Farming Systems and Food Security in Africa

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John Dixon is Principal Adviser Research & Program Manager, Cropping Systems and Economics, Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia.

Dennis Garrity is Senior Fellow at the World Agroforestry Centre (ICRAF), based in Nairobi, Kenya, UNCCD Drylands Ambassador, and Chair of the EverGreen Agriculture Partnership.

Jean-Marc Boffa is Director of Terra Sana Projects and Associate Fellow of the World Agroforestry Centre (ICRAF), Nairobi, Kenya.

Timothy Olalekan Williams is Regional Director for Africa at the International Water Management Institute (IWMI), based in Accra, Ghana.

Tilahun Amede is Principal Scientist and Systems Agronomist at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Nairobi, Kenya.

Christopher Auricht is Managing Director of Auricht Projects, a niche international consulting firm based in Adelaide, Australia.

Rosemary Lott is Director of Vegetation Connections Pty Ltd, and an Assistant Director, Australian Government Department of Agriculture, Canberra, Australia.

George Mburathi is a former FAO Deputy Regional Representative for Africa, Nairobi, Kenya.

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Contents

Figures

Tables

Boxes

Contributors

A. Lead and contributing authors (chapter lead authors underlined)

Samuel Adjei-Nsiah, Country Coordinator, N2Africa Ghana, International Institute of Tropical Agriculture, Tamale, Ghana; **Malachy Akoroda**, Agronomist, Director General, Cocoa Research Institute of Nigeria, Ibadan, Nigeria; **Tilahun Amede**, Principal Scientist, International Crops Research Institute for Semi-arid Tropics, Nairobi, Kenya; **Godwin Asumugha**, Agricultural Economist, National Root Crops Research Institute, Umudike, Nigeria; **Christopher M. Auricht**, Spatial data analyst, Auricht Projects, Brighton, South Australia; **Augustine Ayantunde**, Animal Scientist, People Livestock Environment, International Livestock Research Institute, Niamey, Niger; **Minamba Bagayoko**, Science du Sol et Nutrition des plantes, Gestion des Ressources Naturelles, Directeur de Recherche, Coordinateur du Centre National de Spécialisation sur le Riz, Institut d'Economie Rurale, Mali; **Malcolm Blackie**, Agricultural Economist, BT Associates, UK; **Jean-Marc Boffa**, Director, Terra Sana Projects and Associate Fellow, World Agroforestry Centre, Nairobi, Kenya; **Bernard Bonnet**, Department Head, Institut de Recherches et d'Applications des Méthodes de Développement, Montpellier, France; **Martin Bwalya**, Head of Comprehensive Africa Agriculture Development Programme under the New Partnership for Africa's Development Planning and Coordinating Agency, Johannesburg, South Africa; **Mahamadou Chaibou**, Maître de Conférences, Faculté d'Agronomie, Université Abdou Moumouni, Niamey, Niger; **Olufunke Cofie**, Senior Researcher, International Water Management Institute, Accra, Ghana; **John Dixon**, Principal Adviser, Research & Research Program Manager, Cropping Systems and Economics, Australian Centre for International Agricultural Research, Canberra, Australia; **Sikhalazo Dube**, Regional Representative to Southern Africa, International Livestock Research Institute, Harare, Zimbabwe; **Stéphanie Duvail**, Geographer, Institut de Recherche pour le Développement, Nairobi, Kenya; **Adama Ekberg Coulibaly**, Chief, Agriculture, Food security and Land Section, Regional Integration and Trade Division, United Nations Economic Commission for Africa, Addis Ababa, Ethiopia; **Medhat El-Helepi**, Economic Affairs Officer, Food Security, Agriculture and Land Section, Regional Integration and Trade Division, United Nations Economic Commission for Africa, Addis Ababa, Ethiopia; **Polly Ericksen**, Programme Leader, Livestock Systems and Environment, International Livestock Research Institute, Nairobi, Kenya; **Jean-Marc Faurès**, Senior Officer, Water Resources Management, Land and Water Management Division, Food and Agriculture Organization, Rome, Italy; **Günther Fischer**, Senior Research Scholar, Water Research Program, International Institute for Applied Systems

Analysis, Laxenburg, Austria; **Theodor Friedrich**, FAO Representative to Cuba, Food and Agriculture Organization, Havana, Cuba; **Dennis Garrity**, Drylands Ambassador, UN Convention to Combat Desertification and Senior Fellow, World Agroforestry Centre, Nairobi, Kenya; **Jim Gockowski**, Agricultural Economist, International Institute of Tropical Agriculture, Ibadan, Nigeria **Olivier Hamerlynck**, Senior Research Affiliate, Kenya Wetlands Biodiversity Research Team, National Museums of Kenya, Nairobi, Kenya; **Stefan Hauser**, Soil Scientist, International Institute of Tropical Agriculture, Ibadan, Nigeria; **Pierre Hiernaux**, Geoscience Environment Toulouse (GET), Observatoire Midi-Pyrénées, Toulouse, France; **Nancy Karanja**, Professor of Soil Ecology, University of Nairobi, Nairobi, Kenya; **Amir Kassam**, Agricultural Ecologist, Senior Consultant for the Food and Agriculture Organization, Rome, Italy; **Eric Kueneman**, Director, Kueneman Consultancy, Visiting Scholar, Department of Plant Sciences University of California Davis, West Sacramento, California, USA; **Diana Lee-Smith**, Associate, Mazingira Institute, Nairobi, Kenya; **Jan de Leeuw**, Senior Scientist, ISRIC World Soil Information, Wageningen, The Netherlands; **Mulugeta Lemenih**, Head, Forestry and Natural Resources Management, Farm Africa, Addis Ababa, Ethiopia; **Jan Lombard**, Senior Lecturer, Department of Agricultural Economics, University of Stellenbosch, Stellenbosch, South Africa; **Rosemary Lott**, Vegetation Connections, Canberra, Australia; **NeBambi Lutaladio**, Associate Professor, Plant Production and Protection Department, Faculty of Agricultural Science, University of Kinshasa, and Deputy Director General, Institut National pour l'Etude et la Recherche Agronomiques, Kinshasa, Democratic Republic of Congo; **John Lynam**, Board Chair, World Agroforestry Centre, Nairobi, Kenya; **George Mburathi**, Independent Consultant, Nairobi, Kenya; **Mulugetta Mekuria**, SIMLESA Program Leader and CIMMYT Representative, Southern Africa Regional Office, International Maize and Wheat Improvement Center, Harare, Zimbabwe; **Saidi Mkomwa**, Executive Secretary, African Conservation Tillage Network, Nairobi, Kenya; **Maxwell Mudhara**, Lecturer, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa; **Regassa Namara**, Senior Water Resources Economist, Sector of Water, The World Bank, Washington, DC, USA; **Shadreck Ncube**, Ruminant Nutrition, Head of Institute, Matopos Research Institute, Bulawayo, Zimbabwe; **Constance Neely**, Senior Advisor for Research, Practice and Policy Integration, World Agroforestry Centre, Nairobi, Kenya; Emmanuel Njukwe, Country Representative, IITA, Burundi; **Christian Nolte**, Independent Consultant, Geneva, Switzerland; **Lindsey Norgrove**, Professor, School of Agricultural, Forest and Food Sciences, Bern University of Applied Sciences, Zollikofen, Switzerland; **David Norman**, Professor Emeritus, Department of Agricultural Economics, Kansas State University, Kansas, USA; **Justice Nyamangara**, Deputy Vice Chancellor, Chinhoyi University of Technology, Chinhoyi, Zimbabwe; **Wanja Dorothy Nyingi**, Head, Ichthyology Section, National Museums of Kenya, Nairobi, Kenya; **Timothy Olalekan Williams**, Regional Director for Africa, International Water Management Institute, Accra, Ghana; **Philip Osano**, Research Fellow, Water, Land and Ecosystem Services, Stockholm Environmental Institute Africa, Nairobi, Kenya; **Anthony Palmer**, Specialist Scientist, Animal Production Institute, Agricultural Research Council, Grahamstown, South Africa; **Jean-Luc Paul**, Anthropologist, Senior Researcher, Institut des Mondes Africains, Pointe-à-Pitre, Guadeloupe; **Anne-Sophie Poisot**, Project Coordinator, Plant Production and Protection Division, Food and Agriculture Organization, Rome, Italy; **Gordon Prain**, Senior Scientist, Social and Health Sciences, International Potato Center, Lima, Peru;

Valentina Robiglio, Landscape Ecologist, World Agroforestry Centre, Lima, Peru; **Joseph Rusike**, Economist, International Institute of Tropical Agriculture, Dar-es Salam, Tanzania; **Mohammed Said**, Associate, Institute of Climate Change and Adaptation, University of Nairobi, Nairobi, Kenya; **John Sanders**, Professor, Agricultural Economics, Purdue University, West Lafayette, Indiana, USA; **Sieglinde Snapp**, Professor, Soils and Cropping Systems Ecologist, Department of Plant, Soil and Microbial Sciences, Michigan State University, East Lansing, Michigan, USA; **Katherine Snyder**, Senior Social Scientist, Policy, Institutions and Gender, International Center for Tropical Agriculture, Nairobi, Kenya; **Sibiri Jean-Baptiste Taonda**, Maître de Recherche en Sciences agronomiques (CAMES), Coordonnateur du Projet SAPEP-Burkina, Ministère de l'Enseignement Supérieur, de la Recherche Scientifique et de l'Innovation, Ouagadougou, Burkina Faso; **Philip Thornton**, Principal Scientist, International Livestock Research Institute, Edinburg, UK; **Eric Tollens**, Emeritus Professor, Centre for Bio-Economics, Faculty of Bioscience Engineering, Catholic University of Leuven, Leuven, Belgium; **René van Veenhuizen**, Senior Programme Officer Urban Agriculture, RUAF Foundation, Leusden, The Netherlands; **Harrij van Velthuizen**, Senior Research Scholar, Water Research Program, International Institute for Applied Systems Analysis, Laxenburg, Austria; **Anton Vrieling**, Assistant Professor, Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands.

B. Chapter reviewers

Bruno Barbier, Research Fellow, G-eau Research Unit, Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Dakar, Senegal; **Paula Bramel**, Scientific Advisor, Global Crop Diversity Trust, Bonn, Germany; **Jonathan Davies**, Coordinator, Global Drylands Programme, International Union for Conservation of Nature, Nairobi, Kenya; **Hubert de Bon**, Agronomist, HortSys Research Unit, Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Montpellier, France; **Ousmane Djibo**, team leader GIZ Sector Project Agriculture Policy and Food security; **Pay Drechsel**, Theme Leader, International Water Management Institute, Colombo, Sri Lanka; **Dominique Endamana**, Program Officer, Regional Forest Program for Central and West Africa, International Union for Conservation of Nature, Yaoundé, Cameroon; **Divine Foundjem-Tita**, Market Scientist, World Agroforestry Centre, Yaounde, Cameroon; **Francis Gichuki**, Senior Lecturer, Environmental and Biosystems Engineering Department, University of Nairobi, Nairobi, Kenya; **Ken E. Giller**, Professor of Plant Production Systems, Wageningen University, Wageningen, The Netherlands; **Munir A. Hanjra**, Economist, Agricultural Water Management, International Water Management Institute, Pretoria, South Africa; **Wolf D. Hartmann**, Coordinator, GOPA Consultants/Ministerio do Meio Ambiente, Brasília, Brazil; **Heike Höffler**, team leader GIZ Sector Project Agricultural Trade, Agribusiness, Agricultural Finance; **Irene Hoffmann**, Secretary, Commission on Genetic Resources for Food and Agriculture, Food and Agriculture Organization of the United Nations, Rome, Italy; **Habtemariam Kassa**, Senior Scientist, Forests and Human Well-Being Research Team, Center for International Forestry Research, Addis Ababa, Ethiopia; **Patrice Levang**, Director of Research, Institut de Recherche pour le Développement, Montpellier, France; **Thilak Mallawaarachchi**, Principal

Research Fellow, Risk and Sustainable Management Group, School of Economics, University of Queensland, Brisbane, Australia; **Modesta Medard Ntara**, Senior Social Scientist and Environmentalist, Tanzania Fisheries Research Institute, Mwanza, Tanzania; **Mick S. Mwala**, Dean, School of Agricultural Sciences, University of Zambia, Lusaka, Zambia; **Lucien Nomo Bidzanga**, Coordonnateur, Systèmes de Production, Economie et Sociologie Rurales, Institut de Recherche Agricole pour le Développement, N'Kolbisson, Cameroon; **Remi Nomo-Womdim**, Representative in Cabo Verde, Food and Agriculture Organization, Praia, Cabo Verde; **Pheneas Ntawuruhunga**, Scientist, Cassava Breeder, International Institute of Tropical of Agriculture, Lusaka, Zambia; **Thomas Ochuodho**, Assistant Professor, University of Kentucky, Lexington, USA; **Michael Phillips**, Director of Aquaculture and Fisheries Science, WorldFish, Penang, Malaysia; **Mark Prein**, team leader GIZ Sector Project Sustainable Fisheries and Aquaculture; **Ingrid Prem**, team leader GIZ Sector Project Sustainable Agriculture; **Mongi Sghaier**, Professor, Arid Region Institute, Medenine, Tunisia; **Anneke Trux**, team leader GIZ Global Program Land; **Bernard Vanlauwe**, R4D Director, International Institute of Tropical Agriculture, Central Africa, Nairobi, Kenya; **Jean-Philippe Venot**, Senior Researcher, Institut de Recherche pour le Développement, Montpellier, France; **Ketema Tilahun Zekeke**, Lecturer, Irrigation and Water Management, Charles Sturt University, Wagga Wagga, Australia.

C. Whole manuscript reviewers

Tsedeke Abate, Drought Tolerant Maize for Africa Project Leader, International Maize and Wheat Improvement Center, Nairobi, Kenya; **Caterina Batello**, Team Leader, Agriculture Department, Food and Agriculture Organization; **Simeon Ehui**, Practice Manager, Agriculture Global Practice, The World Bank; **Siboniso Moyo**, Representative of the Director General to Ethiopia, and Program Leader, Animal Science for Sustainable Productivity, International Livestock Research Institute, Addis Ababa, Ethiopia; **Ravi Prabhu**, Deputy Director General Research, World Agroforestry Centre, Nairobi, Kenya; **Mandivamba Rukuni**, Director BEAT Doctoral Academy, Harare, Zimbabwe; **Fergus Sinclair**, Science Domain Leader, World Agroforestry Centre, Nairobi, Kenya.

D. Participants at design and review workshops

Third Review Workshop: Expert Group Meeting on Farming Systems in Africa convened by UNECA at ICRAF, Nairobi, Kenya

The 23 participants included many chapter authors and book editors, and in addition: **Ahmed Abdelwhab M. Abdelhafez**, Associate Professor, Faculty of Agriculture, Ain Shams University, Cairo, Egypt; **Ayma Farid Abou-Hadid**, Professor Emeritus, Faculty of Agriculture, Ain Shams University, Cairo, Egypt; **Nassirou Ba**, Economic Affairs Officer, Food Security, Agriculture and Land Section, Regional Integration and Trade Division, United Nations Economic Commission for Africa, Addis Ababa, Ethiopia; **James Hansen**, Flagship 2 Leader, CGIAR Research Program on Climate Change, Agriculture and Food Security, Columbia University, New York, USA; **Kirigai Kamau**, Agribusiness & Private Sector Advisor, Ministry of Agriculture Livestock, and Fisheries, Nairobi, Kenya; **Stephen Karingi**, Director,

Regional Integration and Trade Division, United Nations Economic Commission for Africa, Addis Ababa, Ethiopia; **Lucy Nyirenda**, Head of Government Services, African Risk Capacity, Johannesburg, South Africa; **Ravi Prabhu**, Deputy Director General, Research, ICRAF, Nairobi, Kenya; **Zakary Rhissa**, Livestock Specialist and Independent Consultant, Niamey, Niger; **Mohamed Sadeck Boulahya**, Regional Advisor in Climate for Development, ClimDev Consult Africa, Toulouse, France; **Moussa Seck**, Chair, Pan African Agribusiness and Agro-industry Consortium, Dakar, Senegal; **Kees Cornelis J. Stigter**, Agrometeorologist, Agromet Vision & International Society for Agricultural Meteorology and Visiting/Affiliated Professor at African Universities and Indonesia, Bruchem, The Netherlands; **Henry Wamwayi**, Acting Senior Policy Officer Trade and Marketing Unit, African Union-Inter-African Bureau for Animal Resources, Nairobi, Kenya; **Cathy Watson**, Chief of Programme Development, ICRAF, Nairobi, Kenya.

Second Design Workshop for the Farming Systems Book, ICRAF, Nairobi, Kenya

The 33 participants included many chapter authors and book editors, and in addition: **Carlo Azzarri**, Senior Research Fellow, IFPRI; **Martin Bwalya**, Advisory Group, NEPAD; **Steve Franzel**, Advisory group member, ICRAF, Nairobi, Kenya; **Zhe Guo**, GIS Coordinator, IFPRI, Washington, DC, USA; **Rosemary Kande**, IT Specialist, ICRAF, Nairobi, Kenya; **Sid Mohan**, Intern, ICRAF, Nairobi, Kenya; **Alice Muller**, Intern, ICRAF, Nairobi, Kenya; **Frank Place**, IFPRI, Washington, DC, USA; **Martin Shem**, Advisory Group Member, Rwanda Agricultural Board, Kigali, Rwanda; **Stan Wood**, Senior Program Officer, Agricultural Development Program, Bill and Melinda Gates Foundation, Seattle, USA.

First Design Workshop for the Farming Systems Book, ICRAF, Nairobi, Kenya

The 22 participants included many chapter authors and book editors, and in addition: **Ermias Aynekulu**, Spatial Data Analyst, ICRAF, Nairobi, Kenya; **Steve Franzel**, Advisory group member, ICRAF, Nairobi, Kenya; **Rosemary Kande**, IT Specialist, ICRAF, Nairobi, Kenya; **Sid Mohan**, Intern, ICRAF, Nairobi, Kenya; **Martin Shem**, Advisory Group Member, Rwanda Agricultural Board, Kigali, Rwanda; **Marleen Schoemaker**, Intern, ICRAF, Nairobi, Kenya; **Stan Wood**, Senior Program Officer, Agricultural Development Program, Bill and Melinda Gates Foundation, Seattle, USA.

E. Other contributors

Other experts consulted for system characterization, trends and interventions:

Ward Anseeuw, Research Fellow, CIRAD; **Marie-Christine Cormier-Salem**, Senior Researcher, IRD; **Philippe Deygout**, Chargé de Programme, IRAM; **Mahamadou Gandah**, Country Representative, ICRISAT, Niamey, Niger; **Mario Herrero**, Chief Research Scientist and Office of the Chief Executive Science Leader, Commonwealth Scientific and Industrial Research Organisation; **Patrick Jagoret**, Agronomist, Centre de Coopération Internationale en Recherche Agronomique pour le Développement; **Bertus Kruger**, Technical Advisor, Rangeland Management, AGRA, Windhoek, Namibia; **Tendayi Maravanyika**, Country Coordinator, HarvestPlus Zimbabwe; **Frank Place**, Senior Research Fellow, IFPRI, Washington, DC, USA; **Francois Ruf**, Agro-economist, CIRAD; **Bekele Shiferaw**, Lead Evaluation Specialist and Cluster Coordinator for Agriculture, Environment and Climate Change, Independent Evaluation Group, World Bank Group.

Preface

Economic growth in Africa accelerated in the new millennium, enhancing confidence in the continent's future. Positive developments have taken place in the liberalization of trade and markets, in the strengthening of institutions and policies, and in investments in human and social capital and infrastructure. However, the growth has not trickled down to the large number of rural people experiencing chronic or crisis-driven hunger and poverty. Thus, Africa has had a larger proportion of extreme poor than any other region of the world.

Most of Africa's poor are rural and most rely largely on crops, livestock, trees and fish – along with off-farm income – for their livelihoods. The improvement of agriculture, particularly smallholder farming systems, is fundamental to overcoming the problems of rural poverty and lagging rural economies. The African rural development context is unique and diverse, in its geography, agro-ecology, history, politics and culture. National and regional decision makers face the challenge of identifying the best agricultural and rural development opportunities with the greatest impact on food security, livelihoods and economic growth. Experience has shown that policy and investment decisions must be better grounded in local context-specific analyses, incorporating multi-stakeholder and systems approaches focused on the livelihood strategies and opportunities of farm men and women. The value of targeting technologies and policies to different farming systems has been recognized in the Science Agenda of the Forum for Agricultural Research in Africa (FARA).

At the opening of the new millennium an FAO/World Bank analysis was published that examined rural development opportunities over the period from 2000 to 2015 from the perspective of farm households in major farming systems of the developing world (Dixon et al. 2001; www.fao.org/farmingsystems/). The analysis classified and mapped farming systems, including those of Africa, examined the drivers of change for the 2000–2015 period and identified strategic priorities for each system. This farming system framework and analysis has proved to be valuable for targeting and prioritizing agricultural research and development initiatives and has been used repeatedly – for example, by the InterAcademy Council report on Africa, the Millennium Villages Project, the CGIAR Collaborative Research Programs, and others.

Given the major changes in African agricultural opportunities, it was time for an update of the 2000 FAO/World Bank analysis of African farming systems looking forward from 2015 to 2030. Since 2000 the African population has increased by a third, dynamism has returned to many African economies and regional agricultural research and development organizations have generated and disseminated many new varieties

and practices – but farm household vulnerability and international market volatility have increased. The Australian Centre for International Agricultural Research supported an update, with assistance and guidance from the New Partnership for Africa's Development, the United Nations Economic Commission for Africa, the CGIAR, the World Bank, and the Food and Agricultural Organization.

The work was coordinated by the World Agroforestry Centre (ICRAF) in Nairobi. More than 60 scientists and development professionals, working in multi-disciplinary teams, assessed constraints, trends and strategic interventions in the 15 major farming systems across the continent. The analysis integrated key recent strategic reports and a wealth of expert knowledge and spatial data – including natural resource, production, infrastructural and nutritional information from FAO, World Bank, CGIAR, International Institute for Applied Systems Analysis (IIASA) and other sources.

The resulting book provides a unique systematic, forward-looking, compendium of continent-wide farming system assessments and databases for agribusiness, policy makers and science leaders. The document will undoubtedly be a fundamental guide for years to come for prioritization and targeting of public and private investments to deliver food and nutrition security and rural transformation in Africa.

Maria-Helena Semedo
Deputy Director General
Natural Resources Management
and Environment Department
Food and Agriculture Organization
of the United Nations

Andrew Campbell
Chief Executive Officer
Australian Centre for
International Agricultural Research

Juergen Voegele
Senior Director
Agriculture Global Practice
The World Bank

Vera Songwe
Executive Secretary
United Nations Economic
Commission for Africa

Anthony Simons
Director General
World Agroforestry Centre

Ibrahim Assane Mayaki
Chief Executive Officer
New Partnership for Africa's Development

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Sixty-six authors, working in multi-disciplinary analysis and writing teams, created the heart of this book. The authors, listed under Contributors, brought to the farming systems analysis the knowledge and data of a great many organizations, including African regional organizations, National Agricultural Research Systems and Universities, as well as several UN agencies, advanced research institutes and the Consultative Group for International Agricultural Research.

The motivation and conceptualization for this farming systems analysis was provided by John Dixon, Australian Centre for International Agricultural Research (ACIAR) and Dennis Garrity, World Agroforestry Centre (ICRAF) who set out to update and deepen the FAO/World Bank global analysis of farming systems in the book *Farming Systems and Poverty* (Dixon et al. 2001). Overall responsibility for technical contents and editing was shared by John Dixon (ACIAR), Jean-Marc Boffa and Dennis Garrity, (ICRAF); with major contributions from Timothy O. Williams, International Water Management Institute (IWMI), Tilahun Amede, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and George Mburathi, formerly of Food and Agriculture Organization (FAO). Book development was coordinated by Jean-Marc Boffa (ICRAF) in consultation with John Dixon (ACIAR). Chris Auricht led the spatial data analysis, and Rosemary Lott led structural editing and copyediting.

The strategic guidance of an advisory committee composed of Martin Bwalya (NEPAD-AU); Martin Shem, Rwanda Agricultural Board (RAB); George Mburathi, John Lynam and Steve Franzel (ICRAF); Maxwell Mudhara (University of KwaZulu); John Dixon (ACIAR); and Dennis Garrity (ICRAF) is gratefully acknowledged. We also are indebted to the advice of many other experienced professionals, including Geoffrey Mrema, Duncan Spencer, Adama Ekberg Coulibaly, Rudy Rabbinge, Nick Austin, John Latham, Stanley Wood, Hans Binswanger and Prabhu Pingali, to name but a few.

The farming systems analysis integrated spatial data, administrative statistics and expert knowledge. Spatial data layers originate from various institutions including the Food and Agriculture Organization, United Nations, International Institute for Applied Systems Analysis, International Food Policy Research Institute, University of Minnesota, Center for International Earth Science Information Network, ITC/University of Twente Faculty of Geo-information Science and Earth Observation, World Agroforestry Centre, and the Centre for World Food Studies. Administrative statistics and reports were sourced from African Union, New Partnership for Africa's Development-African Union, United Nations Economic Commission for Africa, Forum for Agricultural Research in Africa, African Development Bank, R&D projects such as Sustainable Intensification of Maize and Legume Systems for Food Security in

Eastern and Southern Africa (SIMLESA), and the World Bank, International Fund for Agricultural Development, CGIAR and other international development organizations. We benefited from the knowledge of a large number of individuals who contributed local maps and expert knowledge that helped to characterize and refine the boundaries of the farming system zones (Table 2.7) and to enrich the judgments about key drivers, trends and strategic interventions for each farming system.

Our thanks are also due to the painstaking work and advice from external reviewers. The farming systems book chapters were reviewed by 27 external reviewers and 7 reviewers of the whole manuscript (see list of Contributors). Adama Ekberg Coulibaly (UNECA) provided strategic advice and convened with UNECA support an expert group meeting at ICRAF that yielded review feedback on key farming systems chapters. The valuable comments from all these reviewers are gratefully acknowledged.

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The Editors

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Abbreviations

Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADLI	Agriculture Development-Led Industrialization
ADMARC	Agricultural Development and Marketing Corporation (Malawi)
AEZ	Agroecological Zone
AfDB	African Development Bank
AGRA	Alliance for a Green Revolution in Africa
AIDS	Acquired Immune Deficiency Syndrome
APP	Africa Progress Panel
ASAL	Arid and Semi-arid Lands
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ATA	Agricultural Transformation Agency (Ethiopia)
AU	African Union
BEAT	Barefoot Education for Afrika Trust (Zimbabwe)
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CABI	Centre for Agriculture and Bioscience International
CAMES	Maître de Recherche en Sciences Agronomiques
CARE	Christian Action Research and Education
CASI	Conservation Agriculture-based Sustainable Intensification
CBPP	Contagious bovine pleuropneumonia
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Africa
CCPP	Contagious caprine pleuropneumonia
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical)
CIESIN	Center for International Earth Science Information Network
CIFOR	Center for International Forestry Research
CIMMYT	International Maize and Wheat Improvement Center
CIRAD	French Agricultural Research Centre for International Development (Centre de Coopération Internationale en Recherche Agronomique pour le Développement)

CO_2	Carbon dioxide
COMESA	Common Market for Eastern and Southern Africa
COOPAC	Coopérative pour la Promotion des Activités Café (Rwanda)
CORAF	Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricole
CRIG	Cocoa Research Institute of Ghana
CSA	Climate-smart agriculture
CTA	Centre Technique de Coopération Agricole et Rurale
DAP	Di-ammonium Phosphate
DRC	Democratic Republic of Congo
DTMA	Drought Tolerant Maize for Africa
EAC	East African Community
EAHB	East African Highland Banana
ECF	East Coast Fever
EIAR	Ethiopian Institute of Agricultural Research
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Databases (United Nations)
FARA	Forum for Agricultural Research in Africa
FASID	Foundation for Advanced Studies on International Development
FBFS	Fish-based farming system
FDI	Foreign direct investment
FEWS-NET	Famine Early Warning Systems Network
FIPS	Farm Input Promotions Africa Ltd
FMD	Foot and mouth disease
FMNR	Farmer-Managed Natural Regeneration
FRS	Forest rent subsystem of the tree crop farming system
FSA	Farming Systems Approach
FSR&D	Farming Systems Research and Development
GADP	Gross Agricultural Domestic Product
GAEZ	Global Agroecological Zone
GDP	Gross Domestic Product
GET	Geoscience Environment Toulouse
GHG	Greenhouse gas
GHI	Global Hunger Index
GIS	Geographic Information System
GIZ	German Corporation for International Cooperation
GNI	Gross National Income
GWUE	Green Water Use Efficiency
IAGU	Institut Africain de Gestion Urbaine
IBLI	Index Based Livestock Insurance
ICARDA	International Center for Agricultural Research in the Dry Areas
ICIMOD	International Centre for Integrated Mountain Development
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information Communication Technology
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development

IFPRI	International Food Policy Research Institute
IGAD	Inter-Governmental Authority on Development
IIASA	International Institute for Applied Systems Analysis
IITA	International Institute for Tropical Agriculture
ILRI	International Livestock Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INM	Integrated Nutrient Management
INTSORTMIL	International Sorghum and Millet Collaborative Research Support Program
IPM	Integrated Pest Management
IPS	Industrial plantation subsystem of the tree crop farming system
IRD	French National Research Institute for Sustainable Development (Institut de Recherche pour le Développement)
IRDP	Integrated Rural Development Program
ISFM	Integrated Soil Fertility Management
ISRIC	World Soil Information Centre (also International Soil Reference and Information Centre)
IT	Information Technology
ITC	Center for International Earth Science Information
IWAD	Integrated Water and Agricultural Development Ghana Limited
IWMI	International Water Management Institute
JRC	Joint Research Centre
KARI	Kenya Agricultural Research Institute
LER	Land Equivalent Ratio
LGP	Length of Growing Period
LSIFS	Large-scale irrigated farming system
LSLA	Large-scale land acquisition
MENA	Middle East and North Africa region
MPA	Marine Protected Area
M-PESA	M-Pesa (M for mobile, pesa is Swahili for money) is a mobile phone-based money transfer, financing and microfinancing service
N	Nitrogen
NA	North Africa
NALEP	National Agriculture and Livestock Extension Program (Kenya)
NARI	National Agricultural Research Institute
NARS	National Agricultural Research System
NEFSALF	Nairobi and Environs Food Security, Agriculture and Livestock Forum
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organization
NPK	Nitrogen-Phosphorous-Potassium
NRCRI	National Root Crops Research Institute (Nigeria)
NRM	Natural Resource Management
NTFP	Non-Timber Forest Product
NUANCES	Nutrient Use in Animal and Cropping systems – Efficiencies and Scales
NVDI	Normalized Difference Vegetation Index
ODA	Overseas Development Assistance

ODI	Overseas Development Institute (UK)
OECD	Organization for Economic Cooperation and Development
OPV	Open Pollinated Variety
P	Phosphorous
P/PET	Precipitation /Potential Evapotranspiration
PEN	Poverty and Environment Network
PPP	Public-Private Partnership
PPP	Purchasing Power Parity
PPR	Pestes des petits ruminants
PRSP	Poverty Reduction Strategy Programme
R4D	Research for Development
R&D	Research and Development
RAB	Rwanda Agricultural Board
REDD+	Reducing emissions from deforestation and forest degradation in developing countries
ReSAKSS	Regional Strategic Analysis and Knowledge Support System
RinD	Research in Development
RNFE	Rural Non-Farm Economy
RUAF	Resource Centres on Urban Agriculture and Food Security
RUE	Rain Use Efficiency
S3A	Science Agenda for Agriculture in Africa
SADC	Southern Africa Development Community
SAP	Structural Adjustment Program
SAPEP	Smallholder Agricultural Productivity Enhancement Program (Burkina Faso)
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
SIMLESA	Sustainable Intensification of Maize Legume Cropping Systems for Food Security in Eastern and Southern Africa
SIP	Sustainable Intensification Practice
SIS	Smallholder intensified subsystem of the tree crop farming system
SLA	Sustainable Livelihoods Approach
SNSF	Swiss National Science Foundation
SRO	Sub-Regional Organization
SSA	sub-Saharan Africa
STCP	Sustainable Tree Crops Program (West Africa)
TAPRA	Tegemeo Agricultural Policy Research and Analysis (Kenya)
TFP	Total Factor Productivity
TLU	Tropical Livestock Unit
UEMOA	West African Economic and Monetary Union
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Program
UNECA	United Nations Economic Commission for Africa
UPA	Urban and peri-urban agriculture
UPUFS	Urban and peri-urban farming system
USA	United States of America
USAID	United States Agency for International Development (USA)

WECARD	West and Central African Council for Agricultural Research and Development
WFP	World Food Program
WHO	World Health Organization
WUA	Water Users' Association
WWF	World Wildlife Fund

Abbreviations (units)

%, pc	percentage
BP	before present
CV, c.v.	Coefficient of Variation
cm	centimetre
d	day
g	gram
ha	hectare
h, hr	hour
incl	including
k	thousand
kcal	kilocalorie
kg	kilogram
km, km^2	kilometre, square kilometre
mm, m, m^3	millimetre, metre, cubic metre
M (m), Mt	million, million tonne
MW	megawatt
pa	per annum
pc, per capita	per person
pop	population
USD, US$	US dollar

Part I

Introduction

1 Africa through the farming systems lens

Context and approach

John Dixon, Dennis Garrity, Jean-Marc Boffa, Adama Ekberg Coulibaly, Medhat El-Helepi, Christopher M. Auricht and George Mburathi

Key messages

- The African continent is at a turning point, moving from unfulfilled development potential towards sustainable agricultural intensification, which must accompany and drive economic growth to alleviate poverty and improve food security.
- African agriculture is heterogeneous and dynamic. Investing in sustainable agricultural intensification requires a framework to differentiate and target different investments responsive to the needs of different farming system. Each of the 15 broad farming systems in Africa comprises millions of farm households with similar livelihood patterns and broadly similar development opportunities.
- Seven drivers operating in various combinations shape the trends and development options for each farm household and the different strategic interventions for each farming system.
- Farming systems analysis can contribute to broad-based transformation and improved food and nutrition security in several ways. Because most food insecure and hungry people reside in rural areas, effective food systems must be based on productive and resilient farming systems that integrate food consumption and production decisions, maintain diverse local diets to reduce malnutrition, yet also facilitate improved production and trading with wider markets.
- Farming system intensification tailored to local resources, crops and livestock will generally increase farm labour productivity and reduce poverty. Rural poverty reduction strategies for job creation, gender empowerment and youth entrepreneurship should reflect different livelihood patterns in each farming system.
- Analysis of farming systems, including forward and backward linkages and value-addition, can focus investments on bundles of commodities, food processing and agribusiness potential, which improve food and nutrition security for consumers and producers.
- Livelihood systems in Africa are highly vulnerable to shocks, including market volatility, climate variability and climate change. Systematic analysis of farming systems can facilitate the identification of policies and investments that target the development of sustainable and resilient farming systems.

Summary

Despite vigorous national economic growth, significant rural poverty and food insecurity persists in many African countries, despite notable national economic development since the late 2000s. About 90 per cent of Africa's poor live in rural areas and about 80 per cent derive their living from rainfed farming. Improving smallholder agriculture is now seen as fundamental to inclusive sustainable development. The African continent contains a mosaic of natural resources, human settlements and institutions which shape fifteen major farming systems, each with a characteristic mixture of trees, crops, livestock, fish and livelihoods – and particular development pathways. Within each farming system zone, the farm household systems and opportunities are shaped by seven drivers of change, notably population, natural resources and climate, energy, human capital, technologies, markets and policies. To escape poverty and improve food and income security, African farm households follow one or more of a set of strategies including intensification and diversification of production and increased off-farm income.

This book takes a unique farming system perspective on the analysis of the drivers, trends and opportunities for farm households to improve food security or escape from poverty. In this way, the book identifies strategic science, investment and policy interventions, targeted to each farming system. The book updates and deepens the sub-Saharan African (SSA) regional component of the FAO/World Bank 2001 global analysis of farming systems, and it has been carefully structured to complement rather than replace existing sectoral and regional development assessments of the African continent.

This chapter introduces the African agricultural and food security context, the farming system framework, key drivers of change and the fifteen principal farming systems in Africa.

From unfulfilled potential in Africa to sustainable development

The vision of a prosperous rural Africa, with abundant economic opportunities, sustainable use of natural resources, and an end to poverty and hunger, underpins this book.

The roots of the unfulfilled development potential of Africa lie in the stagnation of many African economies and agricultural sectors during the period from the 1970s to the 1990s – sometimes referred to as the 'lost decades'. Subsequently, most countries have emerged from stagnation and are recording impressive economic growth rates in this new millennium (Badiane and Collins 2016). By 2012, six of the ten fastest growing economies in the world were located in Africa. By 2015 the SSA region recorded a 4.4 per cent growth rate, equivalent to the average growth rate of all low- and middle-income countries. Nevertheless, agricultural sector growth is slow and the agricultural sector share, measured in Gross Domestic Product (GDP) terms, is modest, despite the land resources and agricultural population of Africa. In fact, development planners normally expect agriculture to contribute a greater share of GDP given the prevailing levels of per capita income in Africa.

In order to benefit fully from sustainable development pathways, national economic growth must be complemented by vigorous agricultural and rural development. Agriculture remains the main source of livelihoods for the rural population, which represented approximately half of the African population of nearly 1.2 billion in 2015. In contrast to other regions of the world, African farming (including pastoral, livestock, forestry

and fishing) engages two-thirds of the continent's labour force and contributes about one-third of regional GDP. Moreover, growth in farm household income generally stimulates substantial rural non-farm economic growth. However, the persistence of widespread food insecurity and rural poverty in Africa, as well as natural resource degradation, was the motivation for the analysis reported in this book.

For maximum effectiveness of agricultural development policies, investment programs and agricultural research, it is necessary to unpack the diversity of African agriculture into distinct, broad farming system zones (hereafter referred to as farming systems) and ascertain priority strategic interventions for each system. For this purpose, the constraints and opportunities are analysed and probable trajectories of development identified. Farm household income, livelihoods and food security are closely related and dependent on the nature of the farming system. The analysis recognizes the patterns of inherent diversity of farm households within any particular farming system zone and the various coping strategies employed by farm households.

This book takes a unique approach to the African drama and subsequent development, applying the farming systems perspective to the identification of priorities for agricultural policy, investment, agribusiness and technology development. The analysis complements, rather than replaces, existing assessments of African agricultural and rural development. While the geographic scope of this book is continental Africa, the emphasis lies on the complex farming systems of SSA. This book updates and deepens the SSA regional analysis of the FAO/World Bank *Farming Systems and Poverty* publication (Dixon et al. 2001). It takes into account the smallholder development successes with maize, cassava, cotton, horticulture and dairy (Abate et al. 2015; Haggblade and Hazell 2010) and the new policy settings resulting from the 2014 Malabo Declaration by African leaders to eradicate hunger by 2025 within the context of a fully transformed agriculture (Malabo Montpellier Panel 2017). The book has been written for policymakers, research leaders and investors who seek to target agricultural policy, investment plans and science priorities for maximum impact in agricultural and rural sectors.

This chapter introduces the farming systems approach used in this book, summarizes the key drivers and trends in agricultural development, and discusses the strategies used by farm households to escape poverty and improve livelihoods. The chapter also contrasts development progress in SSA with other regions, outlines the status of African food and agricultural systems, and classifies African agriculture into fifteen major farming systems. Chapter 2 outlines the methods and data used for the analysis; Chapters 3–16 list the characteristics, trends and priority interventions in each of the fifteen farming systems; and Chapters 17–19 offer a consolidation of findings, summary of ways forward and the main conclusions of the analysis.

Contrasts with other regions

Development indicators for continental Africa are often presented separately for SSA and North Africa, the latter also forming part of the Middle East and North Africa region (MENA). As shown in Table 1.1, the SSA annual economic growth rate was triple the average of MENA in 2014 and 2015, although slower than the growth rates of South Asia and East Asia. Per capita income in SSA, calculated on a purchasing power parity basis, still lags behind other regions. Conversely, per capita income in North Africa in 2014–15 was above average.

Table 1.1 Food security, economic and demographic characteristics by development region

Item	*Sub-Saharan Africa*	*North Africa and Middle East*	*South Asia*	*East Asia#*	*Developing countries (all)#*
Global hunger index (GHI)	32	12	29	13	22
Extreme poverty (%)*	43	3	19	7	15
GNI/cap ($PPP)**	3,382	11,834	5,299	11,872	8,811
Economic growth (%)	4.4	1.5	6.9	6.7	4.9
Total population (million)	973	357	1,721	2,020	5,682
Population growth rate (%)	3	2	2	1	1

Source: World Bank (2015), IFPRI (2015).

Notes: Estimates are rounded. Data are from 2014 or 2015 except poverty estimates which derive from 2012.

*Extreme poverty is based on US$1.90 per capita consumption per day (representing an update of the earlier US$1.25 poverty level).

**Gross national income (GNI) per capita calculated at purchasing power parity.

#East Asia includes the Pacific. The developing countries' estimates represent all low- and middle-income countries as classified by the World Bank in 2015.

Despite the promising economic growth rate, SSA experienced greater food insecurity than developing countries overall. Moreover, about one-quarter of the SSA population were undernourished, compared with 15 per cent across all developing countries. Food and nutrition security is not only a major current challenge for SSA but also a prerequisite for sustained human development.

By poverty measures, SSA also lags behind other regions. In 2015 more than 40 per cent of the SSA population lived in extreme poverty, consuming less than US$1.90 per day. About 90 per cent of African poor live in rural areas, although the number of urban poor is increasing with the growth of cities. Most of the rural poor scratch a living from rainfed farming, often supplemented by off-farm work. Many poor households are also food and nutritionally insecure (and vice versa). Because of extensive poverty, limited wealth is directly reinvested in farming systems. However, given agriculture is the main source of livelihood for two-thirds of African poor, boosting agriculture generally reduces national income inequality and improves food and nutrition security.

It should be noted that there has been considerable development progress in SSA since the turn of the century. The 2015 growth rate was double the growth rate during the early millennium years or the period from the 1970s to the 1990s. The global hunger index (GHI) improved from 44 in 2000 to 32 in 2015. Similarly, per capita incomes had increased and extreme poverty was reduced substantially over the period 2000 to 2015.

With a population of 1.2 billion (compared with a total population of 5.6 billion in low- and middle-income countries globally), Africa faces major development challenges and, at the same time, great opportunities. Urbanization is increasing rapidly and already approximately half the population lives in cities. Overall, the poverty, food and nutrition insecurity and income inequality stand in marked contrast to the richness of the natural resources (mineral and agricultural) and the development potential of farming systems across Africa. Arguably, the region will need more targeted investment and strengthened institutions to achieve food and nutrition security, boost rural economic growth with equity, and to achieve the Sustainable Development Goals.

Food and agriculture systems

Food and agricultural systems span the full length of food chains – from agricultural resources and inputs to food production, value chains and consumption. In Africa, food and agricultural systems are diverse and complex. In rural areas, food production and consumption are closely integrated, with many farm households producing much of their own food needs, and in African cities informal backyard and peri-urban food production is common.

Smallholder farm women and men produce a wide variety of food grains, root crops, cash crops and livestock that support diverse food and livelihood systems in different zones. Agricultural exports, including cocoa, coffee and cotton, account for about one-sixth of total exports; meanwhile cereals account for about one-tenth of total imports, albeit increasing for rice, wheat and maize. During the period from 1990 to 2015, the terms of trade for African countries worsened appreciably, which has wider policy implications.

Because food represents a large proportion of expenditure for so many low-income families (including smallholder households), persistent high and volatile food prices constrain their ability to obtain food and nourishment. Further, it also restricts their ability to purchase health, education and other essential goods and services. Malnutrition is strongly correlated with poor dietary diversity and, in farming areas, with low production diversity. Hotspots of food and nutrition insecurity and poverty often occur in areas of high population density, severe land degradation and slow agricultural growth.

The main sources of dietary energy and protein for the African population are summarized in Table 1.2 (data on specific nutrients are limited). In 2010, dietary energy was largely sourced from plants, principally cereals and starchy roots; animal products provided about one-quarter of dietary protein and also many other nutrients. The dominant crop sources were maize, sorghum, millet, cassava and wheat, with rice consumption

Table 1.2 Dietary energy and protein availability by food group

Food group	*Dietary energy (kcal/capita/day)*	*Dietary protein (g/capita/day)*
Plant products	2377	52.7
Animal products	217	16.1
Total	2594	68.6
Breakdown by main commodity groups:		
Cereals	1288	33.1
Starchy roots and tubers	329	3.9
Pulses	106	6.7
Oil seeds and oils	281	2.8
Vegetables	47	2.3
Fruit	106	1.2
Meat	87	7
Milk	88	4.5
Fish	19	3

Source: FAOSTAT (2019).

Notes: Dietary energy and protein data intake are relatively stable over the years – the above data refer to the year 2010 for Africa. The category of cereals excludes use for beer. Pulses exclude groundnuts.

Table 1.3 Sources of dietary energy and protein by agricultural commodities

Commodities	*Dietary energy (kcal/cap/day)*	*Dietary protein (g/cap/day)*
Maize	376	9.6
Rice	227	4.5
Sorghum	146	4.4
Millet	99	2.4
Cassava	149	1.1
Yams	79	1.3
Plantains	36	0.3
Cowpeas	–	–
Groundnuts	41	1.8
Cattle	109	5.9
Sheep and goats	14	1.1
Poultry	30	2.9
Fish	19	3.0

Source: FAOSTAT (2019).

Notes: Dietary energy and protein are indicative, referring to continental Africa. The products of the crop or the animal type (cattle meat and milk, poultry meat and eggs) are included within the respective category. Nevertheless, the listed components represent only a part of the full diets and so add up to less than the total intake.

increasing rapidly (Table 1.3). Vegetables and fruit played minor roles in the provision of energy or protein but were important sources of nutrients and minerals. While urban areas consumed significant imports of cereals, rural areas tended to be dependent on local food production.

The averages in Table 1.2 mask the wide variations within Africa in 2010, across regions and population groups. For example, dietary energy ranged from 2136 kcal per capita per day in East Africa to 3140 kcal per capita per day in North Africa; similarly, average protein intake varied from 57 grams per capita per day in East Africa to 92 grams per capita per day in North Africa (equivalent global consumption estimates are 2870 kcal per capita per day and 80 grams per capita per day). As might be expected, dietary energy and protein intakes also vary across different farming systems. Nutritional security, including the consumption of micronutrients, is of growing concern for policymakers. Fortunately, the majority of the rural population benefits from reasonably diverse diets associated with the wide range of food crops and livestock produced on most small African farms.

Through the farming systems lens

Basic concepts

The mosaic of natural resources, climate, institutions, markets and agricultural services across Africa results in diverse land use zones and patterns of farming, referred to in this book as farming systems zones, or simply farming systems. Obviously, agricultural research needs to focus on the issues and opportunities associated with current and future crop, tree and animal production, trade and consumption. Perhaps less obviously, the targeting and impact of many agricultural policies have spatial aspects which differ by agricultural zone. For example, many irrigation policies apply only to large-scale irrigation schemes

(often not small-scale irrigation), livestock water point development targets pastoralists, fertilizer policies are relevant to crop farmers, and export levies directly influence only a subset of farmers producing the export product.

At its simplest, a farming system comprises a population of farm households with similar livelihood patterns and similar development constraints and opportunities (see Box 1.1 for further explanation). The farming systems described in this book extend over large landscapes and multiple countries, and typically support tens of millions of inhabitants.

The pattern of farm enterprises and their management practices depend on the farm resource base along with the financial, social and cultural capitals. They are integral components of a farming system. Because family labour is a key resource of farm households, off-farm employment and remittances are included in the concept of the farming system. The farm enterprise patterns and their management are often influenced by local formal and informal institutions (in the sense of the well-established arrangements for management or exchange, for example competitive markets, common property resource regimes). These are also intrinsic aspects of the farming system. Household consumption is also included because, for many farm households in Africa, decisions on farm production and household consumption are interdependent.

Naturally, communities within each farming system comprise different farm household types with contrasting levels of resources, access to services and coping strategies. Distinct patterns of inter-household interaction can be associated with each farming system, for example the high social capital of traditional herders in pastoral areas, which underpins grazing and water point management, contrasts with the economic and social relationships between large commercial farms and smallholders in Southern Africa.

Systems thinking has been applied to agricultural research and development (R&D) planning and policymaking in Africa for nearly a century. The early pioneers included Allan (1965), based on analyses of Southern Africa during the 1920s, and Ruthenberg (1971), who inspired many farming systems researchers in the following decades. Of course, systems research requires a structured approach to analysing complexity (Cabrera and Cabrera 2015) and integrating knowledge from farmers, value chain entrepreneurs and from multiple scientific disciplines. Over nearly five decades of farming systems analyses, applications have gradually expanded the number of analytical variables (Norman 2002), geographic scope and purpose, notably from applied research in communities, to 'research-for-development' and now to 'research-in-development' at broader scales. Sinclair (2017) conceptualizes how such systems analysis can be applied in order to target, support and monitor impact at scale. A wide variety of methods have been applied, for example household food budgets, nutrient and feed balances, participatory appraisal and evaluation, geospatial analysis, farmer- and community-managed trials, innovation platforms and other multi-stakeholder tools. In order to inform research, extension, planners and policymakers, farming systems analysis can identify constraints and interventions or can identify, classify and characterize different types of farming systems.

In principle, farming system zonation can be undertaken at a number of different scales. Depending on the purpose, the analysis could focus on one or more of the following levels of aggregation: farm household; community (or village) and landscape; country; and region (Dixon et al. 2009). Careful consideration is required in relation to the choice of scale and acceptable levels of heterogeneity. Farming systems analysis can serve many different purposes. For national and regional policymakers and research leaders, the characterization of a modest number of broad farming systems is most useful (Garrity et al. 2017). It is important to identify key drivers and trends which shape the directions

of farming systems development. Each farming system is influenced in different ways by external forces, including predictable long-term trends (e.g. increasing population density), unpredictable variations (e.g. climatic or economic shocks) and development interventions (e.g. projects, new technologies or policy changes).

The 2001 FAO/World Bank analysis of farming systems and poverty (Dixon et al. 2001) focused on resource endowment and 'services endowment' (access to services including markets) as primary determinants of farming system patterns. This analysis described eight generic farming system types across the developing world, and seventy-two 'regional' farming systems across the six developing regions, including fifteen systems in SSA and eight systems in North Africa. Such analyses of major farming systems provide an important evidence base for agricultural policy and decisionmaking (Bwalya pers. comm.) and enables improved priority setting and accurate targeting of policies and investments. This approach supports the development of more specific policies and spatial planning of rural infrastructure, and it facilitates the monitoring of impact on different farming systems.

The above analysis influenced the update of the World Bank Rural Development Strategy and supported the prioritization and targeting of a number of CGIAR research programs. More generally, the study encouraged systems-oriented R&D projects and loans which integrated various aspects of farming including resource management, crops, trees, livestock and markets (Dixon 2006). In Africa, the study underpinned a number of subsequent assessments of African agriculture, including agricultural research and poverty reduction (Inter Academy Council 2004), and water resources development (Faures and Santini 2008). The framework was incorporated in the Science Agenda of the Forum for Agricultural Research in Africa (FARA) and was applied to support national Comprehensive African Agricultural Development Program (CAADP) agricultural investment planning in Ethiopia and Tanzania.

In this book the analyses of broad farming system zones are informed by an understanding of farm household processes, strategies and responses to the local resource, institutional and policy environment. In addition, interactions across scales are considered, for example the functionality and governance of communities, districts, watersheds, local institutions and value chains. Well-structured and functioning systems create incentives for sustainable resource management, higher productivity and improved food security, underpinning rural transformation and economy-wide growth.

Box 1.1 Definition of a farming system

A farming system is defined as a population of farm households, generally of mixed types and sizes, that as a group have broadly similar patterns of resources, livelihoods, consumption, constraints and opportunities, and for which similar bundles of development strategies and interventions would be appropriate. Often, such systems share broadly similar agroecological and market access conditions. There are inherent patterns of heterogeneity in any particular farming system, for example the interdependence between small and large farms.

Some of the major determinants of spatial differentiation in farming systems are discussed in the next subsection. The temporal differentiation or evolution of farming systems is addressed in the section on drivers and trends.

Differentiating African farming systems

Apart from some large-scale irrigation schemes, African farming systems are dominated by rainfed cropping and pastoralism, with trees and shrubs playing important roles in most areas. In SSA alone, there are nearly 100 million ha of starchy staples (cereals, roots, tubers and plantains), more than 20 million ha of cowpeas and groundnuts, as well as cash crops such as oil palm (4.6 million ha), cocoa, coffee, cotton (3 million ha each) and tobacco. Around 230 million head of cattle, 470 million head of sheep and goats, and over 1 billion poultry constitute, along with fish, the animal component of the farming systems. The majority of households manage integrated tree-crop-livestock systems with limited access to agricultural services (notably markets). Cash crops, perennials and livestock contribute importantly to food purchasing power and play critical roles in farming system function, efficiency and resilience. Distinct patterns of household production and consumption characterize each farming system.

These African farming systems are diverse, and they evolve in complex ways (Pingali et al. 1987). The two main determinants of farming systems structure and function are access to agricultural resources (or resource endowment) and access to agricultural services. In relation to the former, while there are well-watered temperate and productive highlands (and even some snow-covered mountain peaks), the vast majority of African lands are in low to mid altitudes with rainfall varying from virtually nil in the Sahara and Kalahari deserts to over 3000 mm in the highlands. The most important agroecological zones in SSA are: moist subhumid and humid zones accounting for 38 per cent of SSA land; dry subhumid areas which cover 13 per cent; and the arid and semi-arid areas which cover 43 per cent of SSA land. Most of North Africa is arid or semi-arid, with well-developed irrigation in some areas.

In relation to services endowment, there is considerable variation in the density and quality of agricultural services. African governments have begun to reinvest in agricultural services in line with the CAADP target of at least 10 per cent of public expenditure to be spent on the agricultural sector. Consequently, some farmers have benefited from improved rural transport and market infrastructure, as well as the boom in mobile phones and information infrastructure led by the private sector, while others have yet to benefit.

The rural population of approximately 0.63 billion is also distributed unevenly across the African landscape. Seventy per cent of West Africa's population lives in the moist subhumid and humid zones; in North Africa the population is concentrated in irrigated zones or semi-arid environments; in East Africa the population is distributed across several agroecological zones.

The diversity of resource endowments overlaid by a mosaic of human settlements, transport routes and markets, has shaped many different farming systems, each with its own structure and function. There might well be a greater diversity of farming systems in Africa than in any other agricultural region of the world – considering the diverse examples of highly productive banana-maize-coffee systems in the East African highlands, cereal-root crop-livestock systems in western Africa, artisanal fisheries off coastal Mozambique, nomadic pastoralism, and urban agriculture in many parts of Africa.

A number of principles guide the identification of African farming systems. First, the farming system classification must be useful for science leaders and policymakers to inform their decisions on how best to accelerate the improvement of food and nutrition security. Second, quantitative national, survey and spatial data, and key informant knowledge are equally important in delineating and analysing farming systems. Third, farming systems are characterized according to their 'central tendency' or median characteristics through

a process of pattern recognition which subsumes local heterogeneity. The main farming systems were mapped, and populations, prevalence of poverty, resource endowments, service endowments (access to markets), cultivated areas and livestock numbers were estimated from the resulting spatial analysis. Compared to the original analysis of Dixon et al. (2001), this update benefited from the availability of greater volumes of spatial data, although the breadth, consistency and compatibility of the spatial data are sometimes less than optimal. The methods and data sources are elaborated in Chapter 2.

The update analysis resulted in fifteen distinct farming systems, which are mapped (apart from the urban and peri-urban system) in Figure 1.1 and characterized in Table 1.4. Consistent with these principles, each of the farming systems is represented by a unique set of core characteristics or 'central tendencies' in relation to agroecology, access to services and livelihood pattern. Naturally, there is a modest degree of local heterogeneity,

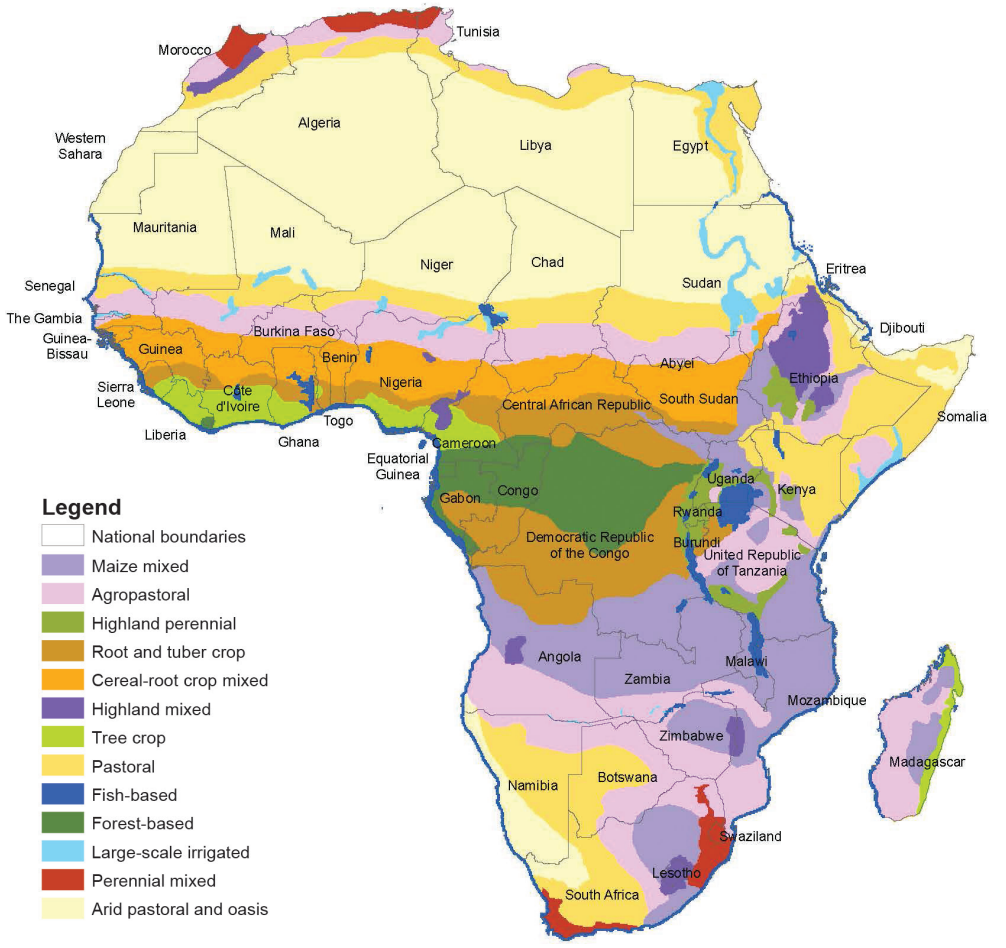

Figure 1.1 The farming systems of Africa.

Source: GAEZ FAO/IIASA, FAOSTAT, Harvest Choice and expert opinion.

Note: The map refers to the year 2015; the island and the urban and peri-urban farming systems were not mapped.

including some differences in farm types and sizes, variation in soils and minor small differences in access to services and markets. The major variation is captured in defined subsystems within each farming system, described in subsequent chapters.

The approach facilitated the organization of data and expert knowledge to characterize and differentiate the agricultural populations and resource bases of each of the farming systems. Each of the systems and subsystems is characterized by a set of typical farm types with recognizable household livelihood patterns. Generally, the boundaries between systems or subsystems are gradients or soft gradations which are represented in Figure 1.1 by 'feathered' boundary zones. The updated and revised farming system classification for African agriculture is therefore pragmatic and differentiates farming system areas spatially, which allows presentation of the analytical results to policymakers in a practical, usable form. The classification combines similar farming systems in North Africa and SSA, for example irrigated, pastoral, and arid pastoral and oases farming systems.

In examining Figure 1.1, the two main determinants of farming systems diversity, namely resource endowment (dependent on agroecology and population density), and services endowment (access to agricultural services including markets), should be recalled. In relation to agroecology, the length of growing season (LGP, measured in days of adequate soil moisture for plant growth) is a key indicator of potential biomass productivity. One approximate indicator of services endowment is the travel time to the closest major market town, based generally on maps of rural roads. In practice, the indicator of travel time to rural market is best combined with expert knowledge on market access, because other factors, in particular supply chains and mobile phone communications, also influence market access.

Table 1.4 describes the levels of resource and service endowments and the poverty, population and farming patterns for each farming system. Most farming systems contain a substantial to high proportion of extremely poor families. Based on the absolute numbers of poor households, nearly 150 million extremely poor farming children, women and men live in the four most-populated farming systems, namely the maize mixed, agropastoral, highland perennial, and root and tuber crop farming systems. The farming systems are listed in Table 1.4 in approximate order of the estimated numbers of extremely poor farm people.

Each broad farming system listed in Table 1.4 has a set of recognizable and distinct development constraints and opportunities, and would benefit from a particular set of policies, investments and research products. Strategic interventions for each farming system are identified in the respective farming system chapters.

Farm household decisions and strategies

The core argument of this book is that an understanding of household strategies, differentiated by type of farming system, should form the basis for the design of effective agricultural policies and allocation of public resources. It is important, therefore, to distinguish the strategies of farm households from agricultural sector strategies. For example, household strategies to intensify food production, even at the risk of declining soil fertility, would conflict with Government strategies to promote sustainable land management, unless complemented by actions to promote food security or establish safety nets. Most countries contain several different farming systems, often with contrasting development constraints and opportunities. For example, a number of West African countries contain both the commercial tree crop farming system and the cereal-root

Table 1.4 Key characteristics of African farming systems

Farming system	*Agricultural population (millions)*	*Key system characteristics*
Maize mixed	107	Mixed farming dominated by maize with medium access to services in subhumid areas of East, Central and Southern Africa. Other livelihood sources include legumes, cassava, tobacco, cotton, cattle, shoats, poultry and off-farm work.
Agropastoral	98	Mixed crop-livestock farming found in semi-arid (medium rainfall) areas of Africa, typically with low access to services. It includes the dryland mixed farming system of North Africa, often depending on wheat, barley and sheep. In SSA the main food crops are sorghum and millet, and livestock are cattle, sheep and goats. In both cases, livelihoods include pulses, sesame, poultry and off-farm work.
Highland perennial	61	Highland mixed farming is characterized by a dominant perennial crop (banana, plantains, enset or coffee) and good market access, and is found in humid East African highlands. Other livelihoods derive from diversified cropping including maize, cassava, sweet potato, beans, cereals, livestock and poultry augmented by off-farm work.
Root and tuber crop	50	Lowland farming dominated by roots and tubers (yams, cassava) found in humid areas of West and Central Africa. Other livelihood sources include legumes, cereals and off-farm work.
Cereal-root crop mixed	43	Mixed farming with medium-high access to services dominated by at least two starchy staples (typically maize and sorghum) alongside roots and tubers (typically cassava) found in the subhumid savannah zone in West and Central Africa. Other livelihood sources include legumes, cattle and off-farm work.
Highland mixed	45	Highland mixed farming above 1700 m dominated by wheat and barley, found predominantly in subhumid north-east Africa with pockets in Southern, West and North Africa. Other livelihood sources include teff, peas, lentils, broad beans, rape, potatoes, sheep, goats, cattle, poultry and off-farm work.
Tree crop	30	Lowland farming dominated by tree crops (> 25% cash income from cocoa, coffee, oil palm or rubber) found in humid areas of West and Central Africa with good access to services. Other livelihood sources include citrus, yams, cassava, maize and off-farm work.
Pastoral	38	Extensive pastoralism (dominated by cattle), found in dry semi-arid (low rainfall) areas with poor access to services. Other livestock include camels, sheep and goats alongside limited cereal cropping, augmented by off-farm work.
Fish-based	22	Found along coasts, lakes and rivers across Africa with medium-high access to services, with fish a major livelihood. Other livelihood sources include coconuts, cashew, banana, yams, fruit, goats, poultry and off-farm work.

Forest-based	12	Lowland, heavily forested humid areas in Central Africa with low access to services and subsistence food crops (cassava, maize, beans, coco-yam and taro). Other livelihood sources include forest products and off-farm work.
Irrigated	48	Large-scale irrigation schemes associated with large rivers across Africa, e.g. Nile, Volta. Often located in semi-arid and arid areas but with medium-high access to services. Includes the associated surrounding rainfed lands. Diversified cropping includes irrigated rice, cotton, wheat, faba, vegetables and berseem augmented by cattle, fish and poultry.
Arid pastoral and oasis	8	Extensive pastoralism and scattered oasis farming associated with sparsely settled arid zones across Africa, generally with very poor access to services. Livelihoods include date palms, cattle, small ruminants and off-farm work, irrigated crops and vegetables.
Perennial mixed	12	Semi-commercial and commercial farming with good access to services, dominated by perennials such as vines, fruit and eucalypts, found in Mediterranean (subhumid) climates in the coastal areas and hinterlands in Southern and North Africa. Other livelihoods include sugarcane, maize, legumes, cattle and small ruminants.
Island	4	Mixed cropping, horticulture, sugarcane and fishing in the principal islands associated with Africa. Other livelihoods include livestock. Often there is medium access to domestic and tourist resort markets, but limited exports.
Urban and peri-urban	na	Located within cities, or on their fringes with high population density and medium-high access to services and markets, often informal. Livelihoods include fruit, vegetables, dairy, cattle, goats, poultry and off-farm work.

Source: Based on existing data and author expert judgements for the year 2015. Off-farm work can be found in all systems, but is noted where it is a main livelihood.

crop mixed farming system, with dramatically different needs related to infrastructure, credit, market development and research.

Farm women and men are the key decisionmakers in the management of natural resources, farm production, family consumption and farm investment. The decisions are framed by formal and informal institutions which are influenced by community values, public policies, markets, resource access regimes and the knowledge, skills and experience of the household, with the broad goal of improved individual and community welfare (Figure 1.2). Climate and economic risks are major considerations in operational and tactical farm and household management decisions. Farm households have a leading role in the management of natural resources – this is sometimes overlooked. Also, with increasing opportunities for women in agriculture, women are playing a wider role in farm management decisions. Other family members, including the elderly and the youth, also may influence strategic management and investment decisions.

There are strong linkages between increased crop or livestock productivity, improved farm household food security and reduced rural poverty. In good seasons or on medium-large farms, food crop surpluses are sold. Smallholders may sell at harvest and then purchase later in the year when their household stocks have been consumed. Although there are exceptions, sales of farm or household produce increase purchasing power, and they generally improve household food and nutrition security and reduce poverty. Increased

food crop productivity often creates opportunities for diversification to higher value cash crop, tree or livestock income for households. Additional off-farm wage income also increases food purchase entitlements, often for the most vulnerable households, and offers flexibility for increasing purchases of fertilizer and other agricultural inputs. Population density and the level of infrastructural development influence the rate of spread of these outcomes. For these reasons, the mix of food crops, cash crops, livestock and trees, and their inter-linkages, is often an important determinant of food security outcomes. Gender roles in household decisionmaking and the management of income also shape the poverty, food and nutrition security outcomes. Farm size and wealth also count: normally smallholders spend a high proportion of additional income on local goods and services, whereas larger farmers tend to spend more outside the region.

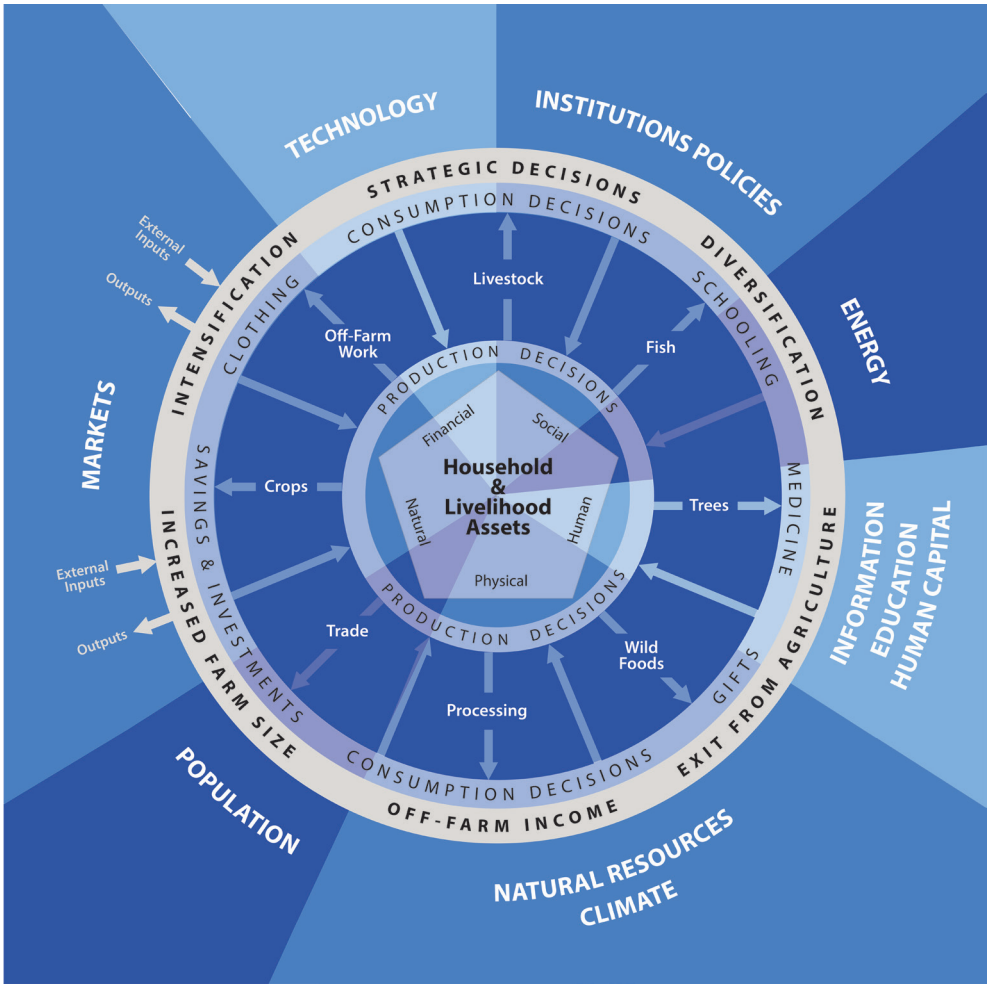

Figure 1.2 Farm household decisionmaking connecting resource management, production, consumption, investment and welfare.

The households in a farming system pursue recognizable strategies to secure household food and nutrition security, increase income, improve livelihoods and satisfy other household goals. For example, pastoralists with limited market access might seek to grow herd size while smallholder vegetable producers might endeavour to intensify production of profitable vegetables sought by the market. The strategies naturally depend upon the prevailing livelihood patterns and opportunities, as well as the pattern of smaller and larger farmers, female- and male-headed households and differing degrees of dependence on off-farm income, cash crops and livestock in the farming system. One typology in the maize mixed farming system in Malawi differentiated households, which were 'hanging in', 'stepping up' or 'stepping out' (Dorward 2009). Such pathway-oriented typologies represent one way to identify evolving patterns of social organization, and they are useful to understand the needs for technology and institutional innovations, and to guide research and policy decisions. Clearly, the development needs and constraints of individual households within one farming system, such as the maize mixed farming system, are more similar to one another than to the households in another farming system.

In broad terms, small farm households have five main strategies to improve livelihoods and household food security or escape poverty, as follows:

- intensification of existing production and processing patterns
- diversification of production and processing patterns
- expanded farm, enterprise or herd size
- increased off-farm income, both agricultural and non-agricultural
- exit of the whole family from farming in the particular farming system.

These strategic options are not mutually exclusive: any particular household will often pursue a mixed set of strategies.

Intensification is defined as increased physical or financial returns from existing patterns of production, representing greater productivity of agricultural outputs including food and cash crops, livestock, trees and other beneficial activities. Although intensification is frequently associated with increased productivity as a result of greater use of purchased inputs, intensification may also arise from improved knowledge that leads to better use of existing household resources, including varieties and breeds, and labour and farm management skills, for example improved irrigation practices or better pest control. In Africa today, access to productive technologies, input and output markets often drives intensification. Readers are cautioned on the limits to rainfed crop-based intensification, partly because small farm sizes limit potential gains in household income. The concept of 'intensification' adopted in this book relates to increased productivity of existing farm activities, in contrast to on-farm diversification (see the following paragraph) and broader, landscape level, agricultural intensification which includes the introduction of new crops or livestock.

On-farm diversification is defined as an adjustment to the farm enterprise pattern in order to increase farm income or livelihoods. Often, there is a corresponding reduction in risk or income variability. Diversification exploits new market opportunities or existing market niches. Diversification may take the form of completely new enterprises, or may simply involve the expansion of existing, high value, enterprises. The addition or expansion of enterprises refers not only to production but also to on-farm processing

and other farm-based, income-generating activities. Farm women and mens' knowledge, adequate technologies (even if adaptation might be required) and access to markets often drive diversification. Diversification, as used in this analysis, should not be confused with improved livelihoods from off-farm sources or additional off-farm income, as found in some rural development literature.

Some households increase income or escape poverty by expanding the farm business size – in this context size refers to managed rather than to owned resources – especially where population density is low, land rights permit and finance is available. Beneficiaries of land reform are an obvious example of this source of poverty reduction. Increased farm size may also arise through incursion into previously non-agricultural areas such as forest – often termed expansion of the agricultural frontier. Two other examples are increased herd size where grazing land is available, and settlers on new irrigation schemes. Although this option is not available within many systems, it is of relevance particularly in parts of Latin America and SSA. Increasingly, however, such 'new' lands are marginal for agricultural purposes, and they may not offer sustainable pathways to poverty reduction.

Off-farm income represents an increasingly important source of livelihood for many poor farmers. Seasonal migration has been one traditional household strategy for escaping poverty. Remittances are often invested in land or livestock purchases. In locations where there is a vigorous off-farm economy, some individuals from poor households augment the family income with part-time or full-time off-farm employment.

Where opportunities for improved livelihoods are perceived, a proportion of farm households will abandon their land and/or herds altogether, and relocate the whole family into other farming systems, or into other rural or urban locations with economically attractive off-farm activities. This means of escaping agricultural poverty is referred to in the following chapters as an exit from agriculture.

These poverty escape strategies refer to extremely poor households which form a significant proportion (sometimes more than half) of the farming population in all systems. The balance of farm households is somewhat better off with greater than US$1.90 consumption per day; a small proportion could be termed 'well off'. The same five strategies apply to the 'non-extremely poor' farm households in relation to the enhancement of livelihoods and incomes. Typically, the strategy mix of poor households differs from that of better-off households, whether smallholder or medium commercial farms.

The above five household strategies for reducing hunger and poverty, and enhancing livelihoods and incomes, will be referred to frequently in the following chapters and their relative importance assessed, based on the judgement of experts who are knowledgeable about each particular system (see also Chapter 2).

Drivers and trends shaping African farmers' opportunities

Overall changes in farming systems since 2000

Since the origins of agriculture, the geography of crops, extent of livestock and the patterns of land use have continued to change. The degree of change in African farming systems over the period 2000–2015 is substantial. The agricultural population density has increased (even allowing for rural-urban migration) leading to a reduction in farm size, intensification of production and induced innovation in production practices. Meanwhile, agricultural market access has improved markedly, which has stimulated major changes in crop combination, herd composition and marketing of surpluses, but

notably not the widespread adoption of fertilizer. The farming systems with traditional export crops such as cocoa or coffee have maintained well-organized market systems. Another effect of improved service endowment has been diversification towards marketable crops and livestock. Such effects are most pronounced in the highland perennial farming system but are also evident in most farming systems including the maize mixed and cereal-root crop mixed farming systems. There has been an expansion of cultivated area in the majority of farming systems, notably the forest-based, cereal-root crop, maize mixed and agropastoral farming systems – reducing (but not off-setting) the pressure from increased population density. Notably, the land frontier has closed or is closing in many farming systems, including the four named earlier and the highland perennial and highland mixed farming systems.

Consequently, this analysis reflected the evolution of farming systems over the period 2000–2015. For example, where maize has been widely adopted in Central African areas that were originally cereal-root crop mixed systems, the areas were reclassified to the maize mixed farming system. The combination of changes in rural consumer preferences and the development of drought tolerant maize has also increased the proportion of maize, alongside sorghum and millet, in the agropastoral farming system, but not sufficiently to reclassify the farming system. The dualistic system characterized by mixed large-scale commercial and small-scale farming in Southern Africa was reassigned to other systems, notably the maize mixed and agropastoral systems. Market development has created more opportunities for smallholders in East Africa, in particular horticulture and dairy, and consequently the commercial smallholder highland perennial system has been enlarged. The key changes in the extent of farming systems over the period 2000–2015 are:

- creation of a newly delineated perennial mixed system in Southern Africa
- distribution of the large commercial and smallholder farming system entirely to other systems, notably perennial mixed, maize mixed and agropastoral systems
- adjustment of boundaries of many systems reflecting, primarily, increased population density, improved infrastructure and access to agricultural services, and improved technology and institutions
- substantial reduction in the extent of the cereal-root crop mixed farming system.

Quite apart from the major spatial changes, farming systems are changing incrementally. Some changes are visible, such as deforestation to expand cultivated land, but others relate to resource use, resource quality (e.g. fertility decline) or economic and social relationships (e.g. returns to labour, changing social capital). These build pressure over time which can generate step changes in enterprise combination or technology adoption. The trends and resulting pressure points can be identified by careful analysis and then future changes predicted. In the medium term, a set of universal drivers frames the evolution of each farming system along relatively predictable pathways. The seven drivers are:

- population, hunger and poverty
- natural resources and climate
- energy
- human capital, knowledge sharing and gender
- science and technology
- markets and trade
- policies and institutions.

Table 1.5 Principal drivers and trends in farming system development

Drivers (trends)	*Example metrics*	*Example influences on farm household decisions*	*Example influences on structure and function of farming system*
Population, food security and poverty (increased pressure)	Population density, migration, urbanization, diet, under-nutrition, poverty	Labour availability and productivity, farm practice adoption decisions, schooling, risk avoidance	Labour-saving technologies, reduced herding/expanded stall feeding, low investment
Natural resources and climate (reduced availability and quality)	Farm size, herd size, irrigation, land tenure, land degradation	Scarcity of land and nutrients creates incentives for irrigation and soil management, increased climate risk	Reduced farm and herd size, reduced land/labour ratios, shift from extensive to intensive practices, stronger integration of crops, trees and livestock
Energy availability and use (increased availability, volatile prices)	Energy availability and use, firewood use, electrification	Timeliness of operations, replacement of labour	Earlier planting, better weeding, post-harvest processing, appropriate mechanization, small-scale irrigation
Human capital, knowledge sharing and gender (improved education, information and benefit sharing)	Education and skill level, mobile phone ownership, extension/farmer ratio	Improved farm decisions and management, improved benefit sharing, adoption of new practices or enterprises, greater involvement of women in decisions	Diversification, increased eco-efficiency (water and nutrient use efficiency), greater market orientation, improved gender equity, better farm-household management and increased total factor productivity
Science and technology (increased technology choices)	Productivity, technology adoption	Adoption of better practices and enterprises	Increased eco-efficiency, expanded production, improved quality of produce
Markets and trade (expanding market access and reduced marketing costs)	Input use, market surplus, supply chain length, food system structure, competition, agribusiness investment	Increased productivity, diversification, value-adding	Stronger market orientation and commercialization, reduced capital and transaction costs, greater intensification and diversification
Institutions and policies (strengthening institutions)	Expenditure on agriculture (incl. research, input subsidies, infrastructure), new regulations	Adoption of institutional innovations (markets, finance, risk sharing, conditional prepayment rate management)	Improved resource management, farmer group and cooperative coordination for marketing and resource management

The drivers correspond in general terms with the various drivers identified by other authors. For example, Reardon and Timmer (2014) identify five 'transformations' of the Asian agrifood economy (urbanization, diet changes, food system transformation, rural factor markets and capital-led farm technology intensification); these apply in part in Africa. Jayne (2016) and other authors describe other similar sets of mega-drivers.

In practice the above seven drivers interact, and the reader might anticipate a fundamental nexus between population density, access to natural resources and access to services including markets. It is important to note that trends (increasing, decreasing, steady) associated with each driver can rarely be assumed to be constant or linear. Whether there are 'necessary' and 'sufficient' conditions for change in each set of drivers plays out differently for different situations and for different farm sizes.

The above seven drivers influence farm household production and consumption decisions and farming system structure and function. Table 1.5 introduces the seven principal drivers which shape the development of farming systems structure and function in Africa; these are discussed in greater depth in the following subsections.

Population, hunger and poverty

People lie at the heart of sustainable development and farming systems options, and rapid population growth is dramatically shaping the limits and opportunities of farming pathways in all parts of the continent. Since 2000 the African region has had the fastest growing population in the world, and this is projected to continue for the coming decades. The total regional population was 1.2 billion in 2015 of whom 585 million (about half) were classified as agricultural. Regional population growth rate has been about 2.6–2.7 per cent p.a. since 1990, despite the effect of HIV/AIDS, but there is considerable variation across countries, for example the Ethiopian population growth rate is above 3.0 per cent. In the African context, such high growth rates boost the food economy and increase the dependency ratio of young and old on the workforce. While fertility rates have begun to drop in urban areas, the rural household's traditional path to social security had been to have many children. However, there are indications of a growing emphasis in rural areas towards small families and well-educated children who can compete in the job market and earn off-farm income for the family.

The trends shown in Table 1.6 for SSA are indicative of the wider African situation. The SSA rural and agricultural populations are growing in absolute size although declining as a proportion of the total, partly because of rural-urban migration. Between 2010 and 2050 the rural population is projected to increase by 56 per cent, and the agricultural population by a slightly lower proportion. The SSA urban population is expected to surpass the rural population in about 2035. Such rapid urbanization stimulates urban and peri-urban farming, and influences other farming systems through opportunities for meeting growing and changing urban middle class demand for food. These demographic changes are expected to lead to a slower rate of decline in the land/agricultural population ratio and farm size – although the current person-land ratio is relatively low compared with that of Asia.

Such massive demographic changes raise four critical and interrelated policy issues. First, although the proportion of farmers in the total population is projected to decline from 56 to 33 per cent by 2050, the number of farmers will increase by half. Second, accordingly, in some farming systems with substantial forest or well-watered grazing lands, conversion of forest or grazing land to cropping is expected (as has happened since 2000

Table 1.6 Trends in population and food security in sub-Saharan Africa compared with the world

	1970	*2000*	*2010*	*2050*
SSA total population (million),	285	642	823	1892
(SSA total pop as % of world)	(8)	(10)	(12)	(20)
SSA urbanization (%),	20	32	36	56
(Global urbanization %)	(37)	(47)	(52)	(67)
SSA agricultural population (million),	206	368	428	617
(SSA ag pop as % of world)	(11)	(14)	(16)	(29)
SSA agric pop as % of total SSA pop,	72	57	52	33
(Global agric pop as % of total global pop)	(83)	(79)	(38)	(23)
SSA farm households (approx million)	38	67	78	112
Household food security (kcal/person/day),	–	2188	2495	2580
(reference year of estimate)		(mid-1990s)		(est 2030)
Undernourishment (% of population),	–	33	24	15
(year of estimate)		(1991)	(2014)	(2030)

Sources: FAO (2015), IFPRI (2015).

Notes: SSA agricultural and farm household populations in 1970 and 2050 were estimated by the authors.

in the forest-based and agropastoral farming systems). In other more densely populated farming systems (such as the highland perennial or highland mixed), average farm size is expected to decline (average farm size has already declined in many farming systems). Third, in either case, increased farm productivity is required, because, in the absence of a major expansion in food imports, each farm household will have to feed three households (themselves and two urban households – the equivalent global ratio will be four to one). Fourth, without adequate mechanization, system intensification and diversification could be held back by labour shortages. A further critical policy concern is whether sufficient viable employment opportunities in secondary and tertiary sectors can be generated to absorb rural populations leaving agriculture, to avoid hotbeds of unemployment and poverty in expanding peri-urban slums which already account for about 60 per cent of the urban population in Africa.

Household food security is a critical determinant of farm family decisions about production and consumption. Food security has energy and nutritional dimensions, and can be analysed from the demand side, supply side and the linking market systems (Qureshi et al. 2015). In SSA nearly half of the rural households are not food secure, with great variation in the distribution of undernourishment across farming systems and between years. In practice, most poor households lack food security, but some well-off households are also malnourished because of nutritionally unbalanced diets. However, the situation is improving, as shown in Table 1.6.

Off-farm income through wages or micro-business is an important source of cash for purchasing food, noting that a high proportion of African smallholders are net purchasers of food. In this context household or per capita income, or average GDP per capita, is an important indicator of purchasing power. Improved cash incomes may alleviate the risk of food entitlement failure, often described in terms of food production, market and consumption risk.

In the mid-1990s the average dietary energy consumption was 2188 kcal/person/day (compared with 2626 in developing countries as a whole). By 2010, dietary energy intake had increased to about 2495 kcal/person/day. Up to 2030, the average energy intake is projected to increase to 2580 kcal/person/day. In spite of the increased calorie supply, it is estimated that in 2030 around 15 per cent of the population (about 165 million people) will still be undernourished – an increase in the absolute number – unless deliberate measures are taken to ensure better access to food. Overall, it is clear that energy and nutrient deficiencies have constrained farmer activities and productivity, and they have slowed development, with long-term consequences for farming systems development.

Natural resources and climate

In many areas, as rural populations have grown, the availability of land for agricultural expansion has become limited. While African farmers have traditionally fallowed depleted cropland to restore soil fertility, many are now forced to crop some of their fields continuously. Fallowing has reduced or has been phased out in some systems. There is increased competition and more frequent conflicts between farmers and livestock herders regarding access to land used for community grazing in the past, thus reducing opportunities for crop-livestock synergies including manure production. The intensity of farming has increased often with inadequate investment in land management to restore fertility and limit soil erosion and other land degradation. Thus, maintenance of crop yields in the face of soil impoverishment has become a primary concern for many smallholder farmers across a range of farming systems.

Approximately two-thirds of agricultural land in SSA is estimated to be subject to degradation. These trends are worrisome, considering the imperative to increase agricultural yields to feed the rapidly growing population. Land degradation and the concurrent depletion of soil fertility which affects agricultural productivity has become a central development issue for policymakers, accentuated by climate change. As noted earlier, Africa is relatively well endowed with natural resources. However, soil resources are heterogeneous, with both some areas of deep fertile soils but also large areas of infertile and highly erodible soils (Inter Academy Council 2004).

One of the best overall indicators of natural resource health is net primary productivity, which varies according to regions in Africa. The decline in the annual biomass productivity of the land is particularly evident in the maize mixed farming systems in Zambia, Angola, DRC, Mozambique and Tanzania. There has also been marked degradation in the forest-based systems in the countries of the Congo Basin. Much of this loss of biomass productivity is due to forest clearing for agriculture, followed by lower productivity land use mosaic when forest is not allowed to sufficiently regrow. In contrast, biomass productivity in some parts of Sahelian and Sudanian West Africa has increased since the late 1990s, particularly in the agropastoral and cereal-root and tuber crops farming systems.

In relation to the 660 million ha of forest (about one-quarter of total land area), current annual deforestation is 0.16 per cent. The decline in closed-canopy forest area is expected to continue. However, as forest area declines and agricultural land is degraded, farmers have begun to regenerate or plant trees on crop lands. This trend, apparent in the agropastoral systems of the Sahel, is associated with the improved nutritional status of households. Wetlands and national parks are also often under pressure, despite national land use regulations or international conventions.

Over recent decades, rainfall patterns have changed across the globe, potentially affecting Africa more than other regions. In Africa, the most affected farming systems are likely to be those in the arid, semi-arid and dry subhumid areas, for instance the agropastoral and pastoral farming systems. The increasing frequency and severity of droughts are likely to cause more crop failures, high and rising cereal prices, low and falling livestock prices, decapitalization, distress sales of animals, and hunger. Vulnerable farm households are likely to buffer crop and livestock livelihoods with off-farm income, for instance seasonal migration, and wood and charcoal sales are common non-farm income sources. The above pressures could exacerbate land degradation and deforestation, accelerate the onset of desertification and drive people temporarily or permanently into more favoured farming systems, for instance the cereal-root crop mixed and maize mixed farming systems, and into urban areas. As a result, rural conflicts over resources will become more common, including between sedentary farmers and pastoralists.

Food and agricultural use of land has expanded steadily across Africa. Of the total land area, about 38 per cent was agricultural land, and approximately 9 per cent of total land was used for annual or permanent crops by 2015 (Table 1.7). The cultivated area increased from 170 million ha in 1961–1963 (including annually cultivated land and permanent crops) to 272 million ha by 2015 – mostly through the conversion of forest and grasslands and the shortening of fallows. Further expansion is possible. It is estimated that the Africa region has up to one-half of global agricultural land available for the expansion of crop land. The availability of suitable arable land in Africa for food and bioenergy crop production attracted much foreign investment and led to intense policy debates, especially since the 2008 food price spike. However, the momentum underlying the bioenergy crop production objective was undercut by recent changes in the European Union's biofuels policies. As the food price spike passed, the priority for overseas food production abated. Domestic investment is now balancing foreign investment in large-scale farming ventures and is also being scaled up in medium-sized family farming.

Under existing climatic conditions, the region has large areas with high potential for rainfed cropping and grazing, and opportunities for expansion of surface water irrigation backed up by extensive (newly discovered) groundwater reserves. Only 2 per cent of the available water resources were utilized for irrigation (15.8 million ha equipped in 2015), compared with 20 per cent in developing countries overall. Projections suggest continued expansion of irrigated areas until 2030.

Table 1.7 Trends in land use in Africa

Land use (million ha)	*1970*	*2000*	*2015*
Agricultural land area	1057	1123	1133
Forest land area	–	670	624
Crop land, including permanent crops	186	230	272
Permanent crop land	17	28	34
Permanent meadows & pasture	870	893	861
Land area equipped for irrigation	8.4	13.2	15.8

Source: FAOSTAT (2015).

Notes: data are indicative, whole of Africa data.

Table 1.8 Trends in livestock and poultry populations in sub-Saharan Africa

Animal type	*1970*	*2000–*	*Growth rate 1970–2000 (% p.a.)*	*2010*	*Growth rate 2000–2010 (% p.a.)*	*2050 (estimate)*
Population (million head)						
Cattle	129	181	1.7	234	2.6	272
Sheep	114	150	1.7	199	2.3	330
Goats	92	184	3.9	269	3.2	446
Poultry	321	766	4.9	1162	3.0	1704
Stocking rates on agricultural land (head/ha)						
SSA cattle	0.14	0.20	–	0.24	–	0.21
(global ratio)	(0.26)	(0.30)		(0.33)		(0.35)
SSA sheep and goats	0.8	1.8	–	2.3	–	2.8
(global ratio)	(2.0)	(4.1)		(5.4)		(7.0)
Farm household ownership (head/household)						
Cattle	3.4	2.7	–	3.0	–	–
Sheep	3.0	2.3	–	2.6	–	–
Goats	2.5	2.8	–	3.5	–	–
Poultry	8.0	8.8	–	10.5	–	–

Source: FAOSTAT (2015).

Notes: The livestock populations and stocking rates are projections to 2050 derived using growth rates generated from the IMPACT model version 3.0 (Enahoro, Tarawali pers. comm.; Robinson et al. 2014).

Livestock are first and foremost an asset for many smallholders. Animal populations in SSA are expanding steadily, as shown in Table 1.8. Poultry and goat numbers have expanded rapidly and nearly trebled over the four decades from 1970 to 2010; cattle, sheep and camels have nearly doubled in numbers during this period. Fishing activities are also increasing in response to local demand from growing populations as well as from cities and for exports, and this offers a form of relatively liquid household savings.

Both agricultural and livestock populations have increased substantially over the three decades to 2010. However, the number of cattle and sheep per farm household have decreased somewhat, in contrast to an increased household holding of goats and poultry. There is, of course, greatly increased pressure on grazing lands (Table 1.8) and crop residues as a result. Continued increase in livestock and poultry is expected, driven by market opportunities and relative prices. In fact the stocking rates are significantly lower in Africa than other parts of the world, which suggests scope to further increase livestock numbers through the use of technologies and institutions for crop-livestock integration.

Energy

In Africa, only approximately 2 per cent of energy consumption is devoted to agricultural and forest production, and this has been relatively steady over the past several decades. There

is a marked variation in energy use between different parts of Africa, with Western Africa reporting less than half the agricultural and forestry energy intensity of Southern Africa.

Two major uses of energy in production are tillage (depending on whether manual, animal draught or mechanized) and water pumping for small-scale irrigation. In marketing, transportation is the dominant use of energy for input and produce chains. The intensification of food production will require greater use of energy for traction, inputs and processing of outputs, although crop production using conservation agriculture[1] practices is energy saving at the field level. Energy and food markets are now interlinked and price movements are correlated. Energy efficiency in food production, processing and marketing will be critically important in future decades.

Human capital, knowledge sharing and gender

Knowledge can be a powerful driver of farming systems development in many ways, and so information, human capital and inclusive approaches merit the close attention of policymakers. A key trend is the 'feminization' of farming as young males seek seasonal and longer-term employment in cities and other countries, leaving women as the *de facto* farm managers. Improved farm household decisionmaking, increasingly by women, requires strengthened capacity through education and farmer training, supplemented by the dissemination and sharing of technological, market, policy and institutional information.

Communication technologies such as radio and mobile phones have accelerated access to information through formal and informal networking, and strengthened social capital and farmer-to-farmer sharing. Of the new communication technologies, mobile phones have had the most far-reaching effects. Two aspects of mobile phones are widely recognized: their rapid adoption and their potential use for agricultural information dissemination. There has been an explosion of mobile phone ownership since the mid-2000s in many African countries. Interestingly, mobile money exchange is expanding at a similar rate to mobile phones in Kenya, albeit with a lag of about four years. Information communication technologies (ICTs) may well revolutionize agricultural technical and market information sharing and offer the potential for fully interactive decision support services – along similar lines to India.

Science and technology

Science and technology, supported by appropriate policies and institutions, have an important role in resource management and productivity growth in crops and livestock in future decades, which is essential to reduce African poverty and food insecurity. Important innovations which have emerged in recent years include improved varieties and breeds, conservation agriculture, better pest control and improved nutrient management – and also a range of institutional innovations which enhance information availability (e.g. ICTs), market access and reduce risk (e.g. index insurance). As a generalization, the past and existing innovations streams seem to have benefited higher potential farming systems (e.g. cereal-root crop mixed system) more than low potential farming systems (e.g. agropastoral and pastoral systems). The existing portfolio of innovations also appear to favour increased productivity over risk management and adaptation to climatic variability. Furthermore, some technologies are not well suited for existing farming systems which, together with weak scaling institutions, have led to low adoption rates.

Increased investment in agricultural research (which shows consistently high economic high returns) is of fundamental importance for the continued supply of innovations to

underpin future food and nutrition security. It is expected that the contribution of the private sector to research will grow in the coming years. The concentration of research effort in a small number of countries creates opportunities for the 'spillover' of innovations between countries with the same broad farming systems.

The aggregate capacity of SSA agricultural R&D institutions is growing in terms of the absolute number of researchers and real public budget. However, when compared with the agricultural sector size, the number of researchers per million economically active agricultural workers has risen only slightly from 5.7 in the early 1980s to almost 7.0 in 2011; the public agricultural research intensity (the expenditure in relation to the Agricultural GDP) has declined over the same period from 0.6 per cent to about 0.5 per cent (compared with the recommendation of 1 per cent research intensity by the New Partnership for African Development (NEPAD)).

The Forum for Agricultural Research in Africa (FARA) has launched its Science Agenda, which provides a forward-looking framework for agricultural innovation. It recognizes the diversity of African agriculture and the different technology and investment needs of various farming systems. The incorporation of the farming systems framework into the Agenda offers a template for the management of spillovers between countries sharing the same or similar farming systems.

Although many metrics of research effectiveness exist, one of the most popular is the relative increase in food crop yields or animal productivity. Another indicator of technology uptake and effectiveness is the rate of closure of yield gaps. Often, technologies are embedded in inputs, so greater use of improved seed or fertilizer is also a useful proximate indicator.

The gaps between farm yields and potential yields are very large for most African crops and livestock production (larger than most other regions of the world). Cereals, fruit, maize and rice have shown modest to strong yield growth since 1970 – this has continued for cereals until 2015. However, the areas harvested of most food crops have expanded alongside the increases in yields. For example, while the yield of maize has increased 1.2 per cent per annum since the late 1980s, the maize area has expanded by 1.5 per cent per annum.

Total crop production is forecast to increase by about 70 per cent over the period from 2010 to 2050. Major increases are expected to come from expanded production on heavy lowland soils scattered across the continent in several different farming systems, in the humid and moist subhumid tropics, and on irrigated land in the maize mixed and several other farming systems. Despite the growth in demand for small-scale irrigation, most food production in Africa will continue to come from rainfed farming.

Livestock and poultry productivity compares favourably with global averages (using the partial productivity metric of kg meat per head; see Table 1.9) except in the case of cattle. Compared with Asia and Europe, Africa has progressed poorly with an overall beef (and buffalo) carcass increase of around 12 per cent over the period 1961–2012, compared with around 40 and 76 per cent in Asia and Europe respectively. As of 2012, average carcass weight in Africa is only 65 per cent that of Europe. However, cattle and sheep recorded an overall increase in productivity between 1970 and 2010, which is expected to continue in the coming decades.

Milk and meat production is expected to triple between 2010 and 2050 in response to strong income-induced demand. Because of different demand patterns, milk production is expected to expand most rapidly in East Africa and poultry production in West and Southern Africa. The increased demand for feed grains will have knock-on effects on crop production.

Although food crop yields have begun to rise recently, African yields lag behind Asia and developed countries for a variety of abiotic, biotic and institutional reasons. Land

Table 1.9 Trends in livestock and poultry productivity in sub-Saharan Africa and globally

Animal type	*1970*	*2000*	*2010*
Cattle meat, kg/head	153	155	170
	(182)	(206)	(212)
Sheep meat, kg/head	13.0	12.5	14.9
	(15.1)	(15.8)	(15.7)
Goats meat, kg/head	11.7	12.6	12.6
	(10.9)	(11.8)	(12.1)
Poultry meat, kg/head	1.0	1.2	1.2
	(1.3)	(1.6)	(1.6)

Source: FAOSTAT (2015).

Note: Estimates are indicative, based on unweighted averages of the four regions of SSA. Global productivity data are shown in parentheses.

degradation and climatic variability are the two main abiotic constraints. Inorganic fertilizer consumption is very low in SSA despite the declining soil fertility noted earlier. From 2002 to 2010, inorganic fertilizer usage was low and scarcely increased (from 11.6 to 11.7 kg N/ha) compared with an increase in global nitrogen nutrient application from 57 to 69 kg N/ha (FAO 2015). The use of compost or other soil amendments is important but does not compensate for these very low levels of fertilizer use.

The adoption of improved varieties of food crops has increased since the late 2000s, especially in Eastern and Southern Africa (one example is drought-tolerant maize). It is expected that the share of modern varieties will grow, inorganic fertilizer application will increase and mechanization will substitute for labour, especially that of women. Similarly, livestock industries will intensify with improved breeds, especially in the dairy sector, and increased use of planted forages and purchased feed. The current trend of tree planting and farmer-managed natural regeneration of trees on farmlands is expected to accelerate.

Biotic constraints also contribute strongly to large productivity gaps for both crops and livestock. Cassava and maize suffer from widespread and severe virus and insect attacks (for example, cassava mosaic virus and mealy bug, and maize lethal necrosis and stem borer). Tsetse infestation is a major factor influencing the distribution of livestock between different farming systems. Tsetse tends to be concentrated in the moist subhumid and humid lowlands, and in drier areas near game reserves, so cattle numbers per household tend to be higher in the dry farming systems than in the moist systems.

The ratios of agricultural workers to farm land influence the trends in crop, livestock and tree productivity. As outlined earlier, with relatively low population pressure on land, per capita food production in Africa has increased steadily, principally through extensification, that is, expansion of cropped area (World Bank 2008), supplemented by some yield increase. In contrast, increases in Asian cereal production arose principally from yield growth. Sometimes this contrast is explained by the overly simplistic notion that the Green Revolution has not yet reached Africa. However, the reality reflects the particular combinations of available land for expansion, population pressure, poverty, farming techniques, investment in R&D, patterns of adoption of science and technology, and input markets and trade. The increasing population in Africa, and the limits to land expansion, will place pressure on households to increase yield and intensify and/or diversify farming. It is noteworthy that trends in other countries pose opportunities and

risks for Africa. For example, the cereal area has contracted in Europe as oilseeds and other high value crops were substituted for cereals, while cereal yields have increased.

Markets and trade

Agribusiness, markets and trade are all vital for agricultural development, and they require policy attention. Farming system intensification and diversification require an increasing volume of services, especially markets and suitably priced and available inputs. In fact, access to services, including markets, fundamentally influences the directions of farming systems development – sometimes this is even more important than the natural resources–population nexus. At a continental scale, the level of services and integration of markets will shape how effectively Africa responds to the challenges of the surging aggregate purchasing power of domestic consumers accompanied by changing consumer preferences.

Until recently agriculture accounted for about half of East African exports, whereas in West and Central Africa agriculture's share of total exports declined from over 70 per cent in 1961 to less than 10 per cent in 2015, partly as a consequence of the expansion of petroleum and mineral exports. Africa's principal agricultural exports are cocoa, coffee and cotton, although sugar, wine and fruits are significant exports in Southern Africa.

The proportion of agricultural products within total imports to the region has been rising. Cereal imports rose ten-fold over the period 1970 to 2010, from 6.5 Mt to 66.4 Mt, largely comprising rice and wheat imports (in contrast to cereal exports of 3–4 million Mt). If these trends continue, in 2030 the region would need to import an estimated one-sixth of its total cereal requirements. Generally, food aid has represented less than half of cereal imports; nonetheless, per capita food aid flows are larger than those to Asia and Latin America. Significantly, meat imports have increased nine-fold from 1970 to 2010, to 1.8 Mt (compared with 0.2 Mt exports).

Cereal and meat imports have surged, while exports have stagnated – despite attractive international prices and apparent, or at least potential, African competitive advantage in their production. Fortunately, intra-Africa regional trade now is growing more rapidly than international trade.

At the farming system and farm household levels, access to markets is mediated by local institutions, culture and traditions, which also influence the nature of current farming systems. Changing trade patterns can also reconfigure farming systems, for example changing trade led to the collapse of the sisal plantations in Tanzania and, later, the growth of smallholder dairy, floriculture, pigeon pea and export vegetables. However, the influence of market access is generally more nuanced, leading to practice change or an increased rate of diversification.

Access to markets can be measured in many ways, and the most common, but admittedly crude, metric is the shortest travel time to market (typically a mix of foot, animal and vehicular transport). Not surprisingly, yield gaps and farm performance gaps increase with greater distance to the national capital (which may determine access to a much broader bundle of services especially outside agriculture, including health and educational services). Naturally, transport infrastructure underpins market access. In the year 2000, SSA had only 8 km of rural roads per 100 km^2 of land, compared with 22 km worldwide and 25 km in Asia (FAO 2015), but global projections are that more than two-thirds of new roads planned for construction by 2040 will be located in Africa, indicating the potential for improved access to markets (but also a corresponding risk for biodiversity).

Agribusiness' principal roles are in market chains, storage, processing and distribution. Investment in input chains and agricultural service provision is essential for increased productivity and production of marketable surpluses, thus affecting intensification, diversification and growth of farm businesses. There are often high returns to investment in weak input markets such as finance, knowledge, seed, fertilizer and machinery. Once there are functioning input markets, investment in produce market chains becomes feasible. Not only are 'business-friendly' policies required but also mechanisms to mitigate business risk stemming from climate variability in rainfed farming. In most contexts, African underinvestment is greater in micro and small rural enterprises than in large corporations; it is sometimes argued that micro and small rural enterprises could underpin the next agricultural development revolution.

Policies and institutions

The perspectives shaping African agricultural policies have evolved since the food self-sufficiency goal expressed in state-led modernization in the 1960s. During the 1970s the intensification perspective of the Asian Green Revolution resonated with many African leaders. There was considerable interest in integrated rural development programs (IRDPs) which linked agricultural development to infrastructure, education and health services. During the 1970s and 1980s public agencies for R&D were strengthened. Multidisciplinary farming systems research with farmer participation was promoted and explored the 'systems-fit' and social aspects of technologies and market linkages in the complex smallholder systems. However, during the structural adjustment era of the 1980s and 1990s, much of the investment in public research and extension capacity was eroded, along with agricultural statistics and other agricultural services. The hopes that the private sector would fill the gap were not realized to the expected level (Mburathi pers. comm.). Today, it is clear that liberalization reform targeting economic growth needs to be complemented by food and nutrition security measures through agriculture as the core focus for development.

The Africa Union (AU) has encouraged improved governance at all levels. There are now many instances of successful regional, national and local institutions which stimulate sound resource management and productivity growth (UNDP 2015).

Regional agricultural development policy in Africa is principally shaped by the strategic framework of CAADP, which is aligned with the Sustainable Development Goals. In 2003, in Maputo, Mozambique, the African Heads of State and Government endorsed the CAADP as a framework to create an ambitious institutional and policy transformation in the agriculture sector. The CAADP development agenda is basically growth oriented. It aims to increase agricultural growth rates to 6 per cent per year, supported by at least 10 per cent of national budgets devoted to agriculture. CAADP focuses on four key pillars: expanding sustainable land management and reliable water control systems; improving rural infrastructure and trade-related capacities for market access; increasing food supply, reducing hunger and improving responses to food emergency crises; and improving agriculture research, technology dissemination and adoption.

Cross-cutting issues include, but are not limited to, capacity strengthening for agribusiness; academic and professional training; and improving access to information for agricultural strategy formulation. CAADP has substantially raised the profile of agriculture in national domestic politics, contributed to the development of incentive-oriented agricultural policies, facilitated the alignment of development partners to country priorities,

and has improved regional coordination. CAADP has been moving forward on both regional- and country-level processes.

Since the 2003 Maputo Declaration, African leaders have adopted various additional decisions and declarations on agriculture and food security, within the overall framework of CAADP. These decisions include, notably, the 2004 Sirte Declaration on the Challenges of Implementing Integrated and Sustainable Development in Agriculture and Water in Africa; the 2006 Resolution of the Abuja Food Security Summit; the 2007 Abuja Declaration on Fertilizer for the African Green Revolution; and the 2009 Sirte Declaration on Investing in Agriculture for Economic Growth and Food Security, among others. Reaffirming their resolve to advance the implementation of CAADP, African leaders adopted an ambitious goal that aims to eradicate hunger in Africa by 2025 within the context of a fully transformed agriculture system. The 2015 Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods (and the Implementation Strategy and Roadmap) sets the scene for a comprehensive package of directives to advance agricultural transformation and root out hunger in Africa. Key to the transformation process is the CAADP Results Framework to track progress, ensure accountability and assess results.

The importance of the resilience of livelihoods was recognized by African leaders in the Malabo declaration, in which they committed to reduce the vulnerabilities of livelihoods, notably: increasing the resilience of at least 30 per cent of farm, pastoral and fisher households to climate and weather-related risks by 2025; enhancing social security for rural workers and other vulnerable social groups; and mainstreaming resilience and risk management in policies, strategies and investment plans. The achievement of these targets will require the analysis of different farming systems to identify priorities and targets, and formulate action-oriented strategies for tangible results and impact.

Ultimately, strengthened institutions, incentives (for private and appropriate collective action) and policies must be aligned with the specific agricultural growth potentials of different farming systems. Land and water policies lie at the heart of effective resource management and rural development. Land reform has been common in Southern Africa and has been one attempt to exploit the inverse farm size-productivity relationship. It is widely recognized that small farms have high productivity, provided services are available. Growth Corridor approaches are now being implemented in a number of countries, often where it is presumed that the conditions exist for mining, commercial farming, forestry and manufacturing (Weng et al. 2013), for instance, in Northern Mozambique, in Southern Tanzania's maize mixed farming systems, and in Northern Ghana's cereal-root crop mixed farming system. Recently African governments have emphasized the potential for intra-regional markets (Badiane and Collins 2016) and have supported improved infrastructure, border facilities and regulations. Increased productivity, both total factor and partial, is an important goal for the agricultural sector.

From farm household strategies to development priorities and policies

Cross-scale and system linkages

The importance of linkages between farm households, communities, landscapes and value chains was noted earlier in the chapter. The institutions which function at each level influence the decisions and management at lower levels with both positive and negative

outcomes. For example, open grazing by many communities threatens the retention of crop residues on the soil surface to reduce soil erosion and the opportunity to establish high-yielding trees. However, government policies might change community practices. For example, regulations which encourage stall feeding and the control of grazing, with a view to the revegetation of degraded watersheds, might lead to an unintended positive outcome through the reduction of grazing pressure, thus enabling the retention of crop residues in the crop fields and diversification into tree enterprises.

In any community there is heterogeneity in farm households' characteristics and behaviour. Typical patterns of farm households' differences – small and large, young and old – can often be recognized throughout a particular farming system. From an institutional and social capital perspective, knowledge of the variation in family composition, stage in life cycle, status in the community and access to external networks of traders can be an advantage in designing watershed management or technology extension programs.

Linkages across farming systems occur through seasonal and annual movement of labour, livestock, water, nutrients and agricultural produce. Capital accumulated in one system is often reinvested in another system. Natural phenomena such as wind, rainfall and runoff, and human, livestock and wildlife movement contribute to the spread of weeds, pests and diseases across systems. Land and water use practices in upstream locations affect farming systems downstream. Transport systems and infrastructure (road, rail and waterways) have traditionally aided trade in agricultural products and inputs. In addition, there are new and emerging linkages promoted by ICT, trade liberalization, new markets, advances in logistics, transport systems, knowledge management and information exchange.

Water management at the farm level has interconnected livelihood, hydrological and ecological impacts at watershed and basin scale. This is because water is both an ecosystem 'good' and a 'service'. As an ecosystem good it provides drinking water, irrigation and hydropower. It also provides a range of ecosystem services – provisioning, regulating, cultural and supporting – that are often important to poor people's livelihoods (Millennium Ecosystem Assessment 2005). The externalities created by upstream water use often lead to conflicts between upstream and downstream communities. Water governance and institutional arrangements thus influence how well conflict is resolved and how equitable water sharing is between upstream and downstream users, while maintaining adequate environmental water flows to sustain ecological functions and deliver critical ecosystem services to both rural and urban households.

Nutrient practices at the household level can have a cumulative effect on farming systems and landscapes, including whether the nutrients are traded and distributed elsewhere. Policies and other drivers, meanwhile, affect household decisions. While nutrients are fundamental to ecosystem function and farming system intensification, in practice urban areas are concentrators of nutrients, partly via food supplies from rural areas and intensive peri-urban livestock production. Recycling solid waste and food wastes can be a crucial part of rural-urban linkages.

Livestock migrations between farming systems are common including transhumance. For example, herders migrate cattle between the agropastoral farming system and higher-potential mixed farming systems, and camel herders migrate between the arid pastoral oasis and the pastoral systems. There are economic, livelihood and resilience advantages to long-distance migration. However, negative side effects include the transmission of animal disease by livestock or by wild species, especially large mammalian herbivores in Eastern Africa. Migratory birds and mammals are also major agents spreading animal and human diseases.

In terms of biotic stress, insect pests which limit crop production (in all African farming systems) also cross farming system boundaries, for example sorghum midge. Plantain and banana are other examples, as they suffer from wind-dispersed pests and diseases, for example black sigatoka. Black pod disease on cocoa is spreading across West and Central Africa. Striga (*Striga hermonthica*) is a frequent parasitic weed of sorghum, millet and maize which has spread widely across Africa.

Framework for strategic interventions

The emergence of a new set of African leaders and stronger national commitments to sustainable development, supported by the New Partnerships for Agricultural Development (NEPAD) and CAADP, have been game changers. Complementary initiatives in rural education, women's empowerment and social capital have strengthened rural institutions. These recent investments in human capital, institutions and infrastructure are now reflected in improvements to food security and economic growth and in development indicators across the region. Farming systems development can contribute to Africa's broad-based transformation in the following ways:

- *Farming systems for improved food and nutrition security*. The vast majority of the hungry and food insecure reside in rural areas. Effective food systems require productive and resilient farming systems, thus farming and food systems are a part of designing and implementing zero hunger programs and effective social security nets – and these have to be differentiated for the different farming systems. Moreover, supporting diverse integrated farming systems facilitates diverse diets, which is associated with reduced malnutrition.
- *Farming systems for poverty reduction*. The majority of rural livelihoods in African countries are dependent on natural resources, including land and water. Some 70 per cent of Africa's poorest labourers are engaged in farming activities which differ by region. Therefore, farming system intensification must be tailored to local crops and livestock, which will generally increase farm labour productivity and reduce poverty. Moreover, to be effective, rural poverty reduction strategies for enhancing job creation, gender empowerment and entrepreneurship should be linked to existing farming and livelihood systems.
- *Farming systems for industrialization*. Industrialization has been identified by African leaders as a transformational path. Agribusiness and food processing will certainly boost agriculture and can help lift rural inhabitants out of poverty. Specific commodity programs can be tailored and targeted towards particular farming systems. In-depth analysis of farming systems, with a particular focus on backward and forward linkages and value-addition, can focus the investments on commodity and agribusiness potential.
- *Farming systems for adaptation to climate change*. The majority of livelihood systems in Africa are highly vulnerable to climate variability and climate change. Therefore, systematic analysis of farming systems can facilitate targeting, diversification and enhanced resilience of particular farming systems.

Knowledge of household responses to trends and interventions within different farming systems is essential information for developing effective public priorities and policies. Indeed, household strategies and development pathways can inform and underpin

Table 1.10 Examples of strategic interventions focused on household pathways

Strategy intervention areas	*Intensification*	*Diversification*	*Increased farm/herd size*	*Increased off-farm income*	*Exit from agriculture*
Population, poverty and food security (increased pressure)	Labour saving technologies	Labour- spreading enterprise mixes, diet education	Resettlement	Labour markets	Migration, land and livestock markets
Natural resources and climate (reduced availability and quality)	Climate-smart agriculture	Irrigation	Land tenure, water points for livestock	Secure land rights	Land for consolidation
Energy availability and use (slowly increasing availability, volatile prices)	Biomass	Renewables	Fuel for mechanization	–	–
Human capital, knowledge sharing and gender (improving availability of information)	Extension, technology training and information sharing	Farmer training in new crops or livestock, empowerment of women	Farm management training	Labour market information	Labour market information
Science and technology (improving varieties, breeds and practices)	Technologies for water and input use efficiency	New crops and livestock	Scalable technologies	Labour saving technologies, mechanization	–
Markets and trade (improving access)	Strengthening existing input and produce chains/markets	Fostering new input and produce markets	Improved access to finance	Functioning labour markets	Land and livestock markets, employment creation especially in rural areas
Policies and institutions (strengthening public goods)	Policies assisting input availability	New markets and inputs	Land tenure and sale/ leasing markets	Labour markets, decentralization, transport	Migration

choices of strategic interventions. For example, diversification would generally require more investment in new market institutions than intensification of existing enterprise patterns. Moreover, the nature of required policy interventions will differ across farming systems, depending on the availability of infrastructure and complementary services such as finance. Table 1.10 provides a framework, with illustrations, for linking farm household pathways to possible strategic interventions for each of the seven drivers discussed earlier. These are developed further in each farming system chapter, where priority strategic interventions are highlighted in terms of the expected effects on farming system structure and function.

In general, the strategies of extremely poor farm households differ from those of somewhat better-off households. At the farming system level, the combination of strategies (in proportion to household types) provides an indication of household responses to market or policy changes. The mix of strategies also informs the targeting of agricultural policies to different farming systems, and to different groups within any particular farming system. Both aspects are important for productivity and for equitable development outcomes.

Guide for readers

Chapter 2 outlines the data sources and methods which were used for the farming systems characterization. The reader will have noted that the names of the fifteen defined farming systems are not capitalized. The analyses of the major farming systems are reported in Chapters 3–16, with chapters in declining order, generally, of the population of extremely poor. Chapter 17 summarizes the key potentials and cross-cutting issues. The ways forward are presented in Chapter 18 and the conclusions in Chapter 19.

Note

Chapter 1

1 Conservation agriculture practices ensure minimum soil disturbance, year-round vegetative coverage of the soil surface and crop rotations, and are widely recognized as sustainable.

Chapter 2

1 In statistics a central tendency is a central or typical value for a probability distribution and relates to the tendency of quantitative data (or systems) to cluster around a central value.
2 See www.fao.org/docrep/W2962E/w2962e-03.htm.
3 A significant issue when modelling LGP from climate station data for Africa is the sparse distribution and maintenance of weather stations. This impacts the rigour and availability of consistent data and thereby limits identification and analysis of areas with bimodal characteristics. An alternative approach based on multi-temporal remote sensing data enables identification of start- and end-of-season parameters and as a result it is possible to identify and characterize areas with bimodal seasonal growing activity (Vrieling et al. 2013).
4 See www.fao.org/nr/climpag/cropfor/lgp_en.asp.
5 See www.fao.org/docrep/W2962E/w2962e-03.htm.
6 See http://link.springer.com/article/10.1007%2Fs10584-011-0049-1.

Chapter 3

1 South Africa was a notable exception where the average farm size continues to increase.
2 For example, in Ethiopia, where the constitutional provisions leave land ownership in the hands of the government, and farmers are only given use rights to land under long-term lease arrangements, the annual average growth in agriculture has been around 6 per cent in recent years.

3 SIMLESA – Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa Program is supported by ACIAR and managed by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with the sub-regional and national research organizations, Australian universities and other centres.
4 Corridor disease (*Theileria parva*) infection in cattle, which caused large losses in the mid-1990s, is considered a serious potential emerging disease (Mbizeni et al. 2013).
5 Nutrient quality of many of these manures is poor. The main effect is the addition of organic matter to the soil.
6 Inefficient bulk cargo and bagging handling operations at Dar es Salaam can increase the cost of imported fertilizer by 40 per cent by the time it has left the port.

Chapter 5

1 Subsystems in this chapter are essentially sub-regions distinguished by different market contexts.
2 Tanzania is not included in FAOSTAT (2010) and national statistics for DRC do not adequately reflect the context for the eastern highland region of DRC.
3 This discussion of the Kenyan highlands draws on various research reports of the Tegemeo Institute. These research reports analyse a nationally sampled panel survey of 1,275 households carried out in 1997, 2000, 2004, 2007 and 2011. This is the most comprehensive data set to analyse changes in farming systems in the post-liberalization period in Kenya.
4 The farm sample for the Neven study was drawn from a list of suppliers for the two largest supermarkets in Nairobi, while the sample for the Rao study was drawn from farmers in Kiambu district, oversampling for supermarket suppliers.

Chapter 7

1 Inland valleys are the natural water drainage channels in the landscape, serving as source of domestic water as well as production environments for long-season crops such as banana and root and tuber crops in addition to rice and vegetables.
2 The tops (stems and leaves) of crop plants after the crop has been harvested.

Chapter 8

1 The productivity of this farming system would be best measured through total factor productivity (TFP), which is a ratio of total outputs to total inputs (measured in an index form). If the ratio of total outputs to total inputs is increasing, then the ratio can be interpreted to mean that more outputs can be obtained for a given input level (Ehui and Jabbar 2002).

Chapter 9

1 Rainforest was defined as having an average canopy height of 35 to 40 m and a canopy coverage of more than 70 per cent.

Chapter 10

1 Agriculture includes crop and livestock production.
2 A Tropical Livestock Unit is a 250 kg animal weight-equivalent index, which allows species of various weights to be combined.
3 NOAA National Oceanic and Atmospheric Administration of the United States.

Chapter 11

1 Defined as the freedom of choice and action to achieve basic material needs, health, security and good social relations (Scholes et al. 2005).

2 Artisanal fisheries (a term used interchangeably with small-scale or traditional fisheries, even though the scale can actually be quite large and that they have often evolved quite far from what would be strictly traditional, e.g. the use of nylon instead of natural fibre) refers to various low-technology, low-capital, fishing practices undertaken by individual households (though sometimes organised into cooperatives or associations).
3 In many societies cars are a status symbol, and the Mercedes Benz is a particularly powerful one across Africa, leading to terms like the Mama Benz for the comparatively rich, fish-trading women of the Gulf of Guinea and Wabenzi (literally 'the people of the benz') in the Swahili-influenced cultures in east and central Africa.
4 Schematically, living beings can be split into long-lived slow reproducing species that are adapted to stable and predictable environments, and short-lived fast reproducing species (i.e. opportunists) typical of dynamic and highly variable environments. Such species will produce very high numbers of young, most of whom will perish even in the absence of harvesting. Extracting a large proportion of such a population before it reproduces, e.g. by fishing out juveniles, will therefore not necessarily affect the capacity of the next generation to maintain the species.

Chapter 13

1 'Small-scale irrigators' refer to farmers in a small-scale irrigation scheme of approximately 50 ha, while 'large-scale irrigators' refer to farmers in a community-managed irrigation scheme of more than 300 ha.

Chapter 14

1 Oases are intensively cultivated areas with access to water in desert or arid environments that are generally characterized by a large deficit between precipitations and evaporation linked to high temperatures and frequent dry winds (Lacoste 1987).
2 Oasis depressions are specific geomorphological units of spatially limited area (up to a few hectares) found in inter-dune depressions with clayish soils where oases are found.
3 salt that comes to the soil surface through capillary action. It is collected, at least partially separated from its muddy base, evaporated, and transported in long blocks on camel back.

Chapter 17

1 The land equivalent ratio measures how much more total production is increased by combining enterprises on the same piece of land versus managing them separately.

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