 2015).

In addition to rice and other other staple foods, beans, fruits, oily nuts, tubers, vegetables and soya products (beanspouts, cakes, soy milk, soy sauce and tofu) play an important role in the Vietnamese diet. The diversity of vegetables include amaranth, beans, bottle gourd, broccoli, cabbage, celery, chayote, green vegetables, Indian spinach, jute, kohlrabi, lettuce, luffa, pumpkin, radish, squash, star-gooseberry and water spinach. Daily meals also tend to incorporate a diverse range of fruits, which also differ according to region. The most popular fruits include banana, grapefruit, guava, jackfruit, mango, oranges, papaya and tangerines. All these fruits are rich sources of nutrients, vitamins, trace elements and fibre. The amount of meat and animal products, as well as seafood, has increased significantly in the Vietnamese diet over recent years.

### 12.1.4 Major cropping patterns and crop diversity

Different ecological zones in Viet Nam have different cropping patterns. However, as the main crop is still rice, cropping patterns are based on the rice-growing seasons. The *Mua* rice season lasts from May-August to September-December, *He-Thu* goes from April-June to August-September; and the third period, *Dong-Xuan* takes place from December-February to April-June. In the south, rice planting follows the wet and dry seasons.

In the midland and mountainous regions, there are other types of farming for upland crops and integrated agro-forestry. With the goal of boosting growth and enhancing productivity, more intensive and monoculture zones have developed with crops of only one or two varieties of species, such as rice and corn, which is grown for export. Many areas cultivate monoculture with two rice seasons in the north and sometimes three rice seasons in the south.

However, as rice is the main staple of the Vietnamese diet, rice farming takes up 94 percent of arable land. In addition, most farming policies, research and new techniques are focused on rice production. As a result, high-yielding rice varieties have largely replaced the traditional varieties in Viet Nam. This focus on rice has led to more minor crops being overlooked and underused in agricultural production.

According to current statistics, Viet Nam has a high diversity of plant genetic resources. Some 16 428 plant species (13 766 plant species excluding water microalgae), of which 60 percent are native to the country have been recorded (Sen, Trinh, 2010; MONRE, 2011).

There are more than 800 plant species cultivated in largely diversified agro-systems throughout the country, of which the most useful and popular are starchy food, fruit, vegetables, oil and fibre, and crops that have medicinal benefits. There are also a range of spices grown and other species planted for their re-greening and ornamental properties.

The most important tropical fruits include annona, banana, carambola, cashew, coconut, durian, guava, jack fruit, mango, mangosteen, papaya, pineapple, pomelo and tamarind.

The most nutritionally important subtropical fruits are chestnut, citrus, litchi, longan and persimmon among others. Temperate zone fruits include apple, apricot, peach, pear, plum and strawberries. Locally popular fruits include banana, carambola, citrus, jackfruit, and mango (Sen, Trinh, 2010). In terms of wild crops in Viet Nam, there are estimated to be over 1 300 species, including many NUS crops. These species could be hugely valuable as future crops, helping farmers diversify and raise revenue.

## 12.2 Situation and gap analysis

### 12.2.1 Hunger and malnutrition

Viet Nam has shown good progress in reducing stunting since 2000. Stunting among Vietnamese children was reduced to 23 percent in 2011 and to

19 percent by 2015. However, the rate of child malnutrition and stunting remains high. There is a shortage of calcium and vitamin D in diets throughout the country. Recent studies have shown that an average Vietnamese diet only meets 50 percent of the daily calcium intake needed for good health. Overweight and obesity have also become national concerns, now affecting 5 percent of children and 8 percent of women, while twice as many women are underweight or malnourished. Iodine deficiencies are becoming a new problem since a relaxing of mandatory salt iodization laws in 2006. This iodine deficiency disorder is now an important public health problem in Viet Nam. The areas with the highest prevalence of goitre and cretinism are located in hilly, mountainous and highland regions, which are home to the country's ethnic minorities. Policy and programmatic interventions to improve nutrition in Viet Nam should focus on strengthening and implementing universal salt iodization policies and addressing high rates of malnutrition among minorities and the poorest segment of the population. The World Bank (2011) estimated that the country loses USD 544 million a year of its GDP due to undernutrition.

Anaemia now affects 29 percent of children under five years old. It is caused by micronutrient deficiencies such as iron and vitamin A and potentially other non-nutritional factors. Anaemia is considered an important indicator of malnutrition. A report from the National Institute of Nutrition showed the rate of anaemia among women at childbearing age is 29 percent and 36.5 percent among pregnant women. The highest rates, of nearly 60 percent, can be found in the mountains of the north and the central highlands. The main cause of anaemia in Viet Nam is due to iron deficiency, with a prevalence of up to 86.3 percent, mainly in rural and mountainous areas. Expectant mothers often have poor diets, which can lead to early malnutrition for newborn babies and children.

In some regions of the country, the story is very different. The National Institute of Nutrition recently released figures that show up to 16.3 percent of people aged 25-64 are overweight or obese. In the 10 years since 2006, the number of people with diabetes in Viet Nam has nearly doubled, from 3 percent up to 5.4 percent of the population, representing some 3 million people. (Viet Nam Ministry of Health, 2016) (Table 1). This rapid rise in the numbers of diabetes sufferers is caused by the huge change in diet and lifestyles. For example, fat consumption increased from 12 g fat per person per day in 1985 to 24.9 g fat per person per day in 2000. This has since skyrocketed to 37.7 g fat per person per day in 2010 causing major health problems, especially among urban dwellers.

TABLE 12.1 Nutrition status of Viet Nam 2015

Indicator		Prevalence (%)	Health effects
Undernourishment		11.0	The life course, activity and growth of the child's body are unusual
Stunting		19.0	
Wasting		6.0	
Underweight		12.0	
Micronutrient deficiencies	Vitamin A	14.0	Stunting, increased risk of disease and death, visual impairment
	Iron	80.0	Anaemia: 29% (VMH, 2016); 14.1% at women reproductive age (IFPRI, 2016)
	Zinc	51.9	Stunting, slow growth, underweight and weakened reproductive ability
	Iodine	55.0	lack of thyroid hormone and cause many different disorders
Overweight		9.7	Increased risk of cardiovascular disease, diabetes
Obesity		6.6	Diabetes: 5.4% (VMH,2016) – 6.5% (IFPRI, 2016)
Adequately iodized salt consumption		45.0	

Source: UNICEF, 2016; WB, 2016; Chaparro, C., *et al.* 2014; VNIN, 2015; Viet Nam Ministry of Health, 2016; IFPRI, 2016.

### 12.2.2 Climate change constraints

Viet Nam's acute vulnerability to climatic change stems from three factors: high exposure to the natural elements; high sensitivity of socio-economic structures to such elements; and low capacity to adapt by protecting those structures or making them less sensitive (François Fortier, 2010).

The country's 3 260 km of coastline, vast deltas and flood plains, short and quickly discharging watersheds, and location in the the path of Western Pacific typhoons and the Southeast Asian monsoon mean that many parts of the country are exposed to predicted rises in sea level and extreme weather patterns. Viet Nam is likely to suffer significantly from this synergetic combination of climate change factors.

Rising sea levels could lead to a significant loss of land, wetlands and marine ecosystems, including the mangrove forests that protect Viet Nam's coastlines. Beyond coastal areas, the unpredictability of climate extremes will affect the entire country through changes in temperature and rainfall, which could result in more droughts, floods, flash floods and landslides. The resulting loss of biodiversity will degrade ecosystems, and the lifestyles and food sources they support. Meanwhile, higher average temperatures are likely to facilitate the spread of pests, and plant, animal and human pathogenic vectors.

All this will severely impact on the livelihoods of people who work in agriculture, aquaculture and forestry, as well as public health and the country's general infrastructure. Viet Nam remains very much an agricultural nation, so climate plays a huge part in people's lives. Around three-quarters of the population live in low-lying fertile plains that can be affected by rising sea levels and fluvial floods in the Red River and Mekong deltas. In addition, a warming climate could lead to more flash floods or droughts in mountainous areas (Bruun and Casse, 2013).

Agricultural intensification and encroachment as well as, land-use intensity is high in Viet Nam resulting in nearly two rice crops a year and yields well above the mean level for Asia. However, the pressure to develop land and the conversion of marginal lands previously regarded as unsuitable for agriculture is leading to environmental problems. Deforestation and over-intensive land use is causing greater levels of soil erosion and reduced soil fertility.

High-intensity rainfall, sub-optimal irrigation techniques, and a lack of incentives for farmers to adopt sustainable natural resources management are also contributing to Viet Nam's high levels of soil loss, and pesticide and fertilizer runoff. These factors have resulted in decreased productivity, and increased groundwater and surface water contamination (ADB, 2013).

Climate change will seriously affect more remote regions of Viet Nam where poor farmers with little access to the

latest knowledge are dependent on agriculture to feed their families live. Meeting the challenge of developing tolerant crops and high-value produce is essential in terms of food security and sustainable living for these vulnerable groups of society.

### 12.2.3 Market and economic constraints

Agro-production and marketing of food produce in Viet Nam currently faces many difficulties. This is because agricultural production is low-key and fragmented, so many of the products coming to market from different regions often do not meet the same standards for quality. There is also increased competition from imported agro-products, along with increasing production costs. Another factor is the loosening on quality controls and laws on chemical and pesticide use that has led to a lack of trust in local produce by Vietnamese people, causing demand for locally produced food to drop.

In addition, planters and farmers tend to only receive a small percentage of the value of agro-products once they are sold at market. This is due to intermediaries taking advantage of farmers' weak bargaining positions, which stems from small-scale production, varied quality of produce and poor market knowledge. The lack of storage facilities for perishable products such as fruit and vegetables, lack of credit and cash shortages also weaken producers' positions when it comes to getting a fair price. Also, many farmers do not have transportation to get their goods to markets themselves.

### 12.2.4 Cultural relevance and local availability

Viet Nam has a traditional culture imbued with national identity. However this has been seriously eroded, especially in youth ethnic groups. Western culture has a powerful appeal for young people, magnified by Viet Nam's re-emergence from international isolation. Young people like to discover new things, and traditional culture has not met this need. In addition, the development of internet-driven social media has had a strong impact on traditional culture.

Cultural changes have also affected the eating habits of young people in recent years. This is due to the influence of more Westernized diets. People are now consuming three times the daily recommended amount of salt, and eating large amounts of sugar, often in soft drinks or snacks. Fried and baked goods are increasingly more common in Viet Nam, too. The country still has a high number of tobacco smokers and there has been an increase in alcohol intake.

## 12.3 Scoping and prioritization of Future Smart Food

### 12.3.1 Scoping of availability of FSF

NUS are those that communities have traditionally used for food, fibre, animal fodder, oil or for medicine, but which are seen as having further undeveloped potential uses (Arora, 2014).

Currently, most NUS crops tend to be grown by local and smallholder farmers in areas where they are still an important food source for local communities. They could also be crops that were once widely grown but have fallen into disuse due to a variety of agronomic, genetic, economic and cultural factors. Some of these species may be globally distributed, but tend to occupy special niches in the local ecology, and in production and consumption systems. While these crops continue to be maintained by socio-cultural preferences and use practices, they remain inadequately characterized and neglected by research, conservation and the economy at large (Markus, *et al.*, 2007). The list of crops selected as FSF in Viet Nam is shown in Table 12.2.

### 12.3.2 Prioritization analysis

#### Cereals and pseudocereals

In the river deltas and plains of Viet Nam, which boast good farming conditions, rice and maize are the most common crops. But in the midland, mountainous and remote areas, with difficult growing conditions caused by drought, sloping land and infertile soils, farmers tend to diversify, making more use of other cereal crops such as millet and sorghum. In the northern part of Viet Nam, millet was long planted as a main crop for multi-use as both food and medicine. But in more recent years, millet-sowing areas have decreased significantly due to the increased production of other crops, which are currently economically more profitable.

Millet contains a high level of carbohydrates and so provides a large amount of energy. Millet is also rich in protein, minerals (with a high content of calcium, iron, magnesium and zinc as well as vitamins B, E and K, and 18 amino acids. Millet is recommended for diabetic patients because of its low glycemic index and high levels of fibre. In Viet Nam, these plants have long been farmed in the mountainous areas in the north (Cuong *et al.*, 2009).

Buckwheat seeds have a high nutrition content, 71-75 percent starch, 18 percent protein, and higher levels of zinc, copper and manganese than other cereal grains. The bio-availability of these minerals is also high



at 90 percent. In addition, buckwheat is a rich source of polyphenols, antioxidants and aromatic compounds.

In Viet Nam, buckwheat is grown in the northern mountainous regions such as Ha Giang, Lao Cai and Cao Bang provinces. The yield averages 1.1 tonne per ha

and it is often eaten by Viet Nam's minority groups. It is a healthy food product and can help reduce fat in the blood and liver, lower cholesterol and slow down atherosclerosis. Buckwheat also is resistant to drought, adapts well to rocky soils and can be intercropped with maize. Buckwheat is sown in the late summer and takes

**TABLE 12.2** List of Neglected and Underutilized Species (NUS) in Viet Nam and their priority

No.	English/Local name	Scientific name	Accessions	Priority
<b>Cereals</b>				
1	Finger millet ( <i>Kê chân vịt</i> )	<i>Eleusine coracana</i>	74	1
2	Foxtail millet ( <i>Kê đuôi chồn</i> )	<i>Setaria italica</i>	37	5
3	Pearl millet ( <i>Kê trăn châu</i> )	<i>Pennisetum glaucum</i>	45	6
4	Proso millet ( <i>Kê châu âu</i> )	<i>Panicum miliaceum</i>	16	
5	Sorghum ( <i>Cao lương</i> )	<i>Sorghum bicolor</i>	301	4
6	Buckwheat ( <i>Tam giác mạch</i> )	<i>Fagopyrum esculentum</i>	20	2
7	Adlay millet ( <i>Ý dĩ</i> )	<i>Coix lacryma-jobi</i>	115	3
<b>Roots and tubers</b>				
1	Taro ( <i>Khoai môn sọ</i> )	<i>Colocasia esculenta</i>	779	1
2	Arrowroot ( <i>Hoàng tinh ngự</i> )	<i>Maranta arundinacea</i>	3	
3	Greater yam ( <i>Củ mỡ</i> )	<i>Dioscorea alata</i>	117	2
4	Asiatic yam ( <i>Củ từ</i> )	<i>Dioscorea esculenta</i>	80	5
5	Tannia ( <i>Khoai mùng</i> )	<i>Xanthosoma sagittifolium</i>	155	6
6	Edible canna ( <i>Dong riêng</i> )	<i>Canna edulis</i>	61	4
7	Elephant yam ( <i>Khoainưa</i> )	<i>Amorphophallus konjac</i> / <i>Amorphophallus campanulatus</i>	13	3
8	Mealy kudzu ( <i>Sắn dây</i> )	<i>Pueraria thomsoni</i>	3	
9	Chinese yam ( <i>Hoài sơn</i> )	<i>Dioscorea opposita</i>	1	
10	Yam ( <i>Khoai vạc dại</i> )	<i>Dioscorea persimilis</i>	2	
<b>Nuts and pulses</b>				
1	Azuki bean ( <i>Đậu đỏ</i> )	<i>Vigna angularis</i>	76	4
2	Lima bean ( <i>Đậu ngự</i> )	<i>Phaseolus lunatus</i>	37	6
3	Rice bean ( <i>Đậu nho nhe</i> )	<i>Vigna umbellata</i>	49	3
4	Cowpea ( <i>Đậu các loạ</i> )	<i>Vigna unguiculata</i>	1 193	1
5	Velvet bean ( <i>Đậu mèo</i> )	<i>Mucuna cochinchinensis</i>	65	
6	Snap bean ( <i>Đậu cô ve</i> )	<i>Phaseolus vulgaris</i>	588	5
7	sword bean ( <i>Đậu kiếm</i> )	<i>Canavalia gladiata</i>	39	
8	Mung bean ( <i>Đậu xanh</i> )	<i>Vigna radiata</i>	701	2
9	Chickpea ( <i>Đậu gà</i> )	<i>Cicer arietinum</i>	25	
10	Lablab bean ( <i>Đậu ván</i> )	<i>Lablab purpureus</i>	205	

No.	English/Local name	Scientific name	Accessions	Priority
<b>Horticulture</b>				
1	Potato bean ( <i>Cây củ đậu</i> )	<i>Pachyrhizus erosus</i>	115	5
2	Amaranth ( <i>Rau dền</i> )	<i>Amaranthus sp.</i> ( <i>A. acutifolius</i> ; <i>A. tricolor</i> ; <i>A. caudatus</i> ; <i>A. spinosus</i> ; <i>A. viridis</i> )	330	1
3	Yardlong bean ( <i>Đậu đũa</i> )	<i>Vigna unguiculata subsp. unguiculata forma sesquipedalis</i>	578	
4	Gigantea ( <i>Độc mùng</i> )	<i>Colocasia gigantea</i>	13	
5	Pumpkin ( <i>Bí ngô</i> )	<i>Cucurbita moschata</i>	600	3
6	Chives ( <i>Hẹ</i> )	<i>Allium tuberosum</i>	6	4
7	Cardiopteris ( <i>Lắc lầy</i> )	<i>Cardiopteris quinqueloba</i>	35	2
8	Snake gourd ( <i>Dưa trời</i> )	<i>Trichosanthes anguina</i>	30	
9	Melientha ( <i>Rau sắng</i> )	<i>Melientha suavis</i>	2	6
10	Winged bean ( <i>Đậu rồng</i> )	<i>Psophocarpus tetragonolobus</i>	35	
<b>Others</b>				
1	Banana ( <i>Chuối</i> )	<i>Musa acuminata</i>	254	
2	Jackfruit ( <i>Mít</i> )	<i>Artocarpus heterophyllus</i>	7	1
3	Langsat ( <i>Bòn bon</i> )	<i>Lansium domesticum</i>	5	2
4	Chestnut ( <i>Dẻ Trùng Khánh</i> )	<i>Castanea mollissima</i>	1	
5	Chinese black olive ( <i>Trám</i> )	<i>Canarium tramdenum/C. album</i>		3
6	Sugar palm ( <i>Búng báng</i> )	<i>Arenga pinnata</i>	wild	
7	Wampi ( <i>Quất hồng bì</i> )	<i>Clausena lansium</i>	1	4
8	Kaki persimmon ( <i>Hồng</i> )	<i>Diospyros kaki</i>	5	6
9	Plum ( <i>Mận</i> )	<i>Prunus salicina</i>	4	5

around three months to grow. For many years, buckwheat-growing areas in Vietnam were reduced, due to a high demand for other major food crops such as corn and rice. But buckwheat is making a comeback in popular tourist areas such as Giang and Cao Bang provinces.

Sorghum is a drought-resistant crop that has been grown for a long time in the high mountain areas of Viet Nam. It is mostly harvested as grain for food and livestock. But over the years this plant has become neglected and less known as a food source.

Adlay millet is a native species of Viet Nam and, during the last two decades of the twentieth century, the country was one of the leading international exporters of this crop.

In terms of nutritional requirements and adaptability to climate change, seven cereals meet the criteria for FSF.

These are adlay millet, buckwheat, finger millet, foxtail millet, pearl millet, proso millet and sorghum (see Table 12.2). However, buckwheat is being given first priority as an FSF in Viet Nam because it meets all the economic and social criteria, and gives farmers the opportunity to make extra income from ecotourism (Table 12.3).

### Roots and tubers

Roots and tubers are traditional and versatile crops in Viet Nam. For a long time taro, in particular, was a commonly planted crop. Taro contains starch, protein and minerals, as well as vitamins A, C, E and B in greater quantities than found in fresh fruit. In Viet Nam, taro is the third most commonly planted crop after rice and maize, and was especially popular during times when other crops were damaged by floods or typhoons. During the time of political conflicts in Viet Nam, taro provided vital food for soldiers and citizens. But since then, roots and tubers have become regarded as food for the poor (Ho *et al.*, 1996) and have a low

socio-economic status. However, with new challenges emerging, such NUS crops are being looked at as FSF. Ten species have been chosen to prioritize for research and cultivation; arrowroot, Asiatic yam, Chinese yam, edible canna, elephant foot yam, greater yam, mealy kudzu, taro, tannia and wild yam (see Table 12.2).

A 100 g of dried elephant foot yam contain 75.2 g of starch, 12.5 g of protein, 0.98 g lipids, 3.27 g non-protein derivatives, 3.67 g cellulose and 4.42 g ash. Its starch rate is double that of taro and it contains Glucomannan, which is often used as an anti-obesity treatment. Purple yam flesh contains significant levels of the antioxidant anthocyanin, which gives this yam great potential as a medical crop.

Roots and tubers are considered multi-purpose crops and have long been grown in Viet Nam's plains, midlands and mountainous agro-ecosystems. Farmers maintain them as supplementary food sources for daily meals. Petiole and its leaves are nutritious and can be used as animal feed, and there is some market potential for industrial processing and medicine.

Taro and yam varieties can grow and thrive in various conditions, such as sandy or clay soils with high saline or alkaline levels. They also do well in hot and cold climates and are well resistant to flooding or drought. They can be farmed alone or as intercrop species. In addition, Taro and yam are part of the religious culture products of many of Viet Nam's minority groups and are often used in festivals.

However, the wider market for roots and tubers is unstable as there can be problems with production and planning and farming technology is limited for this type of crop. Despite these shortcomings, taro and greater yam have been selected as high-priority FSF (see Table 12.3).

### Nuts and pulses

Legumes in general and the pulse group in particular can be exploited to meet the growing demand for vegetable oil and protein for human consumption and animal feed. These crops also benefit from being adaptable for rotational cropping and intercropping, and they can be beneficial for soils.

Pulses are a popular crop in Viet Nam and are becoming more common as people discover their many health benefits. Since they can be intercropped, this helps

encourage biodiversity by ensuring there is a habitat for a range of insects and organisms that would not thrive in a single crop region. Legumes and pulses also do well in barren soils and semi-arid conditions and their nitrogen fixing properties are good for the long-term health and fertility of agricultural lands.

Pulses in Viet Nam boast high genetic diversity and are easily bred with other varieties to improve their resistance to a changing climate. Pulse cultivation also produces less carbon and greenhouse gases and they can be stored for several months without losing their nutrients. This means they are a dependable food stock between harvests.

Some of the pulses grown in Viet Nam, especially by ethnic minority groups include azuki bean, chickpea, cowpea, lablab bean, lima bean, mung bean, rice bean, snap bean, sword bean and the velvet bean (Table 12.2).

Some 2 000 pulse seed samples have already been collected and stored in the National Genebank with cowpea accounting for 60.1 percent of samples followed by rice bean (18.6 percent) and mung bean being the third-most abundant. It is cowpea and mung bean that have been selected as potential FSF due to their huge socio-economic potential (Table 12.3).

### Horticulture

Vegetables and fruit are extremely low in fat and have zero cholesterol. They are also an important source of nutrients including potassium, fibre, folate (folic acid), and vitamins A and C. Viet Nam is lucky to have a diverse range of indigenous fruit and vegetables including spices and native forest plants. Many of these indigenous vegetables and plants play an important role in providing people with their daily nutrients and can easily be adapted to different ecological zones. Another benefit is that they are generally well resistant to disease and pests. The problem is that, currently, people are not looking to conserve such native plants or to grow them sustainably. Local people also do not tend to know the nutritional value of the vegetables they often eat.

According to Nguyen Tien Ban (1994) around 113 species of wild edible vegetables are common in the average Vietnamese diet. An average 100 g of most wild vegetables species have vitamin C levels of 30-50 mg, at least 3 mg of carotene and a large amount of protein. The ten most useful vegetables are amaranth, chives, gigantean, Lac lay (*Cardiopteris quinqueloba*),

TABLE 12.3 List of prioritized FSF

No.	English/Local name	Scientific name	Agro-ecological zone	Characteristics
<b>Cereals</b>				
1	Buckwheat ( <i>mạch ba góc</i> )	<i>Fagopyrum esculentum</i>	Northwest and Northeast	This annual plant is well-adapted to moist climates but has weak cold tolerance. It grows well at temperatures of 15-22 °C and takes 70-90 days to mature
<b>Roots and Tubers</b>				
2	Taro ( <i>Khoai môn sọ</i> )	<i>Colocasia esculenta</i>	Nationwide	An annual plant and tuber stem. Taro thrives in poor soil and attracts few diseases and pests. It is good for intercropping and rotation with other crops
3	Greater yam ( <i>Củ mỡ</i> )	<i>Dioscorea alata</i>	Nationwide	This perennial is suitable for intercropping and can be grown from seeds or tubers
<b>Nuts and Pulses</b>				
4	Cowpea ( <i>Đậu các loạ</i> )	<i>Vigna unguiculata</i>	Nationwide except Mekong river delta	A drought-tolerant and warm-weather crop, well-adapted to the drier regions with poor soils. It is good for intercropping
5	Mung bean ( <i>Đậu xanh</i> )	<i>Vigna radiata</i>	Nationwide	Erect or semi-erect, herbaceous annual that thrives in the warm seasons. It improves soil via nitrogen fixation and can be easily intercropped
<b>Horticulture</b>				
6	Pumpkin ( <i>Bí ngô</i> )	<i>Cucurbita moschata</i>	Nationwide	Annual, herbaceous climber with tolerance to hot, humid weather and resistance to disease and insects

potato-bean, pumpkin, Rau sang (*Melientha suavis*), snake gourd, winged bean and yardlong bean (Table 12.3). However, some of these wild plants have lower quality and yields when grown domestically than they do in their natural habitats.

Viet Nam is well known for its tropical fruits, many of which are exported all over the world. There are many native species of fruit trees and fruit is high in vitamins and nutrients. However, many species are not exploited commercially, and are just grown in people's gardens or picked wild from natural forests. Many of these NUS fruits, including jackfruit, langsat, plum and wampee can help Vietnamese people to meet their nutrition needs.

These fruits and vegetables are suitable for commercial development but it is the pumpkin that meets all the criteria as a FSF in terms of its adaptability, market potential and socio-economic status in Viet Nam.

### 12.3.3 Prioritization results

#### Prioritized FSF 1

#### Buckwheat/*Mạch ba góc* (*Fagopyrum esculentum*)



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#### General characterization

- **Origin and distribution:** Buckwheat is a pseudo-cereal and native to Asia's temperate and tropical zones. In Viet Nam, buckwheat is grown in the mountainous areas of Ha Giang, Cao Bang, Lang Son and Bac Thai provinces.
- **Life form and ecology:** An annual plant, it is adapted to moist and cool climates, with weak cold tolerance, and grows well at temperatures 15-22 °C within 70-90 days.

- **Uses and used parts:** The common uses for buckwheat are as human food, animal fodder, green manure and a nectar source for bees. The flowers are used as ornamental plants in Ha Giang, Ha Noi and others provinces.
- **Yield:** 1-1.5 tonne per ha.
- **Ingredients and health benefits:** Buckwheat seeds contain 71-75 percent starch and 18 percent protein, with bio-availability of 90 percent. Buckwheat is also a rich source of soluble and insoluble dietary fibre, amino acids, iron, zinc and antioxidants. It is also a dietetic product, with many minerals and vitamins, and very light for digestion. The most important nutrient is rutin, which makes veins elastic and regulates blood pressure. It has a favourable effect upon the blood system, liver and digestion.

### Prioritized FSF 2

#### Taro/*Khoai môn sọ* (*Colocasia esculenta*)



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#### General characterization

- **Origin and distribution:** This plant is grown throughout Viet Nam, as well as in Cambodia, Indonesia, Lao PDR and Thailand. It is also cultivated in other tropical regions in Asia, Oceania and Africa.
- **Life form and ecology:** It is an annual plant with a tuber stem. It can be grown both on wet and dry land and in poor soil and attracts few diseases and pests. It is easily cultivated on hilly swidden fields. Its growth period is 6-8 months. It can be intercropped with other crops such as maize, peanut or vegetables with short growth periods. Cultivation in rotation with other crops ensures stable productivity.
- **Uses and used parts:** The tuber can be used as food for humans and for livestock; the stems of the leaves can be used as a vegetable.
- **Yield:** 15-30 tonnes per ha, some varieties can yield 80 tonnes per ha.

- **Ingredients and health benefits:** The fresh root (tuber) stores 69 percent water, 1.8 percent protein, 26.5 percent glucose, 1.2 percent fibre and 1.4 percent ash. It is also a good source of mineral elements (calcium, iron, magnesium and potassium), vitamins such as Beta-caroten, Beta-cryptoxanthin, unsaturated fatty acids and 18 amino acids essential for human health. Traditional medicine uses taro to treat parasites, scabies, snake bites, bee stings, furuncles, mental disorders and fetal derangement.

### Prioritized FSF 3

#### Greater yam/*Củ mỡ* (*Dioscorea alata*)



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#### General characterization

- **Origin and distribution:** This yam is native to Southeast Asia (including Indonesia, the Philippines and Viet Nam and surrounding areas).
- **Life form and ecology:** This is a perennial climbing plant with seed and vegetative propagation.
- **Uses and used parts:** Greater yam has been used for centuries as a food crop and the tuber is cooked or dried and processed into flour.
- **Yield:** 20 tonnes per ha.
- **Ingredients and health benefits:** Nutrient content 30.5-37.9 percent; proteins (of dry matter) 7.5-9.85 percent. It is also a good source of calcium, magnesium, phosphate and sodium, and a rich source of iron, zinc, potassium and beta-caroten, as well as containing 18 amino acids. It has potential as a medical treatment as the anthocyanin pigment can help fight obesity.

**Prioritized FSF 4****Cowpea/Đậu các loại (*Vigna unguiculata*)**

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**General characterization**

- **Origin and distribution:** Cowpea is native to Africa, and cultivated worldwide.
- **Life form and ecology:** A drought-tolerant and warm-weather crop, cowpeas are well adapted to the drier regions of the North and Central provinces of Viet Nam. The plant grows well in poor soils and as an intercropping species. There is a large morphological diversity found within the cowpea crop with 1 193 accessions in National Plant Genebank of Viet Nam.
- **Uses and used parts:** Grains and young leaves are an important daily food and play a part in traditional festivals.
- **Yield:** 1-2 tonnes per ha.
- **Ingredients and health benefits:** Cowpeas provide a rich source of proteins and calories, as well as minerals, amino acids and vitamins. A cowpea seed can offer 25 percent protein and is low in anti-nutritional factors. This diet complements the mainly cereal diet in countries that grow cowpeas as a major food crop. Cowpea can be processed into diversely nutritious foods.

**Prioritized FSF 5****Mung bean/Đậu xanh (*Vigna radiate*)**

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**General characterization**

- **Origin and distribution:** Mung bean is said to originate in India and is now domesticated in Africa and across Southeast Asia including Viet Nam.

- **Life form and ecology:** An erect or semi-erect, herbaceous annual. These are seasonal annuals and highly branched with trifoliate leaves similar to the other legumes. In Viet Nam, mung bean is a multi-purpose crop that fixes nitrogen and so improves soil. It flourishes in the warmer season, and is a short-duration crop, usually flowering within 30-70 days and maturing within 60-110 days of sowing.
- **Uses and used parts:** The grain and leaves are important in daily meals and local festivals.
- **Yield:** 1-2 tonnes per ha.
- **Ingredients and health benefits:** Mung bean is a good source of protein as well as calcium, zinc, and vitamins B2 and B6. It is a rich source of copper, iron, manganese, magnesium, pantothenate, phosphate, potassium and vitamin B1. In traditional medicine mung bean is used as an antiseptic.

**Prioritized FSF 6****Pumpkin/Bí ngô (*Cucurbita moschata*)**

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**General characterization**

- **Origin and distribution:** Pumpkin (*Cucurbita moschata*) is a species which originates in the Americas, probably from Central America or northern South America. It includes cultivars of squash and pumpkin.
- **Life form and ecology:** An annual plant, herbaceous, climber with *tentacle*. *C. moschata* cultivars are generally more tolerant of hot, humid weather than cultivars of *C. maxima* or *C. pepo*. They display a greater resistance to disease and insects, especially to the squash vine borer, and can be used for intercropping and rotation with others crops.
- **Uses and used parts:** Young fruit or ripe, tender shoots, leaves, flowers and seeds of pumpkin are vegetables. Pumpkin can be used for pies, candy and desserts.
- **Yield:** 16 tonnes per ha.

- **Ingredients and health benefits:** High source of vitamins A and C, and beta-carotene, as well as a good source of amino acids. Pumpkin contains a significant amount of antioxidants, tocopherols and carotenoids that might prevent prostate cancer.

## 12.4 Conclusion and recommendations

NUS and FSF crops in Viet Nam have the potential to contribute to improving local income, food security and national nutrition, as most are rich in and micronutrients (vitamins and minerals). Many of the proposed FSF are of indigenous origin and have been domesticated and cultivated by generations of Vietnamese farmers. These include buckwheat, taro, greater yam, cowpea, mung bean and, more recently, pumpkin.

The Government of Viet Nam is aware of the great importance of the nation's biological resources in general, and agricultural resources in particular for the future sustainable development of the country. As a result, concerned agencies have been directed to formulate a range of policies and regulations concerning conservation and the exploitation of agricultural genetic resources. However, there is not yet any specific legislature concerning NUS in Viet Nam.

Minor crops, such as those selected as FSF, have not come under much government scrutiny despite the huge contribution they can make in terms of contributing to national health, ensuring food security and boosting income for local people, especially ethnic or remote minority groups. There has been a lack of development and research into these crops, and UNDP has warned stakeholders about the risks of genetic degradation if these crops are lost due to the expansion of more commercial forms of agriculture in Viet Nam.

There is a great deal of indigenous knowledge regarding NUS crops and FSF, which needs to be collated and studied and there may be highly useful plants in

Viet Nam that have not been included on lists for protection for sustainable development. Currently, only a few sites have been singled out for protection, despite the diverse topographical and ecological nature of Viet Nam. In addition, some of the existing sites of such crops have not been properly managed due to financial and technical constraints. The lack of a database on NUS is also causing setbacks, as information sharing is limited among FSF stakeholders.

The lack of strategic, long-term plans and appropriate policies could lead to the loss of some vital NUS crops. Farmers tend to focus on producing crops that bring immediate benefits as a food or produce to be sold. Food scientists in Viet Nam lack the resources to implement the necessary research in NUS or to promote their benefits. NUS seeds are scarce and there are few agencies willing to put up funds or invest in crops they regard as non-commercial. Market development of these products is still difficult and expensive.

But in a rapidly changing climate, such FSF are vital for our future. There is an urgent need for review of development policies for FSF and NUS conservation. The pressures of increasing population, urbanization and climate change are leading to an erosion of genetic resources. The Government needs to invest and develop policies and national strategies to promote the sustainable use of precious genetic and natural resources.

The Government needs to support conservation strategies and establish central and community gene banks. It is essential that national databases are set up with full documentation to give people information, and to keep track of crops and planting. Communication networks have to be established and links made with the media and via marketing to raise awareness of the importance of FSF and the conservation of NUS. There also needs to be involvement at the community level and government subsidies for training in farming techniques and conservation.

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# 13 West Bengal, India

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## 13.1 Introduction

### 13.1.1 About the state

Lying between 21° 25' 24' and 27° 1' 1' N and 85° 48' 20' and 89° 53' 04' E, the state of West Bengal in eastern India shares its borders with three nations – Bangladesh, Bhutan and Nepal. The climate is tropical and humid except in the northern hilly region close to the Himalayas. West Bengal is an intensely populated state of 91.35 million (2011 census) with 1 029 people per sq km (compared to the Indian average of 325). Although West Bengal is geographically the 12th largest state in India, it ranks fourth in terms of population.

### Agriculture in West Bengal

Agriculture is the predominant occupation of 72 percent of the population. The total area of the state is 8 684 000 ha, of which 5 296 000 ha (or 61 percent) is net sown area with a cropping intensity of 184 percent.

The agricultural sector is characterized by a predominance (90 percent) of small and marginal farmers with average holdings of less than 1 ha. Small and marginal farming communities occupy 84 percent of the state's agricultural land. In addition, about three million landless families have the right to cultivate and grow crops on their land. This arrangement came about after the enactment of "Operation Barga", a land reform movement in rural West Bengal that recorded the names of sharecroppers giving them rights to the land on which they lived.

The cropping pattern is dominated by food crops, which account for about 78 percent of the area under principal crops. Rice is cultivated on 5 848 000 ha (production of 16 148 000 million tonnes) followed by cereals (6 349 000 ha), oilseeds (714 000 ha), jute (609 000 ha) and potato (367 000 ha). This state is the largest producer of rice in India and second largest producer of potato. Over 66 percent of India's jute requirement is met by this state. Tea is the major plantation crop, and 329.3 million kg of tea was produced in 2014-2015, accounting for 27.8 percent of the country's total tea production.

Against the ultimate irrigation potential of 6 743 000 ha, the gross irrigation potential created through major, medium and minor irrigation up to the end of March 2009 was 5 501 000 ha.

West Bengal is a leading producer of freshwater fish and the largest producer of fish seeds (fertilized fish eggs) in India. In the inland fishery sector, West Bengal accounts for 30 percent of total fish production in the country.

### 13.1.2 Agro-ecological zones

The Indian Council of Agricultural Research (ICAR) divided India into 15 broad agro-climatic zones to ascertain scientific management of regional resources and sustainable agricultural development. Of these zones, three are located in the state of West Bengal: Eastern Himalayan Region (Zone II), Lower Gangetic Plain Region (Zone III) and Eastern Plateau and Hilly Region (Zone VIII). Two of these regions have been further stratified into six agro-climatic sub-regions that are described below.

#### Zone II: Eastern Himalayan Region

- a) Hills sub-region (Darjeeling district). Mainly brown forest soil, acidic (pH 3.5-5.0), and with an annual rainfall of 2 500-3 500 mm, high humidity, fewer sunshine hours. The poor soil depth and quality are the reasons for poor productivity. Pre-monsoon showers generally start in March.
- b) Teri sub-region (Jalpaiguri and Coochbehar districts). Soils are mostly sandy to sandy loams, porous, low in base content, poor in available nutrients, acidic (pH 4.2-6.2), chronically deficient in micronutrients, including boron, molybdenum and zinc. In addition there is annual rainfall of 2 000-3 200 mm, a high water table, low water-holding capacity and high humidity. Fewer sunshine hours during the monsoon months and marginal land in some areas limits crop productivity.

### Zone III: Lower Gangetic Region

- a) Old alluvium (North and South Dinajpur and Malda districts). Soils are lighter at higher elevations, and heavier in lower elevations, mildly acidic to neutral (pH 5.2-7.0), fairly fertile. With 1 500-2 000 mm rainfall at higher elevations, and 1 300-1 500 mm at lower elevations, the whole area is prone to flooding.
- b) New alluvium (Murshidabad, Nadia, Hoogly, Burdwan and North 24 Parganas districts). Soils are deep, mostly neutral (pH 5.5-7.0), and mostly fertile thanks to 1 350-1 450 mm rainfall. This is the most productive area of the state in terms of agriculture.
- c) Coastal saline (South 24 Parganas, Howrah and Midnapore (E) districts). Soils are mostly heavy clay, containing higher salts of sodium, magnesium, potassium with organic matter at different stages of decomposition, mostly neutral (pH 6.5-7.5), electrical conductivity 3-18  $\mu\text{S}/\text{cm}$ . The region has 1 600-1 800 mm rainfall and salinity and water congestion that can limit good crop production.
- d) Red laterite (Birbhum, Bankura, and Midnapore (W) districts). Soils are coarse, highly drained with a honeycomb type of ferruginous concentration at 15-30 cm, acidic (pH 5.5-6.2), erosion-prone and nutrient poor. There is 1 100-1 400 mm rainfall, low moisture holding capacity and poor nutrient status, which hinders crop productivity.

### Zone VII: Eastern Plateau and Hill Region

This region covers the Purulia district. Soils are shallow, modulated gravelly, coarse-textured, well drained with low water-holding capacity, and acidic (pH 5.5-6.2). The 1 100 -1 400 mm rainfall is spread over three months (mid-June to mid-September), and upland soils are highly susceptible to erosion. The high slopes of the hill region in the northern part of the state have high rainfall and cooler temperatures year-round; this area is covered with forests, plantations, and orchard crops. Only one-third of this region is cultivated with crops.

#### 13.1.3 Status of West Bengal's food basket: the composition of crops, including staples

Consumers in West Bengal are generally guided by a sustenance principle when choosing food items. Low and fluctuating purchasing power, coupled with an alarming rate of population growth, has kept the population in survival mode rather than improving it qualitatively. Any concern about energy or calorie levels becomes secondary to survival. West Bengal's soil and climate are suited to crops such as rice, wheat, and maize, and so have a major share of the acreage

allocation. As a result, the taste preferences and habits of consumers have been oriented accordingly with cereal-based food items, which play a pivotal role in the daily food basket. Obviously, the low-priced and locally available coarse grains (various forms of rice, pulses, and vegetables) have become staple food items of inhabitants in West Bengal. Rice with fish is the most common food in this state. In the late 1990s, wheat entered the food chain, mainly on the urban fringes.

Rural households primarily thrive on locally produced and available vegetables (e.g. arum, cabbage, cauliflower, drumstick, gourds, lady's finger, potato, pumpkin), pulses (e.g. arhar, black gram, khesari, lentil, mung bean) and leafy vegetables (e.g. amaranthus, fenugreek, spinach), along with rice. The fact remains that intake (in energy terms) or expenditure (in value terms) of non-rice food items is extremely low. However, a perceptible change in per capita income and more equitable distribution of income means that there are fewer people living below the poverty line. People are starting to think beyond 'filling the belly', and nutritional concerns are creeping into the daily food basket. As such, the diet for both vegetarians and non-vegetarians is becoming more balanced. The per capita consumption of pulses, especially arhar, lentil and mung bean, is increasing. Newer food items like broccoli and capsicum are entering the farming system and food habits. At the same time, there is an increasing trend to preserve traditional (and underutilized) crops such as arum, drumstick, neem and taro. Slowly, finer grains (slender rice, scented rice, etc.) are replacing some coarser grains and their acreage allocation. Regrettably, there is a growing trend among the younger generation to turn towards various forms of processed food.

#### 13.1.4 Crop diversity and major cropping patterns

The cropping pattern in West Bengal is dominated by food crops, which account for about 78 percent of the area sown to principal crops. Rice is cultivated on 5 848 000 ha (production of 16 148 000 million tonnes) followed by cereals (6 349 000 ha), oilseeds (714 000 ha), jute (609 000 ha) and potato (367 000 ha). The state is the second largest producer of potato after Uttar Pradesh and one of the highest producers of vegetables in the country. Traditionally, West Bengal has been the highest producer of jute, and accounts for 25 percent of tea production in India.

Crop diversification in West Bengal has largely been in favour of boro rice, potatoes, maize, and oilseeds. Since the late 1990s, horticultural crops have started gaining ground. Diversification has favoured high-value crops or crops which provide a higher relative return to growers.

Important rice-based cropping systems in the various agroclimatic zones of West Bengal (pre-kharif–kharif–rabi cropping season) are listed below.

#### Northern Hill Zone

- 1) Fallow–Rice–Potato
- 2) Maize–Rice–Mustard or Vegetable

#### Terai Zone

- 1) Jute–Rice–Potato
- 2) Jute–Rice–Vegetables
- 3) Vegetable–Rice–Potato
- 4) Rice–Fallow–Rice
- 5) Jute–Rice–Wheat
- 6) Jute–Rice–Tobacco
- 7) Vegetable–Rice–Tobacco

#### Gangetic Alluvial Zone (old and new)

- 1) Rice–Rice–Mustard
- 2) Jute–Rice–Potato
- 3) Rice–Fallow–Rice
- 4) Sesame/Groundnut–Rice–Potato
- 5) Jute–Rice–Wheat
- 6) Mung–Rice–Wheat
- 7) Vegetable–Rice–Mustard
- 8) Rice–Rice–Rice

#### Red Lateritic Zone

- 1) Fallow–Rice–Wheat
- 2) Fallow–Rice–Pulse
- 3) Jute–Rice–Potato
- 4) Vegetable–Rice–Wheat
- 5) Fallow–Rice–Rice
- 6) Sesame–Fallow–Potato
- 7) Maize–Rice–Mung

#### Coastal Saline Zone

- 1) Fallow–Rice–Pulse
- 2) Fallow–Rice–Sunflower
- 3) Fallow–Rice–Chili
- 4) Rice–Rice–Mung
- 5) Fallow–Rice–Cucurbits

- 6) Fallow–Rice–Watermelon
- 7) Fallow–Rice–Cotton
- 8) Dhaincha–Rice–Rice

## 13.2 Situation and gap analysis

### 13.2.1 Hunger and malnutrition

India is facing huge challenges related to the poor nutritional status of the population, particularly in children and women. It is estimated that India loses USD 1.2 billion annually due to pressures on the health system and indirectly from lost productivity (World Bank, 2012). The situation in West Bengal is marginally better than in the rest of the country. In fact, apart from poverty, the main causes of malnutrition in the state are deficiencies in child rearing and poor feeding practices. The nutritional status of infants worsens in higher age groups. The percentage of underweight children below three years was 37.6 percent in the NF-3 survey (ref), which suggests that interventions to prevent declines in nutritional status are needed between six months and three years.

Data on malnutrition in West Bengal is not available separately; however, infant and child mortality rates and anaemic percentages in West Bengal are given in Table 13.2.

A substantial proportion (22.99 percent) of individuals exhibited stage 1 (14.72 percent), and stage 2 (8.27 percent) hypertension and 39.69 percent were in the pre-hypertensive category (ref). Only 2.66 percent were on medication in West Bengal. According to the National Family Health Survey (2007), 6.1 percent of males and 7.1 percent of females were obese in West Bengal. The obesity figures were higher in Kolkata (around 30 percent of women and 18 percent of men), with 11.7 percent being diabetic (National Urban Diabetes Survey, YEAR). According to the India Institute of Technology Kharagpur study, the prevalence of diabetes in rural Bengal is between 3.5 percent and 5.7 percent (ref), with a higher prevalence in three districts: Howrah (13.2 percent), Kolkata (12 percent) and Burdwan (8.7 percent), and comparatively low prevalence in Purulia (2.7 percent), Bankura (3.0 percent), Dinajpur East (3.6 percent) and Dinajpur West (3.5 percent) (IFPRI, 2016).

### 13.2.2 Climate change constraints

West Bengal is prone to climate-related risks and extreme events such as floods, drought and atypical cold spells. More common stresses include the early onset of

**TABLE 13.1** Health conditions across India

India		Prevalence (%)	Health effects
<b>Undernourished</b>		15.1	
<b>Stunted</b>		38.7	
<b>Wasted</b>		15.2	
<b>Mortality under 5 years</b>		4.8	
<b>Micronutrient deficiencies</b>	Vitamin A	250 000-500 000 children	Blindness
	Iron	52% women	Anaemia
	Zinc	Sizeable	Cause of death in children
<b>Overweight</b>		11% adolescents 20% adults	
<b>Obesity</b>			Diabetes

Source: International Food Policy Research Institute

**TABLE 13.2** Infant and child mortality rates and anaemia percentages, urban/rural, West Bengal

Criteria	Urban	Rural	Total
Infant mortality rate (per 1 000 live births)	16	32	27
Under-five mortality rate (per 1 000 live births)	16	38	32
Percentage of children aged 6–59 months who are anaemic (less than 11.0 g/dl)*	55.6	53.7	54.2
Percentage of women aged 15–49 years who are anaemic	58.2	64.4	62.5

\* Haemoglobin in grams per decilitre (g/dl)

Source: National Family Health Survey-4 (2015-16). International Institute for Population Studies, Mumbai.

terminal heat for winter crops and uncertain timing and duration of monsoonal rains, thereby increasing the risk for staple cereal crop production.

From 1969-2005 (37 years), maximum temperatures decreased across West Bengal while minimum temperatures increased. In the New Alluvial, Laterite, and Saline Coastal zones, maximum temperatures have increased by more than 0.5 percent. Minimum temperatures have increased by 0.5°C in the Laterite zone, 1.5°C in the Hilly, Terai, and Old Alluvial zones 1°C in the New Alluvial and Coastal zones.

In terms of precipitation, a recent report by the IMD (Status of Climate in India, 2010, IMD) indicates distinct changes in the observed pattern of rainfall between 1901 and 2003 in the northern (Darjeeling, Jalpaiguri Cooch Behar, Uttar Dinajpur and Dakshin Dinajpur, and Malda) and southern (remaining districts south of Malda) regions of West Bengal. In the southern region, rainfall in the winter and pre-monsoon seasons has decreased by 14.5 mm and 6.7 mm, respectively, and increased in the monsoon and post-monsoon seasons by 57 mm and 25 mm, respectively. In the northern region, rainfall has increased

in the pre-monsoon and monsoon seasons by 10.5 mm and 91 mm, respectively, and decreased in the winter and post-monsoon seasons by 1.7 mm and 5 mm, respectively.

In the monsoon period, June rainfall has decreased by 3.1 percent in the northern region and 0.9 percent in the southern region. No change has been observed in July precipitation in the southern region, but a perceptible increase of 4.5 percent in the northern region. In August, there has been an overall reduction of 0.2 percent and 0.1 percent in the southern and northern parts of West Bengal, respectively. In September, the southern region shows an increasing trend (more than 2.5 percent), while the northern region has declined by 1.1 percent.

### 13.2.3 Market and economic constraints

Production and market-based failures are factors that restrict the adoption of improved farming practices and increased crop yields; risk-reducing technologies are urgently needed as a pathway to sustainable intensification. Further, there are pervasive socio-economic changes occurring that have led to large-scale migration and hence labour shortages and more involvement of women in agriculture.

### 13.2.4 Cultural relevance and local availability

The culture of Bengal encompasses the Bengal region in South Asia, including Bangladesh and the Indian states of West Bengal, Tripura, and Assam (Barak Valley), where Bengali is the official and primary language. Bengal has a recorded history going back 4 000 years and its partition in 1947 has left its own cultural legacy. The partition of Bengal that followed independence from the British in 1947 separated West Bengal from Bangladesh. This caused a significant change in demographics. Populations were divided along religious lines and over three million people were said to have crossed the new Bengal border in either direction. This large-scale displacement along religious lines led to some changes in food and farming, because there were differences in food habits between the Muslims and the Hindus. However, large populations of each religion remained on either side of the border. There are also numerous ethnic

and religious minorities. Bengali cuisine is one of the most extensively developed in Asia. It is notable for its widespread use of freshwater fish and seafood. Bangladeshi cuisine includes more meat, including beef, duck, chicken, mutton, squab and venison. Indian Bengali cuisine is mainly vegetarian, but consumption of chicken, mutton, egg, and pork is common but beef is taboo due to the predominance of Hindu culture. The region is also noted for its vast array of desserts, sweets and confectionery.

## 13.3 Scoping and prioritization of Future Smart Food

### 13.3.1 Scoping of availability of FSF

Table 13.3 lists FSF for West Bengal based on climate change adaptations to untimely rainfall, drought and other factors, market and economic potentials, and sociocultural importance.

**TABLE 13.3** List of FSF and their priority level, West Bengal

Sl. No.	English/local name	Scientific name	Accessions	Priority
<b>Cereals</b>				
1	Aromatic rice ( <i>Kalo Nunia</i> )	<i>Oryza sativa</i>		1
2	Buckwheat	<i>Fagopyrum esculentum</i>		2
3	Finger millet	<i>Eleusine coracana</i>		3
4	Sorghum	<i>Sorghum bicolor</i>		4
5	Barley	<i>Hordeum vulgare</i>		5
6	Oat	<i>Avena sp.</i>		
7	Pearl millet	<i>Pennisetum glaucum</i>		6
<b>Roots and tubers</b>				
1	Swamp taro	<i>Cyrtosperma chamissonis</i>		1
2	Elephant foot yam ( <i>Ol kachu</i> )	<i>Amorphophallus campanulatus</i>		2
3	Sweet potato	<i>Ipomoea batatas</i>		3
4	Asiatic yam	<i>Dioscorea esculenta</i>		
5	Turmeric	<i>Curcuma longa</i>		5
6	Radish	<i>Raphanus sativus</i>		6
7	White yam	<i>Dioscorea rotunda</i>		
8	Beetroot	<i>Beta vulgaris</i>		
9	Jerusalem artichoke	<i>Helianthus tuberosus</i>		
10	Garlic	<i>Allium sativum</i>		4



Sl. No.	English/local name	Scientific name	Accessions	Priority
<b>Nuts and pulses</b>				
1	Lentil	<i>Lens culinaris</i>		1
2	Black gram	<i>Vigna mungo</i>		2
3	Mung bean	<i>Vigna radiata</i>		3
4	Pigeon pea	<i>Cajanus cajan</i>		
5	Grass pea	<i>Lathyrus sativus</i>		4
6	Pea	<i>Pisum sativum</i>		
7	Horse gram	<i>Macrotyloma uniflorum</i>		
8	Faba bean	<i>Vicia faba</i>		6
9	Rice bean	<i>Vigna umbellata</i>		5
10	Chickpea	<i>Cicer arietinum</i>		
<b>Horticulture</b>				
1	Jackfruit	<i>Artocarpus heterophyllus</i>		1
2	Drumstick	<i>Moringa oleifera</i>		2
2	Amaranth	<i>Amaranthus sp.</i>		4
3	Fenugreek	<i>Trigonella foenum-graecum</i>		3
4	French bean	<i>Phaseolus vulgaris</i>		
5	Ash gourd	<i>Benincasa hispida</i>		
6	Ridge gourd	<i>Luffa acutangula</i>		
7	Pumpkin	<i>Cucurbita moschata</i>		
8	Snake gourd	<i>Trichosanthes anguina</i>		
9	Jamun	<i>Syzygium cumini</i>		6
10	Indian olive	<i>Elaeocarpus floribundus</i>		5
<b>Others</b>				
1	Tamarind	<i>Tamarindus indica</i>		1
2	Elephant apple	<i>Dillenia indica</i>		2
3	Burmese grape	<i>Baccaurea ramiflora</i>		6
4	Black cumin	<i>Nigella sativa</i>		
5	Coriander	<i>Coriandrum sativum</i>		
6	Ajowan	<i>Trchyspermum ammi</i>		
7	Indian bael	<i>Aegle marmelos</i>		3
8	Ber	<i>Ziziphus mauritiana</i>		4
9	Kamranga/Carambola	<i>Averrhoa carambola</i>		5
10	Jamrul	<i>Syzygium jambos</i>		

### 13.3.2 Prioritization analysis

#### Cereals

In West Bengal, the agro climate is very suitable for rice cultivation not only in monsoon but also in winter, however, some difficult areas which are drought prone, sloping, or have less fertile soil have tremendous scope for other cereal crops such as buckwheat, millet or sorghum. One aromatic rice, *Kalo Nunia* has the potential to grow in flood prone areas under a system of organic farming. Farmers cultivate these crops for a variety of uses including food and medicine. However, recently production areas have decreased to make space for more commercial crops. So conservation of the germplasm and the development of drought or flood tolerant varieties is required.

The aromatic rice type *Kalo Nunia*, millets and buckwheat contain a large proportion of carbohydrates and can provide the bulk of energy in diets. Millet is also rich in protein, minerals, sulphur-containing amino acids with low glycemic index and high fibre, so is recommended for diabetic patients. Buckwheat seeds have a high nutrition content of 71-75 percent starch and 18 percent protein. It also contains higher levels of copper, manganese and zinc than other cereal grains. In addition, buckwheat is a rich source of polyphenols, antioxidants and aromatic compounds. Sorghum is another drought-resistant crop which has long been grown in the mountain areas of West Bengal for food and livestock. But over the years this plant has become neglected and is cropped less often now than in times past.

Due to the of FSF priority criteria regarding economic, nutritional, social, cultural perspectives and restriction of priority selection, no cereals were recommended at this time for the programme.

#### Roots and tubers

In West Bengal, roots and tubers are traditional crops and commonly used in daily life by people as vegetables. Taro contains high amounts of potassium, calcium, and vitamins C, E and B, in addition to copper, magnesium and manganese. Its leaves contain large quantities of vitamins A and C, fibre and protein. This crop has also properties of flood tolerance and is an important crop in the monsoon period.

Different types of roots and tubers were selected as NUS priorities, including nine species: Asiatic palm, beetroot, elephant foot yam, ginger, Jerusalem artichoke, radish, swamp taro, sweet potato and white yam.

The main nutritional value of roots and tubers lies in their potential ability to provide a cheap source of dietary energy in developing countries in the form of carbohydrates. This energy is about one-third of that of an equivalent weight of grains, such as rice or wheat, because tubers have a high water content. However, the high yields of most root crops ensure an energy output per hectare per day which is considerably higher than that of grains (FAO, 1990). For each 100 g dry weight, elephant foot yam contains 75.2 g starch, 12.5 g proteins, 0.98 g lipids, 3.27 g non-protein derivatives, 3.67g cellulose and 4.42 g ash. Its starch rate is almost double that of taro and it includes high rates of glucomannan which can be an anti-obesity treatment. Its purple pigment has significant anthocyanin levels and antioxidants which have potential in the medical sphere.

Root and tuber crops are important subsidiary or subsistence food and nutritional crops in West Bengal. Tropical root and tuber crops have better adaptability to varying climatic conditions and play a significant role in meeting the food and feed requirements of the people. They have potential for the commercial market and some of them are used as materials for industrial processing, medicine, etc.

So with regard to their socioeconomic potential and under the FSF criteria, swamp taro and elephant foot yam have been selected for top priority.

#### Nuts and pulses

Pulses and nuts are all valuable sources of protein as well as being low in saturated fat and sodium and are also cholesterol free. They are also good sources of fibre, complex carbohydrates, vitamins and minerals including thiamine (B1) riboflavin (B2), niacin (B3), folate, calcium, potassium, iron and phosphorus. Nuts can be a good alternative to snacks which are high in saturated fat. They are a good source of monounsaturated fat, which can help reduce levels of cholesterol in the blood.

Pulses are important foods and have the advantage over animal proteins of being both inexpensive and versatile in how they are cooked, as well as being packed with nutrients. Due to their high soluble-fibre content, legumes are believed to help reduce blood cholesterol. They also have a very low glycemic index, which means they are absorbed relatively slowly into the blood stream and do not cause sudden increases in glucose blood levels. This makes this group of foods particularly beneficial for anyone who has diabetes and those at risk of developing this disease. This includes people who are overweight or have a family history of diabetes.

Pulses can be grown as intercrop with other crops to increase biodiversity and diversity of animals and insects. Pulses have a unique position in Indian agriculture because they provide food and fodder as well as add nitrogen and carbon to the soil and make it healthy for other crops. In fact, each legume plant is a 'mini fertilizer plant'.

India produces a quarter of the world's total pulses, accounting for one-third of the total global acreage under pulses. Indians consume 30 percent of the world's pulse production. The domestic production of pulses has not kept pace with population growth. Even though Indians today are consuming far fewer (41.9 grams per capita per day in 2016 from 69 grams per capita per day as of 1961) (Chand *et al.* 2015). There is a big gap at national level in the demand and supply of pulses, and the state of West Bengal is no exception to this.

Among the 10 different pulses listed, only lentil has been selected as an FSF priority crop due to its wide variation, cultivation practices and its wide adoptability in climatic conditions.

### Horticulture

Many underutilized, nutritious horticultural crops (fruits and vegetables) are cultivated, traded, and consumed locally. These crops have many advantages such as being easier to grow and hardy in nature, producing a good crop even under adverse soil and climatic conditions. So, exploitation of these underutilized horticultural crops can become a solution to the problem of health and nutrition insecurity, poverty and unemployment. The consumption of underutilized horticultural crops can provide nutrition to the poor by meeting the nutrient

requirements of vulnerable groups. Underutilized fruits, nuts, and vegetables are a rich source of carbohydrates, fats, proteins, energy, and vitamins including A, B1, B2, B3, B6, B9, B12, C and folic acid, as well as being good sources of dietary fibre and minerals including calcium, phosphorus and iron. They have the nutritional capacity to prevent various diseases like anaemia, cancer, diabetes, hidden hunger, hypertension, kwashiorkor and night blindness. It is also an established fact that seasonal, locally available, and cheap fruits and vegetables can keep the population healthy and nutritionally secure more effectively than costly off-season ones. Also, the underutilized crops have the potential to give economic security to rural people by enhancing employment opportunities and by fetching good returns from their sale in raw form and as value-added products.

Among the 10 different horticultural crops like amaranth, ash gourd, drumstick, fenugreek, French bean, Indian olive, jackfruit, jamun, pumpkin, ridge gourd and snake gourd, only drumstick, fenugreek and jackfruit have been selected as priority for intervention.

### Other crops

Other crops, such as ajowan, ber, black cumin, Burmese grape, coriander, elephant apple, Indian bael, jamrul, kamranga and tamarind were selected as FSFs. These crops are highly nutritious, with wide climatic adoptability and huge market potential. However no crop was given top priority.

### 13.3.3 Prioritization results

Based on the above findings, a list of prioritized FSFs is given in Table 13.4.

**TABLE 13.4** List of prioritized FSF, West Bengal

Sl. No.	English name	Scientific name	Agroecological zone
<b>Roots and Tubers</b>			
1	Swamp taro	<i>Crytosperma chamissonis</i>	Terai and Gangetic alluvial
2	Elephant foot yam ( <i>OI kachu</i> )	<i>Amorphophallus campanulatus</i>	Terai and Gangetic alluvial
<b>Nuts and Pulses</b>			
3	Lentil	<i>Lens culinaris</i>	All zones
<b>Horticulture</b>			
4	Jackfruit	<i>Artocarpus heterophyllus</i>	All zones
5	Drumstick	<i>Moringa oleifera</i>	All zones
6	Fenugreek	<i>Trigonella foenum-graecum</i>	All zones

### 13.3.4 Details on prioritized FSF

#### Prioritized FSF 1:

Swamp taro (*Cyrtosperma chamissonis* (Schott) Merr.)



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#### General characterization

- **Origin and distribution:** Grown throughout Oceania and into South and Southeast Asia. It is a riverine and swamp crop similar to taro but with bigger leaves and larger, coarser roots.
- **Life form and ecology:** Plants may reach heights of 4–5 m, with leaves and roots much larger than *Colocasia esculenta*. It is relatively resistant to diseases and pests. It is not suitable for growing in upland or rain-fed conditions; it is adapted to growth within freshwater and coastal swamps.
- **Uses and used parts:** Giant swamp taro contains toxins which must be removed by cooking for long periods. The stem requires prolonged boiling, with the water replaced once to remove irritating chemicals. If cooked carefully, the rhizomes taste like taro and the leaves like spinach.
- **Yield:** around seven tonnes per ha; growth duration 160–170 days.
- **Ingredients and health benefits:** Taro is loaded with potassium, an important mineral for many bodily processes. Taro also contains calcium, vitamins C, E and B, in addition to copper, magnesium and manganese. Taro leaves contain large quantities of vitamins A and C, fibre and protein.

#### Prioritized FSF 2:

Elephant foot yam (*Oi kachu*)  
(*Amorphophallus campanulatus*)



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#### General characterization

- **Origin and distribution:** Tropical tuber crop grown primarily in Africa, South Asia, Southeast Asia, and the tropical Pacific islands. Because of its production potential and popularity as a vegetable in various cuisines, it can be raised as a cash crop.
- **Life form and ecology:** Prefers a rich red-loamy soil with pH 5.5–7.0. Requires well-distributed rainfall with humid, warm weather during the vegetative phase and cool, dry weather during corm development.
- **Uses and used parts:** The corm is edible. The upper portion is also used as a vegetable.
- **Yield:** 30–40 tonnes per ha; growth duration eight months.
- **Ingredients and health benefits:** Widely used in Indian medicine and a recommended remedy in all three major Indian medicinal systems: Ayurveda, Siddha, and Unani. The corm is prescribed for abdominal pain, asthma, bronchitis, diseases from vitiated blood, dysentery, elephantiasis, emesis, enlarged spleen, piles and rheumatic swellings. Pharmacological studies have shown a variety of effects, specifically analgesic, and cytotoxic activities. It also has the potential for reducing bacterial activity when used with antibiotics.

**Prioritized FSF 3:****Lentil (*Lens culinaris*)**

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**General characterization**

- **Origin and distribution:** An early domesticated plant species, as old as those of einkorn, emmer, barley and pea. Lentils probably originated in the Near East and rapidly spread to Egypt, central and southern Europe, the Mediterranean Basin, Ethiopia, Afghanistan, India, Pakistan, and China. Important lentil-growing countries include Bangladesh, Canada, China, India, Iran, Nepal, Syria and Turkey.
- **Life form and ecology:** A well-adapted plant that grows in a wide range of soil types; sandy loams are the most suitable for growing lentils but heavy textured soils reduce yields. Lentils can be raised in rain-fed drought-prone areas.
- **Uses and used parts:** Prepared using several methods including soaking, boiling, sprouting and germination, fermentation, frying and dry heat. Other benefits include lentil snacks and medicinal products. Lentil straw is a valued animal feed due to its low cellulose levels. Vegetative parts can be used as green manure.
- **Yield:** 1-2 tonnes per ha; growth duration 3-4 months.
- **Ingredients and health benefits:** The seed has relatively high contents of calories, carbohydrate and protein compared to other legumes. Lentil is a desired crop because of its high average protein content and fast cooking time. Seeds are a source of commercial starch for the textile and printing industries.

**Prioritized FSF 4:****Jackfruit (*Artocarpus heterophyllus*)**

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**General characterization**

- **Origin and distribution:** Native to parts of South and Southeast Asia and believed to have originated in the southwestern rainforests of the Western Ghats in the Indian subcontinent. It is found in most South Asian countries.
- **Life form and ecology:** The tree is 9-21 m tall, with evergreen, alternate, glossy, somewhat leathery leaves 22.5 cm long, oval on mature wood, sometimes oblong or deeply lobed on young shoots. Short, stout flowering twigs emerge from the trunk and large branches, or from the soil-covered base of very old trees. The interior consists of large 'bulbs' (fully developed perianths) of yellow, banana-flavoured flesh, massed among narrow ribbons of thin, tough undeveloped perianths (or perigones), and a central, pithy core. Each bulb encloses a smooth, oval, light-brown 'seed' (endocarp) covered by a thin white membrane (exocarp). Jackfruit is adapted to humid tropical and near-tropical climates. It is sensitive to frost in its early life and cannot tolerate drought. If rainfall is deficient, the tree must be irrigated. In India, it thrives in the Himalayan foothills and from sea level to an altitude of 1 500 m in the south.
- **Uses and used parts:** Jackfruit is a sweet, delicious and exotic fruit that is packed with many nutrients and benefits. It is also used as a vegetable in Indian cuisine.
- **Yield:** 25-100 fruits per plant, perennial.
- **Ingredients and health benefits:** a rich source of carbohydrates, electrolytes, fat, fibre, minerals, phytonutrients, protein and vitamins. The fruit contains no cholesterol or saturated fats. Jackfruit is consumed for its flavour, and many health benefits. It contains antioxidants, flavonoids and phytonutrients that protect from cancer. The antioxidants in jackfruit protect the body from free radicals. Jackfruit contains potassium that maintains sodium levels in the body as well as fluid levels to balance electrolytes. So, it is useful for reducing high blood pressure, and the risk of stroke and heart attack.

**Prioritized FSF 5:****Drumstick (*Moringa oleifera*)**

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**General characterization**

- **Origin and distribution:** Originating in South West India, drumstick became a popular vegetable in South Indian states. The crop is widely distributed in Cuba, Egypt India, Jamaica, Malaysia, Pakistan, Singapore and Sri Lanka.
- **Life form and ecology:** Small to medium-sized perennial tree of about 10 m height with a fragile and corky stem. Flowering varies with location and is greatly influenced by rain, temperature, humidity, wind, soil temperature and soil moisture.
- **Uses and used parts:** All parts of this tree are useful either for nutritional or medicinal purposes. This tree has small leaves, white flowers and seedpods which are long, slender and triangular, resembling drumsticks. For cooking, the leaves, flowers and pods are used for their miraculous health benefits. Bark and roots are used in traditional medicines.
- **Yield:** 20-40 tonnes per ha.
- **Ingredients and health benefits:** Helps in the management of cardiac disease. Contains no cholesterol and is beneficial for patients suffering from hypertension. Constant ingesting of drumstick and its leaves is thought to decrease the probability of getting cancer and it is thought to be particularly useful for women recovering from breast cancer. Rich in beta-carotene and vitamin A, it improves vision and prevents ageing macular degeneration. It is also beneficial for managing sugar levels in diabetics.

**Prioritized FSF 6:****Fenugreek (*Trigonella foenum-graecum*)**

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**General Characterization**

- **Origin and distribution:** Indigenous to countries bordering the eastern shores of the Mediterranean, extending to Central Asia and South Eastern Europe. Grown in India, and parts of North Africa, Argentina, France, China, Pakistan and Morocco.
- **Life form and ecology:** An annual plant in the family *Fabaceae*, with leaves consisting of three small oblong leaflets. Fenugreek is cultivated worldwide as a semi-arid crop. Its seeds are a common ingredient in dishes from South Asia. It has wide adaptability and is successfully cultivated in the tropics as well as temperate regions. It is tolerant of frost and freezing weather. Fenugreek does well in areas of moderate to low rainfall but not heavy rainfall. It can be grown in a wide variety of soils, but prefers clayey loam. The optimum soil pH is 6.0–7.0.
- **Uses and used parts:** Fenugreek is used as an herb (dried or fresh leaves), spice (seeds), and vegetable (fresh leaves, sprouts, and microgreens). Sotolon is the chemical responsible for fenugreek's distinctive sweet smell. Cuboid-shaped, yellow- to amber-colored seeds are frequently encountered in the cuisines of the Indian subcontinent, both whole and powdered in the preparation of pickles, vegetable dishes, *daals*, and spice mixes such as *panch phoron* and *sambar*. They are often roasted to reduce bitterness and enhance flavour.
- **Yield:** 1 200-1 500 kg per ha of seed and 800-1 000 kg per ha leaves.
- **Ingredients and health benefits:** The health benefits of fenugreek include relief from anaemia, biliousness, dandruff, diabetes, fever, inflammation, insomnia, loss of taste, mouth ulcers, respiratory disorders, sore throat, stomach problems and wounds. Fenugreek appears to slow the absorption of sugars in the stomach and stimulate production of insulin. In traditional Chinese medicine, the spice is known as a phlegm mover and is said to cool inflammation within the body.

TABLE 13.5 Prioritized FSF with possible interventions, West Bengal

Group	Crop	Possible interventions
Root crops	Swamp taro, Elephant foot yam	i. Germplasm collection and identification of elite genotypes ii. Area expanding to marginal land of waste after slash–burn cultivation iii. Standardization of agronomic practices
Pulses	Lentil	i. Incorporation of high yielding varieties in existing rice–wheat, rice–rice or rice–oilseeds cropping systems ii. Inclusion of short duration varieties iii. Biotic stress management iv. Adoption of resource conservation technology v. Development of high nitrogen-fixing varieties, selection of efficient <i>Rhizobium</i> and PSB strains
Horticultural crops	Jackfruit, Drumstick	i. Germplasm collection and identification of elite genotypes ii. Standardization of organic production technology iii. Integrated disease and pest management
Others	Fenugreek	i. Exploration of intercropping with maize/other crops ii. Standardization of production technology

### 13.4 Conclusion and recommendations

A variety of nutritious, underutilized but useful foods grow in West Bengal, but only benefit those who live in the areas where they are grown. The problem is that most of the local foods cannot be stored long-term and preservation technologies have not been locally developed. This has resulted in a shift to foods like cereals and pulses which may not be as nutritious but can be stored easily. Local food is losing favour even in rural areas despite being readily available. Many of the younger generation are unaware of many of these food items.

Local foods are rarely a subject of research. Recently, ICAR made efforts to increase consumption of healthy foods through the development of superior varieties of indigenous and underutilized crops such as bankla,

buckwheat, cowpea, cluster bean, fenugreek, kakdi, photo, ras bhari, sem, tinda and wild brinjal.

The prioritized crops identified for intervention are root crops (swamp taro, elephant foot yam); pulses (lentil); horticultural crops (jackfruit, drumstick); and others (fenugreek). There are many other underutilized crops in the diet of Bengali people (see Table 13.5).

Research on these crops shows they have great potential for sustainability, profitability and diversification of cropping systems in West Bengal. Specific strategies and dynamic approaches are required to sustainably manage these crops. Work on the conservation, utilization and sustainable use of such crops should be emphasized. Priorities for future collection and exploration and diversity are required. Basic studies should be made on species to be introduced and conserved.

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# 14 Conclusion: Way forward

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*“Agriculture diversification with sustainable intensification is indispensable to address hunger and malnutrition in a changing climate.”*

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Hunger, food insecurity and malnutrition are major challenges for Asia and the Pacific region in the twenty-first century. To achieve Zero Hunger, which stands at the core of the SDGs, food systems urgently need to be improved and dietary patterns have to change. There is a disconnect in the value chain between production, consumption and nutrition: current agricultural production patterns are not sustainable, are unlikely to achieve necessary growth rates and do not offer the right mix of nutrients needed for a healthy diet. Consumers are often unaware of their potential food choices and stick to dietary patterns that do not suit an urbanized lifestyle. Poor people's diets are still overly-dependent on a few staple crops that lack important nutrients and minerals; at the same time, the newly affluent strata of society are increasingly likely to suffer from obesity and related health issues.

A sustainable food system is defined as a food system that ensures food nutrition, and nutrition for all, in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised (HLPE, 2014). Ensuring sustainable food production systems (SDG Target 2.4) is one important target under SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030.

All United Nations Member States are committed to the SDGs, and the awareness of the importance of sustainable food systems has reached a high level among governments. Farmers and other stakeholders whose livelihoods, health and incomes are challenged by climate change and price turbulence are certainly aware of it.

However, many Asian farmers have grown up knowing only input-intensive rice farming, and many consumers make dietary choices that are unhealthy or unsustainable. An increasing number of people eat greater volumes than necessary and prefer foods that are high in sugar, salt and fat, partially due to the lack of knowledge on what constitutes a healthy diet. This trend leads to various forms of malnutrition and high levels of food waste.

Traditional food systems have developed over hundreds of years in Asia, featuring a wide abundance of crops. However, the importance of some crops in modern society has been declining and many are now considered neglected. We need to recognize that preference and policy support provided for cash crops or monocropping have driven that transition. It has led to today's situation in which many of the region's neglected species are no longer found in the agricultural sphere, but are confined to the region's forests and wetlands. The disconnect with current agricultural practices is a systematic and multidimensional problem that requires interdisciplinary solutions starting with the identification of appropriate NUS, or FSF for prioritization in each country.

To achieve SDG2 calling for Zero Hunger, agriculture must be more sustainable – we have to prioritize a paradigm shift: 'save and grow'. One challenge is the unsustainable agricultural production patterns resulting from the over-reliance on high inputs. Unsustainable high-input, intensive crop production and monocultures have led to environmental degradation through pollution, deforestation, desertification, soil erosion, salinization and depletion of soil nutrients. Apart from the ecological damage, conventional high-input

agriculture does not work well in marginal areas, which is one reason for the perceived production gap between rich and poor areas.

If we are to achieve Zero Hunger, agriculture must be reoriented – we have to make food and agriculture more nutrition-sensitive. We observe a clear connection between malnutrition, low dietary diversity, and limited diversity in agricultural production. Over-reliance on one staple crop is a leading cause of persistent malnutrition. In Asia, the dependency mainly on rice and the low consumption of vegetables and fruits leads to insufficient intake of nutrient-rich foods, which in turn leads to a significant ‘nutrition gap.’

If we are to achieve the SDGs, agriculture must be more efficient – we need to produce enough high-quality, low-cost food for the poor, and to stop allowing it to rot along the value chain. Moreover, production must be environmentally sustainable or it will not be efficient, and we will deplete our natural resources. Food must make people healthy, not just offer starch and empty calories. Adding to the challenge, improved production of more nutritious food has to happen in the context of major uncertainties, including climate change, demand for biofuels and price volatility.

To address the current nutrition and production gaps in agriculture and food systems, countries need to promote agricultural diversification and sustainable intensification. This requires an integrated approach combining both nutrition-sensitive and climate-smart agriculture. This is especially meaningful for the rural poor, who suffer the most from the production and nutrition gaps, as well as from shocks and uncertainties. It should not be forgotten that the vital food systems in Asia, featuring a wide variety of food crops that are nutrition-dense and climate-resilient, have been declining in recent times, and many traditional crops are now considered neglected. We need to recognize that preference and policy support provided for cash crops or monocropping have driven that transition.

Agricultural diversification and sustainable intensification offer enormous opportunities for addressing hunger and malnutrition especially in the context of climate change. In this regard, NUS offer diverse and nutritious food resources. NUS are important in specific agro-ecological niches and are often linked with the traditions and cultural heritage in their places of origin. They are an essential source of protein and micronutrients, enhance climate resilience, improve agricultural sustainability and boost household income and livelihoods thanks to their considerable commercial potential.

While NUS are abundant in most Asian countries, their potential nutritional and market value, as well as their suitability for climate adaptation and mitigation, are underexploited. Not only are these crops inadequately characterized, but also their nutrient contents are yet to be systematically analysed. Significant research, nutrient content identification, and policy analysis will pave the way to an enabling environment in which the promising nutrition and commercial potential of FSF can materialize. Wider adaptation is needed to tap the hidden potential of agro-biodiversity to address the challenge of hunger and malnutrition in the changing climate. Rediscovering their value, and providing tailor-made policies and technical support for their wider application, post-harvest and value chain development will help to alleviate malnutrition and reintroduce diversity into the diets of millions.

Governments need to shift their focus from staple crops only and tap into the huge potential of alternative crops that are nutrition-dense and climate-resilient. These crops need to be economically viable, socially acceptable and locally available. The limited production diversity has partly been caused by a bias towards agricultural policies that favour staple and cash crop production to reduce hunger without targeting micronutrient deficiencies.

This publication expands on the message formulated by a Regional Expert Consultation on Scoping, Prioritizing and Mapping of NUS, organized by FAO in collaboration with national and international partners, which was held in Bangkok from 3–5 December 2016. A panel of experts representing eight countries, as well as 22 national and international partners, attended the Consultation and developed ten key recommendations as follows:

- 1 Issue an urgent call for all national decision makers to raise awareness of the nutrition-sensitive and climate-resilient benefits of NUS to address hunger, malnutrition and climate change.
- 2 Recognize, identify and promote the complementarities of NUS with existing staple crops for nutrition enhancement, climate change resilience and diversification of cropping systems, and re-label NUS as ‘Future Smart Food (FSF)’ to popularize these species.
- 3 Establish a National Coordinating Committee on FSF involving concerned ministries and appoint a Strategic Coordinator at the inter-ministerial level.



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- 4 Create an enabling environment by strengthening national institutional support for mainstreaming FSF into national policies and programmes, using appropriate incentives, procurement of FSF for food programmes (e.g. mid-day meal/school meal schemes) to enhance national consumption, local production and facilitate marketing.
5. Establish nationally coordinated research for development programmes targeting FSF with high potential, and expand coverage of national agriculture statistics and national food composition data on FSF for evidence-based decision making.
- 6 Document and validate best-bet FSF case studies, compile indigenous knowledge related to FSF, undertake clinical and field studies to demonstrate the health benefits and climate resilience of FSF, and assemble quantitative data for public dissemination.
- 7 Enhance public awareness of the importance of FSF by developing nutrition and climate change education materials and curricula on the importance of FSF for consumers, traders, producers, health professionals, researchers, teachers (e.g. school curricula), farmers, women and youth.
- 8 Identify key entry points in the value chain and encourage value chain development for specific FSF, including innovative and targeted interventions for promotion (e.g. ready-to-use food products) and increase funds for research, development and extension capacities on FSF production and processing technologies.
- 9 Strengthen multi-disciplinary and multi-sectoral collaboration through existing coordination mechanisms and build partnerships at national and regional levels, including academia, civil society and the private sector, to enhance research and consumption and to attract the private sector to boost production, processing, value addition, product development, and marketing of FSF.
- 10 Establish a regionally coordinated network on FSF to facilitate the exchange of information, policy, technologies and genetic resources as well as FSF promotion in target countries.

Addressing hunger and malnutrition in a changing climate is considered a top priority by most countries in Asia. Within an agricultural diversification and sustainable intensification strategy, promoting FSF through a food systems approach is a cost-effective intervention to address the dual challenge of malnutrition and climate change. An enabling environment for promoting FSF is essential and requires a long-term vision and holistic approach that integrates political, economic and

environmental aspects, multi-stakeholder cooperation, and forward-looking institutions covering production, marketing and consumption stages.

### National food security and nutrition strategy framework and governance

- Strengthen existing and establish new and innovative national, regional and international institutions and mechanisms that focus on agricultural diversification and ensure intersectoral collaboration.
- Promote strong commitments on agricultural diversification and mainstreaming FSF into national food security and nutrition strategy frameworks.
- Initiate policy reforms to include FSF in crop diversification programmes specifically to address malnutrition.
- Provide supporting policies, such as including FSF in school feeding programmes, promoting them as components in sustainable diets, enriching food aid with nutritious underutilized crops, and subsidizing cultivation and marketing of crops.
- Provide incentives to support farmers to grow and conserve NUS on their farms, complemented by incentives to conserve these crops *ex-situ*. Mainstream best practices, methods and tools relating to these crops into routine operations. At the international level, including NUS in the Annex 8 International Treaty on Plant Genetic Resources for Food and Agriculture will be important.
- Enhance public services, particularly in health, commerce and education sectors for FSF.

### Research

- Help direct national research programmes towards incorporating higher levels of biological diversity in production systems.
- Include NUS in research addressing screening and selection of high-yielding improved cultivars adaptable to different agro-climatic conditions.
- Identify improved agronomic practices for soil and water management, pest and disease control, integrated pest control, weed control etc.
- Identify good agricultural practices, and appropriate cropping systems and patterns for the selected FSF to suit the different agro-climatic zones prevailing in different areas of the country.

- Develop pilot initiatives at a sub-national scale to test and assess promising measures. If proven effective, these could then be scaled up under national agricultural policies and the national adaptation programmes of action for crop diversification to address malnutrition.
- Strengthen links between international and regional institutions engaged in NUS technology development to facilitate knowledge sharing.

### Seed and planting material

- Provide adequate seed or plant material of improved cultivars freely to smallholder farmers in remote agricultural areas in the country.
- Screen the available genetic resources for improved varieties.
- Establish a multiplication and distribution system.
- Establish a systematic seed and planting material production and distribution mechanism through united efforts involving national institutions such as the ministry of agriculture, plant genetic resource centres, agricultural research institutions, NGOs and seed production farm units.

### Field production

- Provide good agricultural practices for FSF to smallholder farmers to enhance crop productivity under diverse agro-ecological domains.
- Identify good agronomic practices relating to operations including planting, irrigation and water management, fertilizer application, and pest and disease management.
- Increase awareness of other stakeholders in the supply chain from farm to market, namely collectors, processors, and wholesale and retail traders, on good manufacturing practices related to field production, post-harvest management, processing and marketing, as this is a critical limitation to promoting underutilized crops through crop diversification.
- Provide farmers with knowledge and skills on FSF crop-production techniques, integrated farming systems (including crop rotation and intercropping), and climate-resilient production techniques.
- Identify the best cropping systems and patterns that would optimize the use of scarce water and other agricultural inputs, such as fertilizer, and maximize returns to suit different agro-ecological conditions.

### Post-harvest handling and processing

- Note that improper post-harvest practices lead to serious losses in quantity and quality of the crop, which can limit promotion of FSF in crop diversifications.
- Identify improved post-harvest techniques for crop harvesting, threshing, cleaning, drying, storage, and primary and secondary processing that would significantly minimize losses and improve product quality while maintaining food safety.
- Improve post-harvest operations including harvesting, threshing, drying, storage and processing aspects of FSF.

### Marketing

- Identify market forces and marketing strategies to improve market opportunities.
- Create awareness of potential markets and market demand for underutilized crops among stakeholders throughout the supply chain, including farmers, collectors, transporters, wholesalers and retailers, and national agricultural extension and marketing organizations.
- Utilize further the Farmer TV Channels operated by government agricultural institutions to provide market information to smallholder farmers. This helps as farmers rely primarily on collectors and traders to get information on current and future market demands and prices for agro/food products through mass media such as TV and radio.
- Provide marketing support to growers through government procurement.
- Provide alternative marketing arrangements through contract farming and the farmer-producer company model.
- Develop and adopt more efficient crop-production technologies along with favourable policies, and market support to encourage farmers to increase areas under FSF cultivation.
- Consider tools such as Geographic Indication and OVOP for marketing.

### Financial mechanisms and economic development

- Improve the economic situation of traditional communities through innovative financial mechanisms and approaches.
- Strengthen microfinance systems, as the rural population lacks sufficient capital to acquire improved production and post-harvest agro-processing technologies.

## 14 CONCLUSION

- Ensure that concessionary credit is given by the agriculture development banks to the production and post-harvest agro-processing activities of FSF.
- Extend concessionary credit not only to farmers but also to rural community-based entrepreneurs who are either processors or service providers.
- Extend the Rural Development Funds allocated by the governments to develop rural sector production and post-harvest activities relating to FSF.

### Capacity building, awareness raising and knowledge sharing

- Document and disseminate information and knowledge, and create public awareness through radio, TV and other mass media on the advantages of promoting the use of underutilized crops and the importance of incorporating FSF into diets.
- Give special attention to strengthening local food systems through better production alternatives, improved access to infrastructure, access to credit and access to markets to support the rural poor, especially those in disadvantaged areas.
- Support education, extension and capacity-building programmes, particularly among local communities.
- Ensure, through more effective engagement in the decision-making process, that indigenous knowledge, traditions and cultures are fully recognized and included in development policy.
- Foster strengthening of the role of women in planning and decision-making processes that affect communities, cultures, livelihoods and environments.
- Increase awareness by farmers and other stakeholders in the value chain on the benefits of NUS crops in terms of nutrition and climatic resilience.

- Provide training to farmers and other groups along the food value chains in crop management, producing good quality seed, selecting varieties, intercropping, crop rotation, improved farming systems, managing soil health, adding value, and developing products, packaging, bookkeeping and marketing.
- Provide training for women as it empowers them to play an important role in taking FSF to markets.
- Strengthen the national agricultural extension agencies, both governmental and non-governmental to disseminate knowledge pertaining to FSF.
- Provide knowledge on good agricultural practices to farmers and other farm-level service providers through governmental and non-governmental extension networks operating within the country.
- Organize public activities and food fairs to promote the multi-dimensional benefits of FSF.

### Financial mechanisms and economic development

- Improve the economic situation of traditional communities through innovative financial mechanisms and approaches.
- Strengthen microfinance systems as the rural population often lacks sufficient capital to acquire improved production and post-harvest agro-processing technologies.
- Ensure that concessionary credit is given by the agriculture development banks to production and post-harvest agro-processing activities of FSF.
- Extend concessionary credit not only to farmers but also to rural community-based entrepreneurs who are either processors or service providers.
- Extend the Rural Development Funds allocated by the governments to develop rural-sector production and post-harvest activities relating to FSF.





“ I found that FAO’s Future Smart Food Initiative is brilliant, and its focus on neglected and underutilized species particularly relevant. The methodology has high originality with strong interdisciplinary nature. The identification of species that are nutrition-dense, climate-resilient, economically-viable, and locally available or adaptable as Future Smart Food for Zero Hunger will have significant importance from policy, institutional and technical perspectives to enhance food security and nutrition strategies. It will certainly contribute to improve practices promoting agriculture and diet diversification and healthy eating at national, regional and global levels. ”

**Dr. Patrick Caron**, Chair of The High Level Panel of Experts on Food Security and Nutrition (HLPE) of the UN Committee on World Food Security (CFS)

### Original partners to FAO’s Future Smart Food Initiative



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