Lesotho
Climate-Smart Agriculture Investment Plan

Opportunities for transitioning to more productive, climate-resilient, and low carbon agriculture

KHOTSO PULA NALA

WORLD BANK GROUP

Lesotho
Climate-Smart Agriculture Investment Plan

Lesotho
Climate-Smart Agriculture Investment Plan




Opportunities for transitioning to more productive, climate-resilient, and low carbon agriculture


THANK YOU
LEMON LOOSE
R23.99KG
PADKOS

Foreword

Lesotho's agricultural system faces a growing number of climate-related vulnerabilities with drought, floods, pests, and extreme temperatures occurring more frequently. In response, the Government of Lesotho is collaborating with the World Bank to integrate climate change into the country's agriculture policy agenda through the Lesotho Climate-Smart Agriculture Investment Plan (CSAIP).

The Lesotho CSAIP aims to identify climate-smart agriculture (CSA) investments that offer the greatest potential to transform Lesotho's agriculture into a more productive, resilient, and low-emissions sector. CSA is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. CSA comprises three pillars: increasing productivity, enhancing resilience and adaptation, and reducing greenhouse gas emissions from the agriculture sector compared to past trends. This report provides evidence that shows that the adoption of CSA offers multiple wins: increased productivity and incomes; enhanced food security and dietary diversity; reduced impacts of climate change on agricultural produce; and improved commercialization, employment opportunities, and rural livelihoods. The report shows that CSA can also reduce soil erosion, generate carbon sequestration, conserve biodiversity, and provide other public goods that accrue to society—well beyond the farmers engaged in market transactions alone.

Lesotho's CSAIP is the outcome of a partnership between the Government of Lesotho and the World Bank. The CSAIP represents a commitment by the World Bank's Food and Agriculture Global Practice under the Eighteenth Replenishment of the International Development Association (IDA18) to support the development of country-level CSA strategies and investment plans. The CSAIP builds on existing strategy documents, including Lesotho's Second National Strategic Development Plan (NSDP II), and Lesotho's international climate commitments articulated in its Nationally Determined Contribution (NDC). Through a process that combines several modeling approaches, and consultations with stakeholders in the public and private sectors, civil society, and farmer groups, the report evaluates context-specific opportunities for scaling up CSA in Lesotho.

The current agricultural production pathway in Lesotho focuses on extensive animal grazing and expansion of cropland to keep pace with food demand for the population. The pathway is characterized by agricultural support for a monoculture cropping system dominated by maize. This pathway is largely unsustainable and depletes the land resources on which production relies over time. The CSAIP offers two alternative pathways for scaling up CSA in Lesotho. The first is the commercialization pathway, which entails focusing on commodities for which the country has distinct comparative advantage, such as horticulture, potatoes, and aquaculture; developing the country's irrigation to its full potential; and developing linkages that connect smallholders to export and domestic markets. The second pathway is the resilient landscape pathway which combines modern scientific knowledge with the Machobane farming system (MFS) that is highly adapted and resilient to climate change. The MFS is a traditional farming system that combines the use of crop rotation, relay cropping, and intercropping practices with the application of manure and plant ash to conserve soil moisture and replenish soil fertility. The resilient landscape pathway primarily focuses on investing in sustainable landscape and integrated catchment management that is combined management of land and water resources, and strengthening local institutions to enhance landscape resilience; that is, the ability of a landscape to sustain desired ecological functions, native biodiversity, and critical landscape processes over time in the face of changing conditions and multiple stressors.

The commercialization pathway is more profitable, requires larger farm sizes (greater than 2.5 hectares), takes up less land per unit of production, creates more jobs, produces more food calories, and offers Lesotho the potential to export horticulture, potato, fish, and vegetables. However, it requires strong market-oriented agricultural policies to be successful, and would require developing Lesotho's agricultural value chains and ensuring the proper functioning of land markets.

On the other hand, the resilient landscape pathway produces higher yields, and is more effective in controlling land degradation and delivers about ten times more carbon benefits per hectare compared to the commercialization pathway.

Thus, compared to the commercialization pathway, the resilient landscape pathway could potentially benefit more from climate finance which can come from a variety of sources including the United Nations Framework Convention on Climate Change (UNFCCC) funding mechanisms, multilateral and bilateral funds, national and regional climate funds, and private-sector investment. The resilient landscape pathway is costlier for the public sector, but is also easier to implement. It is more tailored toward locally adapted technologies that the average smallholder farmer in Lesotho can practice.

Commercialization can be prioritized largely in the lowlands and foothills—the fertile and most productive parts of Lesotho that are suitable for potatoes, orchards, and vegetables, while resilient landscape can be emphasized largely in the highlands more prone to soil erosion, suitable for afforestation and farmer-managed natural regeneration of vegetation, and where less fertile land would benefit from restoration and replenishment.

The effective scaling up of CSA in the country will require addressing a number of adoption barriers, including limited implementation capacity, insufficient access to inputs and credits, and insufficient agricultural research.

Some of the policy actions to support effective scaling up of CSA identified in the study include:

Realigning agricultural support to promote CSA. It is vital that government policies and investments address the demand and supply sides of agricultural inputs required for CSA by building sustainable, private sector-led input markets. Market-smart subsidies, that is, time-bound interventions implemented as part of a comprehensive, long-term input promotion strategy that encourage market development and private investment in fertilizer and other agricultural inputs, are vital. An example is the electronic input voucher system that local microfinance institutions or agricultural credit cooperatives can use to qualify farmers for loans and issue cash or credit vouchers that can be used to redeem inputs such as seeds or fertilizers.

Strengthening agricultural research and extension. There is a need to strengthen research and establish partnerships with international research institutes to develop high-yielding, stress-tolerant, climate-ready varieties. Agricultural extension services should be upgraded to catalyze the agricultural innovation process; improve CSA knowledge; facilitate access to information, knowledge, and expertise; and provide technical advice to farmers.

Building capacity to access climate finance. Lesotho faces a financing gap in the agriculture sector with low capacity to access climate finance. Critical areas that need capacity development include identifying funding gaps and needs; assessing public and private financing options; developing payment for ecosystem services programs that offer incentives to farmers in exchange for sustainably managing the land to provide some sort of ecological services such as carbon sequestration; developing bankable investment plans, a project pipeline, and financing propositions; and developing financially viable opportunities for effective private sector engagement.

Our hope is that the CSA strategies and delivery methods outlined in this report will bring about sustainable improvement in the lives and livelihoods of Lesotho's smallholder farmers. Protecting smallholder farmers from falling into poverty in the event of climatic shocks and giving them the tools to thrive are important objectives in the partnership between the Government of Lesotho and the World Bank.

Hon. Lits'oane Lits'oane
Minister
Ministry of Agric. and Food Security
Lesotho

Hon. Tlohelang Aumane
Minister
Ministry of Development Planning
Lesotho

Hon. Moeketsi Majoro
Minister
Ministry of Finance
Lesotho

Simeon Ehui
Director
Sustainable Development, Africa
The World Bank Group

Marie-Francoise Marie-Nelly
Country Director
Lesotho
The World Bank Group

Acknowledgments

This report was prepared by a World Bank team led by Ademola Braimoh, Senior Natural Resources Management Specialist, and consisting of Giacomo Branca, Agricultural and Natural Resources Economist, Yuxuan Zhao, Economist (World Bank) and Annette Huber-Lee, Senior Scientist and Agricultural Systems Modeler; Brian Joyce, Senior Hydrologist and Decision Support Specialist; and David Yates, Senior Climate Modeler (Stockholm Environment Institute).

Guidance and support for the report was provided by Paul Noumba Um, former Country Director; Emmanuel Noubissie Ngankam, Country Program Coordinator; Janet K. Entwistle, Country Representative; Mark E. Cackler, former Practice Manager; and Erwin De Nys, Program Leader.

The work benefitted from insights from several World Bank Colleagues: Holger Kray, Practice Manager; Tahira Syed, Senior Rural Development Specialist; Meeta Sehgal, Senior Agricultural Specialist; Bobojon Yatimov, Senior Agricultural Specialist; Asa Giertz, Senior Agriculture Economist; Tobias Baedeker, Agriculture Economist; Sébastien Dessus, Lead Economist; Zivanemoyo Chinzara, Economist; Rex Ukaejiofo, Consultant Agriculture Specialist; Alemayehu Zeleke, Consultant Agriculture Economist; and Anna Reva, Private Sector Development Specialist. We also acknowledge the advice provided by peer reviewers: Erick Fernandes, Lead Agriculture Specialist; Ana Bucher, Senior Climate Change Specialist; Teklu Tesfaye, Senior Agriculture Economist; Stephen D'Alessandro, Senior Agriculture Economist; Christine Heumesser, Economist; and Flore Martinant de Preneuf, Senior Communications Officer.

Sincere thanks also go to Ntaoleng Mochaba, Environmental Specialist; Palesa Mokorosi, Water Resources Management Specialist; Moipone Ndlovu, Social Development Specialist; Edmund Motseki, Operations Officer; Keneuoe Mofolo, Program Assistant; Relebohile Mohlakoana, Team Assistant; Masekeleme Sekeleme, Program Assistant; Seitebatso Tsemane, Team Assistant; and Elita Banda, Communications Officer.

The team gratefully acknowledges the support to this work by the Lesotho Ministry of Agriculture and Food Security. Sincere thanks to Hon. Mahala Molapo, former Minister, Ministry of Agriculture and Food Security, Hon. Lits'oane Lits'oane, current Minister of Agriculture and Food Security, and Principal Secretary Mr. Malefetsane Nchaka, staff of the Department for Policy and Planning and the Department of Agricultural Research for their support. We thank the following colleagues from the Ministry of Agriculture and Food Security: Mathoriso Molumeli, former Director, Department of Planning and Policy Analysis, Lucia Phakisi, Acting Director, Department of Planning and Policy Analysis; Lefu Lebelesa, Director, Department of Agricultural Research; Maoala Khesa, Senior Economic Planner (Monitoring and Evaluation), Monica Lephole, Chief Research Officer - Food and Nutrition, Department of Agricultural Research; Selebalo Ramakhanna, Senior Research Officer, Soil and Water Conservation, Department of Agricultural Research; Bataung Kuenene, Chief Research Officer, Crops Division, Department of Agricultural Research.

We also thank Letete Maluke (NSDP Coordinator), Mary Njoroge, Country Director, WFP; Peter Kimotho, Purchase for Progress Coordinator, WFP; Mokitinyane Nthimo, Assistant Representative, FAO; David Mwesigwa, Emergency and Resilience Coordinator, FAO; Khotso Mathafeng, National Geographical Information System (GIS) Expert, FAO; and Malintle Kheleli (Geography and Environmental Movement) for their support. We also thank Puseletso Likoetla, Motselisi Ratii and Mpho Liphoto (National University of Lesotho) for help with data collection at various stages of the report preparation. Finally, we thank staff of all the organizations that participated in the stakeholder consultations for their contributions in making this report a success.

Acronyms and Abbreviations

ACSE	Agriculture Clusters Service Enterprise
AF	Adaptation Fund
AfDB	African Development Bank
AI	Artificial Insemination
APPSA	Agriculture Productivity Project for Southern Africa
APS	Agricultural Production Survey
ASAP	Adaptation for Smallholder Agriculture Programme
Bio-CF	BioCarbon Fund
BMG	Bill and Melinda Gates Foundation
CA	Conservation Agriculture
CAGR	Compound Annual Growth Rate
CAMP	Catchment Area Management Plan
CBA	Cost-benefit Analysis
CDM	Clean Development Mechanism
CIF	Cost, Insurance, and Freight
CIMMYT	International Maize and Wheat Improvement Center
COMACO	Community Market for Conservation
CPF	Country Partnership Framework
CSA	Climate-smart Agriculture
CSAIP	Climate-smart Agriculture Investment Plan
CSIRO	Commonwealth Scientific and Industrial Research Organization
CT	Current Trends
CV	Coefficient of Variation
CZ	Commercialization
DFID	Department for International Development
EIRR	Economic Internal Rate of Return
ENSO	El Niño-Southern Oscillation
EX-ACT	Ex-Ante Carbon Balance Tool
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FCPF	Forest Carbon Partnership Facility
FFS	Farmer Field School
FIRR	Financial Internal Rate of Return
FOB	Free on Board
GCF	Green Climate Fund
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas
GIS	Geographical Information System
GoL	Government of Lesotho
HIV/AIDS	Human Immunodeficiency Virus Infection and Acquired Immune Deficiency Syndrome
HSP	High Shadow Price of Carbon
ICT	Information and Communication Technology
IDA	International Development Association

IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IK	Indigenous Knowledge
INDC	Intended Nationally Determined Contribution
IPCC	Inter-governmental Panel on Climate Change
IPM	Integrated Pest Management
IRR	Internal Rate of Return
ISFM	Integrated Soil Fertility Management
KfW	German Development Bank
LDCF	Least Developed Countries Fund
LENAFU	Lesotho National Farmers Union
LesAgMod	Lesotho Agricultural Sector Model
LMS	Lesotho Meteorological Services
LNFP	Lesotho National Forestry Policy
LNNPS	Lesotho National Nutrition Policy and Strategy
LP	Linear Programming
LSP	Low Shadow Price of Carbon
LSU	Livestock Unit
LZHSR	Lesotho Zero Hunger Strategic Review
MAFS	Ministry of Agriculture and Food Security
MCC	Millennium Challenge Corporation
MFD	Maximizing Finance for Development
MFS	Machobane Farming System
MGF	Matching Grant Facility
MHE	Market Hub Enterprise
MKS	Market-smart Subsidy
MSMEs	Micro, Small, and Medium Enterprises
NAIP	National Agricultural Investment Plan
NCF	National Climate Fund
NCCP	National Climate Change Policy
NDC	Nationally Determined Contribution
NGO	Nongovernmental Organization
NPV	Net Present Value
NRM	Natural Resource Management
NSDP	National Strategic Development Plan
NSP	National Seed Policy
NTFP	Non-Timber Forest Product
OER	Official Exchange Rate
PPP	Public Private Partnership
PSCED	Private Sector Competitiveness and Economic Diversification Project
RBF	Results-Based Finance
RCF	Regional Climate Fund
RISDP	Regional Indicative Strategic Development Plan
RL	Resilient Landscapes
RSA	Republic of South Africa
RUSLE	Revised Universal Soil Loss Equation
SACU	Southern African Customs Union
SADC	Southern African Development Community
SADP	Smallholder Agricultural Development Project
SCD	Systematic Country Diagnostic
SCF	Standard Conversion Factor

SCCF	Special Climate Change Fund
SDG	Sustainable Development Goal
SER	Shadow Exchange Rate
SLM	Sustainable Land Management
SSP	Shared Socioeconomic Pathway
TCAF	Transformative Carbon Asset Facility
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
USAID	United States Agency for International Development
VAT	Value Added Tax
VCM	Voluntary Carbon Markets
WEAP	Water Evaluation and Planning
WFP	World Food Program
WHO	World Health Organization
WTP	Willingness to Pay

Exchange rate used in this report: U$1 is equivalent to LSL 13.66

Contents

Executive Summary XVIII
- Climate Change and Agricultural Vulnerability XVIII
- Climate Smart Agriculture Investment Plan (CSAIP) Analytical Approach XIX
- CSA Impacts at Sector and Household Levels XXI
  - Crop Yield XXI
  - Cropland Expansion under Climate Change XXIII
  - Food Production XXIII
  - Food Availability and Trade XXIV
  - Profitability of CSA XXVI
  - Carbon Balance XXVI
- Prospect of Meeting Lesotho's CSA Targets XXVIII
- Barriers to CSA Implementation XXIX
- CSA Investment Needs XXXI
- Prioritization of Scenarios and Investment Decision XXXVI
- Financing the Investment Plan XXXVIII
- Policy Recommendations XXXIX
- CSA and the World Bank Agenda in Lesotho XLI

I. Introduction 1

II. Methodology 9

III. CSA Impacts at the Household Level 25

IV. CSA Impacts at the Sector Level 33
- 4.1 Crop Prices for the Scenarios 33
- 4.2 Planted Areas under No Climate Change 34
- 4.3 Livestock Units 35
- 4.4 Climate Projections 36
- 4.5 Crop Yields 40
- 4.6 Production 41
  - 4.6.1 Area under Cultivation for the Narrative Scenarios 41
  - 4.6.2 Crop Production for the Narrative Scenarios under Climate Change 43
  - 4.6.3 Livestock Production 44
- 4.7 Food Availability and Trade 44
- 4.8 Soil Erosion 46

4.9 Pest Infestation under Climate Change 48
4.10 GHG Emissions 49
4.11 Impact of CSA Adoption on Job Creation 52
4.12 Linkages between SDGs and NDC in Lesotho 53
4.13 Potential for Meeting Lesotho CSAIP Targets 55

V. CSA Investment Needs 59
5.1 CSA Adoption Constraints 65
5.2 Improving the Enabling Environment for CSA Implementation 66
5.3 Financing the Investment Plan 78

References 87

Annex 1: Major Stakeholders Consulted During the CSAIP Process 90

Annex 2: Land-Use Scenarios Assumptions 92

Annex 3: Approach for the CBA 94
Assumptions and Computation of the Overall Direct Benefits 95

Annex 4: LesAgMod Use and Limitations 99
Model Objectives 99
Interpretation of Model Results 99
Computational Method 99
Some Model Limitations 100

Annex 5: Land Suitability Evaluation for Lesotho 101

Annex 6: Critical Investments for Lesotho's Agricultural Transformation 106

Annex 7: Estimation of GHG Balance 113

List of Boxes

ES.1 Brief Description of the Lesotho CSAIP Components XXXIII
1.1 Key Findings from Lesotho CSA Profile 6
5.1 Brief Description of the Lesotho CSAIP Components 61
5.2 Carbon Payment Supports CSA Adoption in Zambia 80
5.3 Best Practices in Designing Payment for Ecosystem Services 85
A6.1 CSA Options Articulated in Lesotho's NDC 106

List of Figures

ES.1	Positioning of Scenarios on the Axes of Drivers of Agricultural Land Change	XX
ES.2	Change in Crop Yields Due to Climate Change	XXII
ES.3	Ratio of Crop Yields under Climate Change Versus Historical by 2050	XXIII
ES.4	Ratio of Cropland Extent under Climate Change Versus Historical by 2050	XXIII
ES.5	Livestock Production (tons) for the Narrative Scenarios Averaged for All the Future Climate Projections	XXIV
ES.6	Ratios of Calories Potentially Derived from National Food Production by 2050 under Climate Change for the CZ Scenario Versus Calories from Historical (2000–2010) National Production	XXV
ES.7	Relationship Between Economic and Financial Benefits of CSA at the Farm Level	XXVI
ES.8	Relationship Between CSA Benefits and Climate Smartness of Technologies	XXXII
ES.9	Net Present Value and Internal Rate of Return of Lesotho CSAIP Delivery Mechanisms	XXXVI
ES.10	Lesotho Agricultural Versatility Map	XXXVII
ES.11	Cumulative Annual Proportion of Funds under Existing Agricultural Projects and CSAIP Financing GAP	XXXVIII
ES.12	Sources of Finance for CSA Implementation	XXXIX
1.1	Sector-Wise Percentage Contribution to Lesotho GDP	2
1.2	Lesotho Food and Agriculture Trade Balance (US$, Millions)	3
1.3	Lesotho Agriculture GHP Emissions Sources (100% = 1.224 Million tCO_2eq)	4
2.1	The CSAIP Development Process	10
2.2	Positioning of Scenarios on the Axes of Drivers of Agricultural Land Change	15
2.3	Projected Distribution of National Land Cover by 2050 (Ha)	17
2.4	Schematic Representation of Lesotho Agricultural Sector Model	21
2.5	Illustrative Example of Water-Saving Potential of CSA Practices	22
3.1	Relationship between Economic and Financial Benefits from CSA Farm Budgets	28
4.1	Historical Commodity Prices (Blue) and the Estimated Prices by 2050 to Achieve Production Levels Envisioned under the Narrative Scenarios	33
4.2	Historic Average Annual Temperature and Total Annual Precipitation over Lesotho	37
4.3	Summary of Temperature and Precipitation Change for the 30-Year Averaging Period of 1980–2010 Relative to the 30-Year Averaging Period of 2035–2065 for 121 Climate Projections	38

4.4	Projected Mid-Century (2035 to 2065) Average Temperature and Precipitation Change	39
4.5	Average Change in Crop Yields Due to Climate Change	40
4.6	Ratio of Crop Yields under Climate Change Versus Historical by 2050	41
4.7	Ratio of Cropland Extent under Climate Change Versus Historical by 2050	42
4.8	Cropland Extent for the Narrative Scenarios Averaged for All the Future Climate Projections	42
4.9	Ratios of Crop Production by 2050 under Climate Change for Three Scenarios Versus Historical Crop Production	43
4.10	Livestock Production (tons) for the Narrative Scenarios Averaged for All the Future Climate Projections	45
4.11	Ratios of Calories Potentially Derived from National Food Production by 2050 under Climate Change for the CZ Scenario Versus Calories from Historical (2000–2010) National Production	45
4.12	Lesotho Crop Yield Gap	46
4.13	Predicted Soil Loss under Climate Change for the Scenarios for Lesotho's Sub-Catchments (Thousand tons per Year)	47
4.14	Cumulative Frequency Distribution of Average Erosion Rates Across Sub-Catchments for the Scenarios	48
4.15	Predicted Probabilities of African Armyworm Infestation under no Climate Change (Left) and Climate Change (Right)	49
4.16	GHG Mitigation Options in Livestock	51
4.17	Agricultural Value Chain Ecosystem	53
5.1	Relationship Between CSA Benefits and Climate Smartness of Technologies	59
5.2	Impact of Factors on the Adoption of CSA Practices	69
5.3	Net Present Value and Internal Rate of Return of Lesotho CSAIP Delivery Mechanisms	75
5.4	Lesotho Agricultural Versatility Map	76
5.5	Cumulative Annual Proportion of Funds under Existing Agricultural Projects and CSAIP Financing Gap	78
5.6	Sources of Finance for CSA	79
B5.3.1	Land Managed Primarily for Agricultural Production Versus Land Managed to Provide Multiple Ecosystem Services under a PES Scheme	85
B5.3.2	The Role of Environmental, Socioeconomic and Political Contexts on PES Design and Outcomes	86
A5.1	Land Suitability and Versatility Maps	102

List of Tables

ES.1	Lesotho CSA Targets	XIX
ES.2	Strategies for Achieving Lesotho CSA Goals	XX
ES.3	Projected Impacts of Climate Change on Crop Yields (%)	XXII
ES.4	Crop Production and their Proportions for the Scenarios Under Climate Change	XXIV
ES.5	Average Historic Imports, Exports, and Nationally Produced Crop Subsector Commodities and the Kcal per Capita per Day Provided by Each of Those Commodities for 2000–2010	XXV
ES.6	Carbon Balance from CSA Practices under Rl and CZ Scenarios	XXVII
ES.7	GHG Emission Intensities for Crops and Livestock (tCO_2eq per Ton Product)	XXVII
ES.8	Estimated Number of Farming Jobs Created Under Climate Change Over a 5-Year Investment Period	XXVIII
ES.9	Potential of Meeting Lesotho's CSA Targets	XXIX
ES.10	Relative Importance of Factors for Adoption of CSA Practices in Lesotho	XXX
ES.11	CSAIP Investment Costs (US$, Thousands per Year)	XXXIII
ES.12	Role of Delivery Mechanism in Addressing Constraints to CSA Adoption	XXXIV
ES.13	Comparison of Indicators under the Two Scenarios	XXXVII
ES.14	Potential Sources of Funding for CSAIP Delivery Mechanisms	XXXIX
ES.15	Lesotho CSA Policy Measures and Time Frame for Implementation	XLII
1.1	The Mainstreaming of Climate Change within Agriculture-Related Policies in Lesotho	5
2.1	Normative Vision for CSA in Lesotho	11
2.2	CSA Goals for Lesotho	11
2.3	Lesotho CSA Targets	12
2.4	Strategies for Achieving Lesotho CSA Goals	12
2.5	Outcome Indicators of the CBA	19
2.6	LesAgMod Outcome Indicators	23
3.1	Income from Crop Production for the Representative Household and Farmer Group	25
3.2	Income Benefits from Adoption of CSA Practices	26
3.3	Income Benefits from Adoption of Improved Feeding and Breeding Management Practices for Livestock	27
3.4	Benefits from Aquaculture Production	29
3.5	Costs of SLM Options	30

4.1 Ratio of the Commodity Prices for the Alternative Scenarios Relative to the Historical Prices by 2050 34
4.2 Distribution of Crops under the Scenarios by 2050 35
4.3 Annual Livestock Growth Rates (Percent) 35
4.4 Target Livestock Numbers and Livestock Units for Each Narrative Scenario 35
4.5 Dry and Wet Spell Attributes of the Historic and Climate Projections 38
4.6 Projected Impacts of Climate Change on Crop Yields (%) 40
4.7 Crop Production and their Proportions for the Scenarios Under Climate Change 43
4.8 Average Historic Imports, Exports, and Nationally Produced Crop Subsector Commodities and the Kcal per Capita per Day Provided by Each of Those Commodities for 2000–2010 44
4.9 Erosion Rates by Land Cover (Ton per Ha per Year) 48
4.10 Estimates of Erosion-Induced Carbon Emissions under Climate Change 49
4.11 Lesotho Land Area under Different Predicted Probability of Pest Infestation 49
4.12 Annual GHG Emissions (tCO_2eq) under the Scenarios 50
4.13 Climate-Smart Options for Livestock Production and Their Contribution to the CSA Pillars 50
4.14 GHG Emission Intensities for Crops and Livestock (tCO_2eq per Ton Product) 52
4.15 Estimated Number of Farming Jobs Created Under Climate Change 52
4.16 Pathways to Agricultural Jobs in Lesotho 54
4.17 SDGs–NDCs Linkages in Lesotho 54
4.18 Potential of Meeting Lesotho's CSA Targets 56
5.1 CSAIP Investment Costs (US$, Thousands per Year) 61
5.2 Flow of Economic Benefits (US$, Thousands per Year) of the CSAIP under the RL Scenario 62
5.3 Flow of Economic Benefits (US$, Thousands per Year) of the CSAIP under the CZ Scenario 63
5.4 CSAIP Profitability Indicators without Carbon Benefits 63
5.5 Sensitivity Analysis 64
5.6 Economic Evaluation of the CSAIP Mitigation Impact Using the Shadow Prices of Carbon 65
5.7 CSAIP Profitability Indicators Incorporating Carbon Benefits 66
5.8 Relative Impact of Factors for Adoption of CSA Practices in Lesotho 67
5.9 Role of Delivery Mechanisms in Addressing Constraints to CSA Adoption 71
5.10 CSAIP Delivery Mechanisms 74
5.11 Comparison of Indicators under the Two Scenarios 75
5.12 Recommended Climate-Smart Agriculture Practices for Lesotho's Agroecological Zones 77
5.13 Examples of Upfront and Result-Based Climate Finance 79

5.14	Agriculture Projects with CSA-Related Expenditure	81
5.15	Potential Sources of Funding for CSAIP Delivery Mechanisms	81
5.16	Lesotho CSA Policy Measures and Time Frame for Implementation	83
A2.1	Land Cover Extent for the Scenarios (Ha) by 2050	92
A2.2	Cropland Proportions under Each Scenario (Percent)	93
A2.3	Irrigation Land under the Scenarios (Ha)	93
A3.1	Computation of SER and SCF	95
A3.2	Distribution of Farm Sizes in Lesotho	95
A3.3	Import Parity Price for Key Importable Inputs	96
A3.4	Export Parity Price for Exported Output	97
A3.5	Benefits from Climate Information Services, Land Administration, and Erosion Control	97
A6.1	Lesotho CSA Investment Activities	110
A7.1	Estimated Carbon Balance for the RL Scenario	113
A7.2	Estimated Carbon Balance for the CZ Scenario	114

Executive Summary

1. **The objective of this report is to fill knowledge gaps and identify investments to transform Lesotho's agriculture to a productive, resilient, and low-emissions sector.** The report identifies climate-smart agriculture (CSA) strategies to mitigate and adapt to climate vulnerability and evaluates the costs and benefits of investments to implement the strategies. CSA is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. CSA comprises three pillars: increasing productivity, enhancing resilience and adaptation, and reducing greenhouse gas emissions from the agriculture sector compared to past trends. A CSA strategy refers to a plan of actions to achieve CSA goals and targets for a country. Apart from climate change, Lesotho's agriculture sector is confronted with several endogenous and exogenous risk factors that make the country heavily dependent on food imports to meet domestic consumption needs.

2. **Lesotho's agricultural productivity challenges include small landholding of less than 1 ha for most households, outdated farm technologies and farm management practices, limited technical expertise, suboptimal use of inputs by most farmers, lack of an adequate irrigation and drainage system, weak rural infrastructure, a rudimentary rural advisory system, and limited access to credit and investment capital.** In addition, severe land degradation and climate variability with regular cycles of drought and intense rainfall have contributed to massive soil erosion, loss of scarce agricultural land, and rural poverty.

Climate change and agricultural vulnerability

3. **Climate is a major determinant of crop yield variability in Lesotho.** Very dry conditions can suppress yields, leading to low productivity. The variability of yield and thus production from year to year can be extreme and are primarily due to rainfall deficits leading to soil moisture stress and reduced rangeland productivity. The El Niño-Southern Oscillation (ENSO) phenomenon particularly affects climate variation in Lesotho. High intraseasonal and

interannual rainfall variability, with frequent droughts, has often resulted in delayed planting or farmers not planting at all, reduced seed germination due to hardened soil and lack of water, crop failures, deterioration of rangelands and pastures, water scarcity for livestock, and increased food prices.

4. **Increasing agricultural productivity, enhancing its resilience to climate change, and reducing the emissions that come from the agricultural sector are, therefore, triple imperatives that require alternative sets of practices.** CSA seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing greenhouse gas (GHG) emissions and sequestering carbon.[1]

Climate smart agriculture investment plan (CSAIP) analytical approach

5. **The CSAIP analytical approach began with a stakeholder process that identified the vision and goals for Lesotho's agriculture sector.** Five CSA targets were developed that focus on increasing agricultural productivity, enhancing resilience, and reducing emissions. All five targets address productivity, the central goal of most agricultural policies, while two targets each focus on enhancing climate resilience and mitigation (table ES.1). A number of strategies were identified for achieving the specified targets. A CSA strategy refers to a plan of actions to achieve CSA goals and targets for the country. A CSA strategy typically includes techniques to managing climate risks, understanding and planning for adaptive transitions that may be needed for example into new farming systems or livelihoods, and exploiting opportunities for reducing GHG emissions. The strategies are clustered into three groups: climate resilience and nutrition security, commercialization, and capacity development strategies (table ES.2).

6. **The CSAIP analytical approach also includes scenario development that helps define specific pathways to achieve the proposed targets.** It was also a stakeholder-driven process to test the plausibility of identified agriculture sector goals and served as a "reality check" to the outcomes given future uncertainties and other constraints. Two major drivers that may influence agricultural development in Lesotho—agricultural trade and sustainable landscape management—were used to formulate land-use scenarios for 2010 to 2050. The scenarios developed were Current Trends, Commercialization, and Resilient Landscape (figure ES.1).

7. **The Current Trends (CT) scenario generally follows the current development pathway and ongoing tendency of market liberalization but with relatively low ambition toward sustainable landscape management.** A general

TABLE ES.1: LESOTHO CSA TARGETS

No.	Targets for long-term vision	CSA pillars addressed
1	Increase yields of major staples by a factor of 2.5.	P
2	Double income of smallholder farmers.	P, R
3	Increase agricultural exports by a factor of 2.5.	P, R
4	Reduce agricultural GHG emissions by 25%.	P, M
5	Reduce livestock emissions intensity by 25%.	P, M

Source: Authors based on stakeholder workshops
Note: P = productivity; R = resilience; and M = mitigation

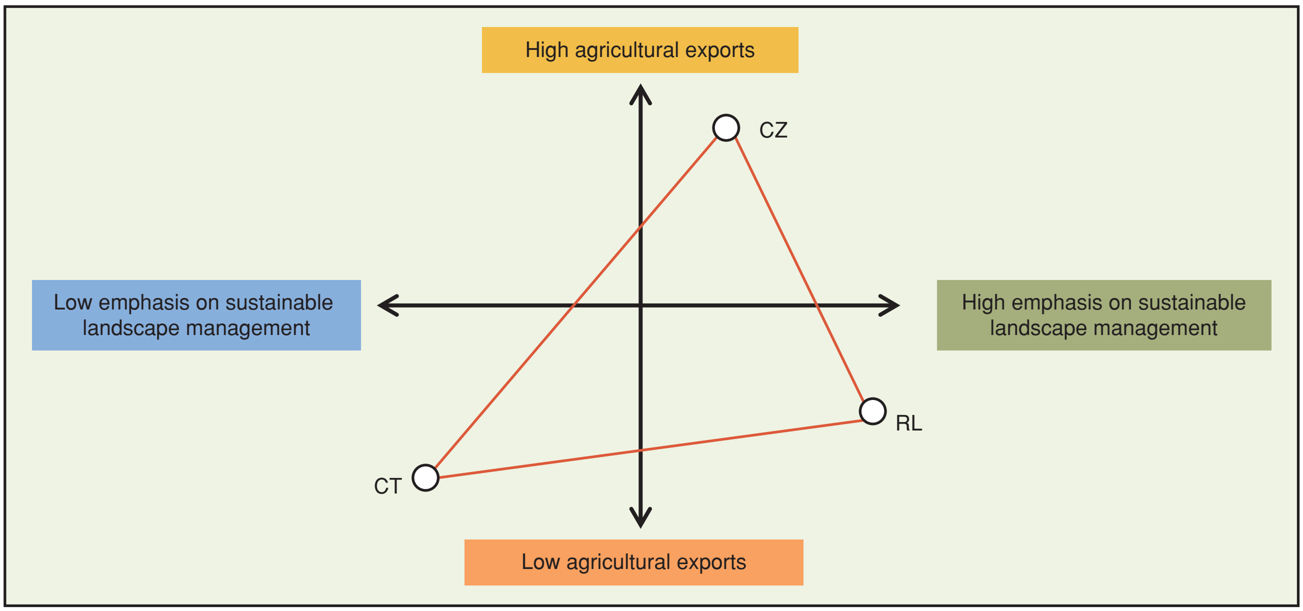
[1] Adaptation refers to adjustments in social and ecological systems, in response to actual or expected disturbances such as climatic impacts. Resilience on the other hand is the ability of social and ecological systems to absorb such disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change. Adaptation is the key factor for understanding how the resilience of social and ecological system changes over time. For simplicity, both terminologies are assumed to be synonyms in this report.

TABLE ES.2: STRATEGIES FOR ACHIEVING LESOTHO CSA GOALS

Climate resilience and nutrition security	Commercialization	Capacity development
Crop diversification	Agricultural value chain	Agricultural research and extension
Stress-tolerant crop and livestock breeds	Commodity standards	Knowledge development
Biofortified crops	Warehouse receipt system	Integrated weather and market advisories using Big Data and information and communication technology (ICT)
CSA practices at the farm level[2]	Greenhouse agriculture	—
Landscape approaches[3]	Market infrastructure development	—
Cost-effective irrigation	—	—

Source: Authors based on stakeholder workshops

FIGURE ES.1: POSITIONING OF SCENARIOS ON THE AXES OF DRIVERS OF AGRICULTURAL LAND CHANGE



Source: Authors

assumption under the CT scenario is for agricultural land under cultivation to grow through extensification and for production to keep pace with the current population growth rate. The CT scenario implies continued agricultural support for the dominant, unsustainable historical monoculture cropping system generally characterized by maize. To achieve this outcome, price support and subsidy must increase, implying an increasing social cost. In this scenario, maize, wheat, sorghum, and beans continue to be the primary crops, while sheep and goat production for wool and mohair remains vital. Agriculture continues to be dominated by small-scale rain-fed cereal production and extensive animal grazing.

[2] This includes integrated soil fertility management, conservation agriculture, agroforestry, improved feeding practices for livestock, animal health, and herd management.

[3] This includes rangeland rehabilitation and afforestation, terracing, soil erosion control, and flood management.

8. **The Commercialization (CZ) scenario prioritizes a high degree of market liberalization following trends in neighboring Republic of South Africa and takes into consideration agricultural commodities for which Lesotho has distinct comparative advantage.** The scenario assumes high ambitions for international cooperation, market liberalization, and increased agricultural exports as a main strategy to graduate from the United Nations (UN) ranking of least developed countries. The scenario implies a reduction in price support for field crops, notably maize, where deficits are assumed to be met by imports, supported through climate-smart agriculture investments in more profitable commodities, most notably potato, vegetables, and orchard products on the crops side and animal products on the livestock side of agriculture.

9. **The Resilient Landscape (RL) scenario assumes a lower priority to market liberalization but prioritizes a land management system that empowers smallholders with ambitions toward sustainability, socioeconomic resilience, and low ecological impact from economic growth.** The RL scenario focuses on integrating climate-smart, modern scientific knowledge like use of improved crop varieties and climate advisory services with the Machobane Farming System (MFS), a traditional farming practice that combines the use of crop rotation, relay cropping, and intercropping practices with the application of manure and plant ash to conserve soil moisture and replenish soil fertility. A main strategy to graduate from the least developed country status under the RL scenario is supporting smallholders, investing in sustainable landscape management, and building institutions to enhance landscape resilience.

10. **To determine the impacts of CSA at sector and household levels, the CSAIP approach combined quantitative analysis and qualitative assessment.** Two innovative quantitative techniques were employed for the assessment. At the sector level, the Lesotho Agricultural Sector Model (LesAgMod) computer tool was purposefully developed to explore alternative agricultural pathways and investment priorities for Lesotho. The agricultural planning tool couples agricultural, water, soil nutrients, and land-use practices and climate change scenarios to assess key vulnerabilities of the agricultural sector and employs a profit maximization approach to estimate changes in land-use and cropping patterns over time. Each narrative scenario was run for a set of 10 future climate projections, resulting in 30 unique simulations. The climate projections are assumed to be an exogenous factor that has an influence on crop and livestock productivity.

11. **The second CSAIP quantitative technique includes a financial and economic analysis to determine the profitability of adopting CSA at the household and sector levels.** The analysis provided answers to two key questions:

    1) **What is the financial viability of CSA practices for a household?**

    2) **How do the anticipated costs needed to scale up CSA compare to the anticipated economic benefits?**

12. **While the first question helps in determining the incentive requirements for an average Lesotho household to adopt CSA, the second question assesses the economic and societal benefits of adopting CSA and establishes the economic rationale for the public sector to support farmers' adoption and scaling up of CSA.** For the Cost-Benefit Analyses, the CT scenario characterized by conventional farming practices was assumed to be the "without CSA investment scenario" or baseline scenario while the RL and CZ scenarios are the "with CSA investment scenarios."

CSA impacts at sector and household levels

Crop yield

13. **The projected changes in yield under climate change are summarized in figure ES.2 and table ES.3.** The minimum projected impact of climate change on yield is negative for wheat (15 percent decrease), maize (6 percent decrease), orchards (5 percent decrease), and beans (2 percent decrease). On average, potato has the largest positive

FIGURE ES.2: CHANGE IN CROP YIELDS DUE TO CLIMATE CHANGE

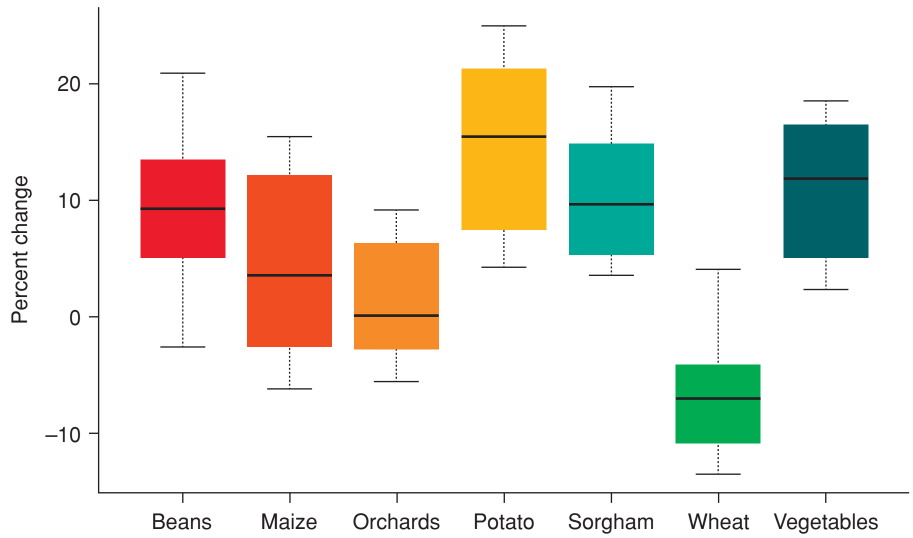


TABLE ES.3: PROJECTED IMPACTS OF CLIMATE CHANGE ON CROP YIELDS (%)

Crops	Minimum	First quartile	Median	Third quartile	Maximum
Beans	–2	5	9	13	21
Maize	–6	–2	3	12	15
Orchards	–5	–2	0	6	9
Potato	4	8	15	21	25
Sorghum	3	6	10	14	20
Wheat	–14	–11	–7	–4	4
Vegetables	2	6	12	15	18

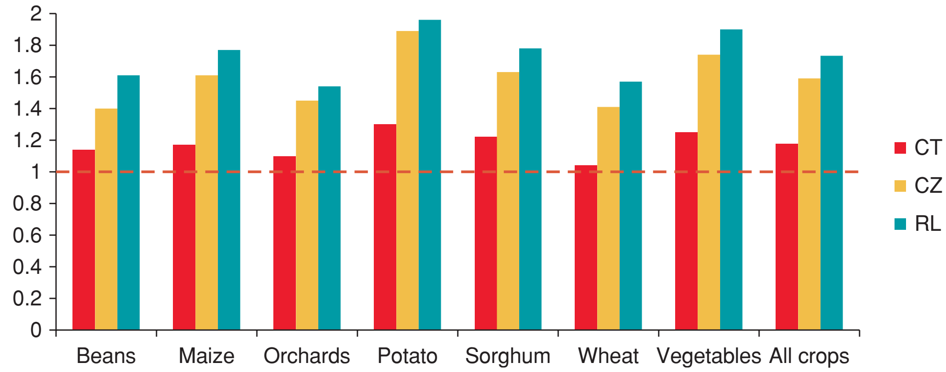
Negative Positive

Source: Authors

impact with 15 percent increase in yield, followed by vegetables (12 percent increase), sorghum (10 percent increase), and beans (9 percent increase), suggesting that crops would generally benefit from global warming in Lesotho. The warmer temperatures extend the growing season supported by mostly adequate moisture regimes. By extending the growing season, the period of successful pollination and initiation of kernel development in cereals that ends with physiological maturity of the kernels is maximized that may otherwise have been curtailed by cooler temperatures. Wheat is the exception, which shows a general decline, with reduced winter and spring soil moisture that results in suppressed yields. The maximum projected positive impact of climate change on yield ranges from 4 percent for wheat to 25 percent for potato.

14. **The RL and the CZ scenarios show the influence of CSA practices on yield, with the RL scenario resulting in higher yields compared with the CZ scenario.** Figure ES.3 indicates an increase in yield relative to historical for all scenarios under climate change. Relative to the CT scenario, the overall benefit of the CSA practices on yield under climate change is substantial. The variability of yields is primarily due to soil moisture deficits and heat stress. Potato and vegetables show the greatest increase in yield overall, benefiting from CSA practices, including the increase in application of nitrogen fertilizers.

FIGURE ES.3: RATIO OF CROP YIELDS UNDER CLIMATE CHANGE VERSUS HISTORICAL BY 2050

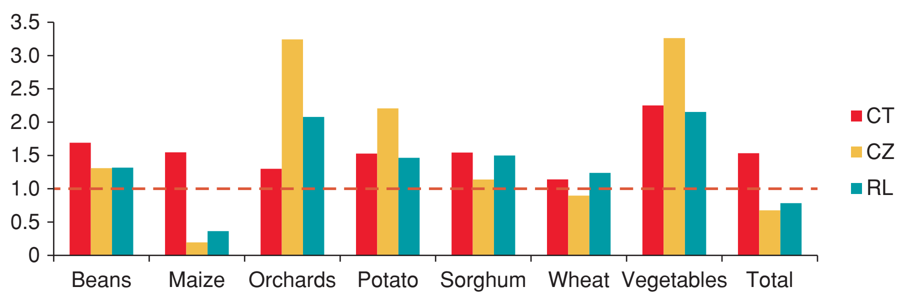


Source: Authors. Ratios above 1 show that relative to historical, crop yields will increase. On the other hand, ratios below 1 indicate that crop yields will decrease relative to historical.

Cropland expansion under climate change

15. **A major key to making agriculture climate-smart is increasing land-use efficiency through higher productivity, thereby reducing the need for clearing more land for agricultural production.** Relative to historical land use patterns, adoption of CSA leads to a reduction in the estimated cropland requirement by 20 percent for the RL scenario and 30 percent for the CZ scenario. On the other hand, the CT scenario shows cropland expansion by 50 percent (figure ES.4).

FIGURE ES.4: RATIO OF CROPLAND EXTENT UNDER CLIMATE CHANGE VERSUS HISTORICAL BY 2050



Source: Authors. Ratios above 1 show that relative to historical, cropland extent will increase. On the other hand, ratios below 1 indicate that cropland extent will decrease relative to historical.

Food production

16. **The estimated total production under climate change is 496,000 tons for CT, 590,000 tons for RL, and 742,000 tons for CZ.** Due to difference in cropping strategies under the scenarios described in paragraphs 7 to 9, the proportion of maize production decreases from 30 percent for CT to 3 percent for CZ. Potato is the most dominant crop accounting for 43 percent under CT, 54 percent under RL, and 62 percent under CZ scenario. The production of orchards under CZ doubles that of the CT scenario (table ES.4).

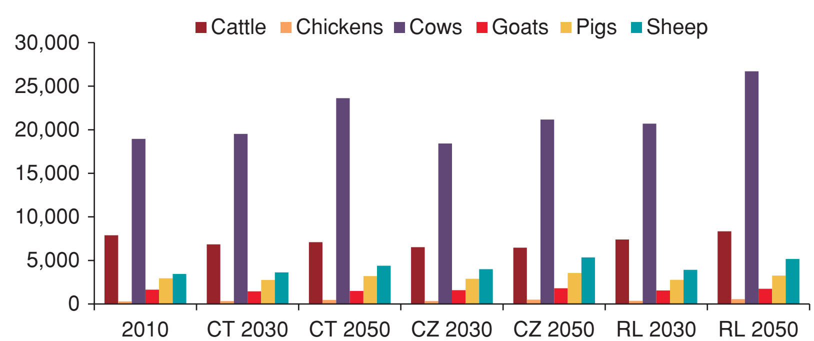
17. **While modeling results suggest steady increases of livestock over time, these changes are occasionally moderated by variability in climate and water supply (figure ES.5).** However, these effects are modest. The effects of climate and water supply reliability are more pronounced when looking at net production of livestock, because stresses caused by heat and scarcities of food and water have a larger influence on reducing the productivity of livestock than on increasing mortality.

TABLE ES.4: CROP PRODUCTION AND THEIR PROPORTIONS FOR THE SCENARIOS UNDER CLIMATE CHANGE

	CT		CZ		RL	
	ton	%	ton	%	ton	%
Beans	10,075	2	10,169	1	12,020	2
Maize	146,770	30	24,536	3	51,172	9
Orchards	17,555	4	57,692	8	40,000	7
Potato	214,100	43	461,743	62	320,493	54
Sorghum	18,015	4	19,098	3	26,631	5
Wheat	18,418	4	21,160	3	32,125	5
Vegetables	70,881	14	147,415	20	107,993	18
Total	**495,815**	**100**	**741,813**	**100**	**590,433**	**100**

Source: Authors

FIGURE ES.5: LIVESTOCK PRODUCTION (TONS) FOR THE NARRATIVE SCENARIOS AVERAGED FOR ALL THE FUTURE CLIMATE PROJECTIONS



Source: Authors

18. **The potential for aquaculture development has recently increased and could represent an interesting investment for the private sector. Aquaculture helps to diversify food production, increase nutrition security, and enhance resilience.** The aquaculture model developed in the report refers to the most consolidated production system, that is, warm-water fish farming in the lowlands, where temperatures are relatively high. The model includes common carp production (trout), the main species being produced, and assesses the benefits to the individual fish farmer who has access to abundant water and exploit this for fish farming. Over a 5-year investment period, scaling up aquaculture to yield economic benefits of $8.2 million for the Resilient Landscape Scenario and $24.7 million for Commercialization Scenario.

Food availability and trade

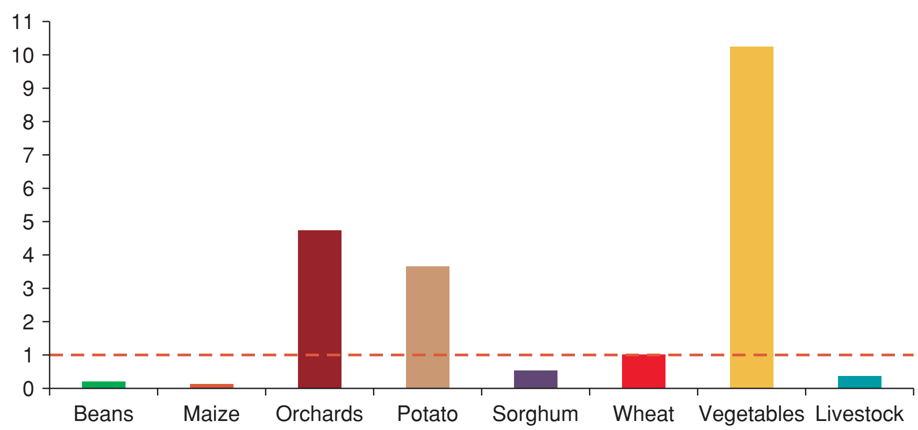
19. **Food calorie intake in Lesotho is about 2,450 kcal per capita per day, implying a calorie deficit of 11 percent compared to the recommended average of about 2,750 kcal per capita per day.** National food production contributes only 34 percent of Lesotho's per capita calorie intake (table ES.5) with more than half of per capita food calories derived from maize. While imports are 30 percent more than total national production, only about 2 percent of national production is exported. Per capita food rates have been modestly low and would benefit from increased production. Within the context of the CZ scenario, some nationally produced agricultural commodities—such as vegetables, orchards, and potato—could serve Lesotho's export market. Assuming population will grow to 3 million

TABLE ES.5: AVERAGE HISTORIC IMPORTS, EXPORTS, AND NATIONALLY PRODUCED CROP SUBSECTOR COMMODITIES AND THE KCAL PER CAPITA PER DAY PROVIDED BY EACH OF THOSE COMMODITIES FOR 2000–2010

	National production (ton)	Import (ton)	Export (ton)	Net (ton)	Calorie intake (kcal per capita per day)	National production as proportion of consumption (%)	Calorie (kcal per capita per day) from national production
Beans	17,000	83,000	2,000	98,000	370	17	64
Maize	96,000	213,000	2,000	307,000	1,350	31	422
Orchards	16,000	5,000	0	21,000	20	76	15
Potato	100,000	8,000	0	108,000	95	93	88
Sorghum	22,000	7,000	0	29,000	100	76	76
Wheat	17,000	83,000	2,000	98,000	370	17	64
Vegetables	26,000	17,000	0	43,000	12	60	7
Livestock	27,000	8,000	0	35,000	130	77	100
Total	**321,000**	**424,000**	**6,000**	**739,000**	**2,447**		**836**

Source: Based on FAOSTAT. Food items were converted to calories using Lesotho food composition table.

FIGURE ES.6: RATIOS OF CALORIES POTENTIALLY DERIVED FROM NATIONAL FOOD PRODUCTION BY 2050 UNDER CLIMATE CHANGE FOR THE CZ SCENARIO VERSUS CALORIES FROM HISTORICAL (2000–2010) NATIONAL PRODUCTION



Source: Authors. Orchards, potato, and vegetables can be prioritized for export. Ratios above 1 show that relative to historical, calories derived from national production will increase. On the other hand, ratios below 1 indicate that calories derived from national production will decrease relative to historical.

by 2050 and current food calorie shortfalls will be met through national production, figure ES.6 indicates that calories potentially derived from national production by 2050 could increase by a factor ranging from 3.6 for potato to 10.2 for vegetables.

20. **Potato production would grow to 462,000 tons by 2050, and Lesotho could target 200,000 tons for national consumption, doubling the historical requirement of 100,000 tons.** Thus, more than 260,000 tons could be available for export. Likewise, vegetable and orchard production are shown to grow at rates exceeding population growth rates and could also be used for exports, in addition to making food calorie intake grow to more acceptable standards of around 2,750 kcal per capita per day. To improve nutritional quality, Lesotho could also step up its biofortification efforts to cover beans, maize, wheat, and sorghum. Biofortification, a technique that uses conventional

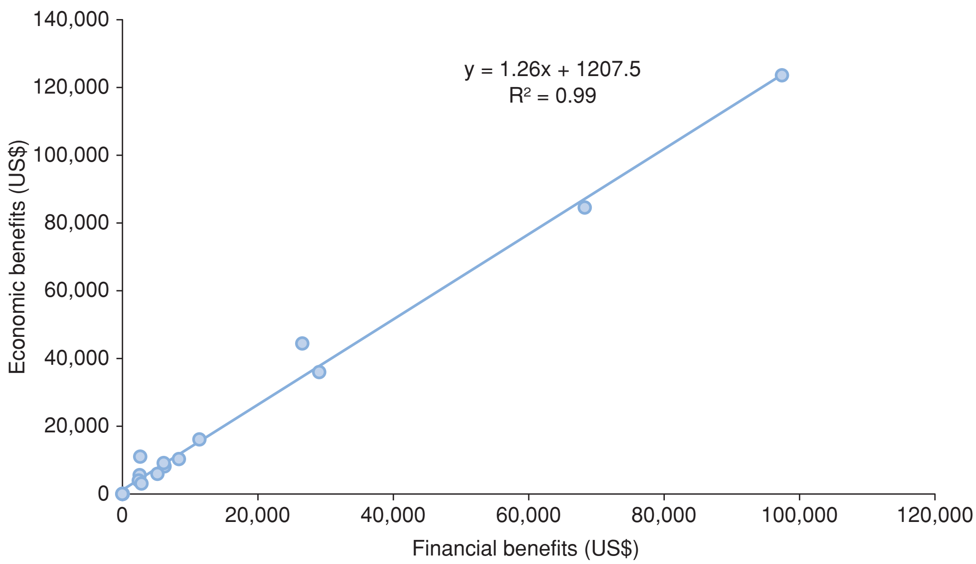
breeding methods to produce more nutritious crops—with a higher content of vitamin A, zinc, iron, or other micronutrients than standard crop varieties—could contribute to healthier diets in Lesotho.

Profitability of CSA

21. **Farm budget analyses reveal that climate-smart crop and livestock production are more profitable than conventional practices.** The annual net income of the representative farming household is about three times higher under the RL scenario, and about five times higher for the CZ scenario. Higher profitability of commercial farming results from increase in farm size, intensification of cereals production, and expansion of high-value crops: potato, vegetables, and fruits crops. Switching from a conventional to a commercial farming system is more profitable but requires more private investments, while switching from conventional to climate-resilient farming practices is less profitable but will be more affordable for the smallholders.

22. **Societal benefits of climate-smart crop production are higher than private benefits derived by individual farmers.** For every US$100 the farmer profits from CSA adoption, the society benefits an additional US$26 through transfer payments to producers (figure ES.7). CSA can also reduce soil erosion, generate carbon sequestration, conserve biodiversity, and provide other public goods that accrue to society but not to the farmers engaged in market transactions alone.

FIGURE ES.7: RELATIONSHIP BETWEEN ECONOMIC AND FINANCIAL BENEFITS OF CSA AT THE FARM LEVEL



Source: Authors

Carbon balance

23. **Table ES.6 indicates that relative to Current Trends, the RL scenario will generate a net carbon sink (that is, absorbs more carbon than it releases as carbon dioxide into the atmosphere) of 26 million tCO_2-eq, equivalent to 0.87 million tCO_2-eq per year, or 1.5 tCO_2-eq per ha per year.** Livestock activity is the major carbon emitter with 6 million tCO_2-eq, followed by inorganic fertilizers (1.9 million tCO_2-eq). However, improved grassland management helps to reduce most of these emissions with carbon sequestration of 21 million tCO_2-eq. Afforestation, switching from annuals to orchards, rangeland improvement, forest rehabilitation, and improved crop production all sequesters about 13.5 million tCO_2-eq. GHG dynamics for the CZ scenario are similar but generate considerably lower carbon sink of 2.5 million tCO_2-eq, equivalent to 84,000 tCO_2-eq per year, or 0.2 tCO_2-eq per ha per year. Livestock activity is also a

TABLE ES.6: CARBON BALANCE FROM CSA PRACTICES UNDER RL AND CZ SCENARIOS

Project activities	RL Scenario		CZ Scenario	
	Over the economic project lifetime of 30 years (tCO_2-eq)	Annual average (tCO_2-eq per year)	Over the economic project lifetime of 30 years (tCO_2-eq)	Annual average (tCO_2-eq per year)
	Net GHG emissions			
Afforestation	−6,517,278	−217,243	−2,281,062	−76,035
Annual crops to orchards	−18,223	−607	−174,423	−5,814
Rangeland improvement	−2,498,661	−83,289	−3,358,130	−111,938
Improved annual crop production	−1,954,768	−65,159	−1,213,410	−40,447
Improved orchards practices	−149,243	−4,975	−1,413,030	−47,101
Grassland management	−20,741,663	−691,389	−6,102,907	−203,430
Livestock management	6,236,615	207,887	7,055,693	235,190
Forest rehabilitation	−2,504,146	−83,472	–	–
Fertilizers and pesticides application	1,900,070	63,336	4,890,078	163,003
Aquaculture	18,804	627	75,215	2,507
Total	**−26,228,494**	**−874,283**	**−2,521,976**	**−84,066**
Per hectare	**−46**	**−1.5**	**−5**	**−0.2**

Source: Authors. The CT was assumed to be the "without project" scenario.

TABLE ES.7: GHG EMISSION INTENSITIES FOR CROPS AND LIVESTOCK (tCO_2eq PER TON PRODUCT)

	Conventional	CSA	Difference
Crops			
Maize	2.2	−11.7	−13.8
Maize - CA		−8.2	−8.2
Other cereals	1.3	−6.1	−7.4
Legumes: beans and peas	8.4	−11.9	−20.4
Potato and vegetables	0.4	−0.7	−1.1
Livestock			
Dairy cattle	115.38	78.54	−32
Other cattle	316.61	245.57	−22
Sheep	3.38	3.34	−1
Pigs	0.18	0.12	−32
Goats	2.32	2.29	−1
Poultry	0.07	0.04	−37

Source: Authors

major carbon emitter (7 million tCO_2-eq), while application of fertilizers and pesticides emits about 4.9 million tCO_2-eq. Grassland management, conversion of annuals to orchards, afforestation, rangeland improvement, and improved practices in orchards are estimated to sequester about 8.4 million tCO_2-eq.

24. **Emissions intensity, defined as the quantity of GHG emitted per unit of produce declines following the implementation of CSA practices, therefore positively contributing to climate change mitigation.** For crops, the decline in emission intensity ranges from 1.1 tCO_2eq per ton of product for potato and vegetables to 20.4 tCO_2eq per ton of product for legumes. Switching to climate-smart livestock practices leads to a decline in livestock emission intensity, ranging from 1 percent for sheep and goats to 37 percent for poultry. The average decrease in livestock emissions intensity, estimated at 21 percent, is lower than the 25 percent CSA target for the country.

25. **In addition, CSA adoption could create jobs that will stimulate Lesotho's rural economy.** Shifting from low-value grain production to more labor-intensive and higher value-added crops like potato, orchards, and vegetables could generate 4,600 to 16,600 stable jobs (table ES.8). The CZ scenario will generate about 40 to 60 percent more jobs generated by the other two scenarios. However, unlocking the job creation potential of potato and horticulture subsectors will require Lesotho to strategically exploit its comparative advantage in the production of these commodities. The country can leverage research knowledge, export infrastructure, and market intelligence from its proximity to the Republic of South Africa (RSA). In addition, public-private partnership could be useful to take advantage of the abundant water resources required for commercial agriculture (World Bank Group 2018b).

TABLE ES.8: ESTIMATED NUMBER OF FARMING JOBS CREATED UNDER CLIMATE CHANGE OVER A 5-YEAR INVESTMENT PERIOD

	Coefficient (jobs/ha)	CT	RL	CZ
Beans	0.02	609	475	472
Maize	0.01	1,859	438	235
Orchards	1.30	6,658	10,643	16,599
Potato	0.30	3,194	3,060	4,614
Sorghum	0.05	2,013	1,956	1,486
Wheat	0.05	992	1,077	779
Vegetables	1.30	10,484	10,033	15,193
Total		**25,809**	**27,682**	**39,378**

Source: Data on number of jobs per ha for different cropping systems are modified from World Bank (2011, 2018a).

Prospect of meeting Lesotho's CSA targets

26. **The probability of Lesotho meeting its CSA targets vary from low for increasing productivity and agricultural exports to high for reducing agricultural emissions and livestock emissions intensity (table ES.9).** There are interdependencies in the prospect of meeting the targets; for instance, increasing agricultural productivity (target 1) is a prerequisite to doubling farmers' income (target 2), increasing exports (target 3), and to a lesser extent reducing agricultural emissions and livestock emissions intensity (targets 4 and 5). Thus, it is crucial that the CSAIP identifies an integrated solution that will address the potential constraints to meeting the targets, while synergistically delivering productivity and climate benefits to farmers.

TABLE ES.9: POTENTIAL OF MEETING LESOTHO'S CSA TARGETS

No.	Targets	Probability of meeting the target	Remarks
1	Increase yields of major staples by a factor of 2.5.	Low	Yield gap must be narrowed by introducing climate-ready, stress-tolerant species and cultivars adapted to Lesotho's context. Other constraints that must be addressed to effectively close the yield gap include weather-induced yield variability, soil fertility constraints, pest infestation, and market accessibility.
2	Double income of smallholder farmers.	Medium	Famers' income more than doubles for most CSA practices, but cost of adoption may be a barrier to meeting this target.
3	Increase agricultural exports by a factor of 2.5.	Low	The target can be met if Lesotho is able to narrow yield gap, prioritize horticulture and potato for exports, and create the enabling environment for higher levels of CSA adoption.
4	Reduce agricultural GHG emissions by 25%.	High	Target can be met following the adoption of climate-smart livestock practices under the RL scenario. Integrated catchment management will help reduce soil erosion and the associated loss of soil carbon. Better rangeland management will also help sequester carbon. Sustainable crop intensification will help reduce cropland expansion, and the associated carbon emission.
5	Reduce livestock emissions intensity by 25%.	High	This target has high probability of being met by stepping up the adoption of climate-smart livestock practices. More efforts are particularly required in lowering emission intensities from goat and sheep.

Source: Authors

Barriers to CSA implementation

27. **Even though CSA technologies can generate private and public benefits, their adoption faces many socioeconomic and institutional barriers.** Ranking of adoption constraints against CSA practices reveals that inadequate implementation capacity (75 percent) and access to inputs or finance (71 percent) are the most critical adoption barriers for all groups of CSA practices (table ES.10). Within crop management, the adoption of improved crop varieties (68 percent), postharvest management (68 percent), and Integrated Pest Management (65 percent) are influenced by the adoption factors the most. For climate-smart livestock management, animal health control (75 percent), grassland reseeding (73 percent), and improved animal breeds (73 percent) suffer from the adoption constraints the most. For integrated catchment management, afforestation/reforestation (69 percent), small-scale irrigation (69 percent), and gully control (63 percent) are mostly influenced by the adoption factors. Among CSA practice groups, livestock and grassland management are influenced the most, scoring highest across most of the adoption factors.

28. **Land tenure most influences agroforestry and fodder production (70 percent), terracing (73 percent), rotational grazing and grassland rehabilitation (78 percent), grassland reseeding (80 percent), and afforestation (88 percent).** Secure land tenure is critical to the sustainability of land use and CSA implementation. If land tenure cannot be protected effectively, farmers and commercial investors will be unwilling to invest, or will even give up long-term investments on farmland entirely. Inadequate research impacts post-harvest management (83 percent) and the adoption of climate-smart livestock practices the most, with stakeholders scoring improved animal breeds and feeding practices as the most critically impacted (85 and 80 percent, respectively).

TABLE ES.10: RELATIVE IMPORTANCE OF FACTORS FOR ADOPTION OF CSA PRACTICES IN LESOTHO

	Inadequate access to finance including inputs and credits	Inadequate access to markets	Limited implementation capacity (awareness, skill, training, and education)	Land tenure issues	Research	Inadequate access to infrastructure (roads, storage facilities, and ICT)	Public policy	Average
Crop management								
Minimum soil disturbance, residue retention	48	40	80	50	65	35	60	54
Crop rotation	58	50	60	53	58	38	55	53
Agroforestry	73	48	73	70	63	43	68	62
Judicious fertilizer application	73	48	60	35	55	35	55	51
Organic fertilization	58	45	60	28	58	43	53	49
Inorganic fertilizer	73	58	58	35	55	43	48	53
Improved crop varieties	80	80	70	48	73	63	60	68
Integrated Pest Management	75	55	73	53	73	50	75	65
Postharvest management	75	75	88	35	83	60	58	68
	68	**55**	**69**	**45**	**64**	**45**	**59**	**58**
Livestock and grassland management								
Rotational grazing	60	45	70	78	63	43	80	63
Fire management	50	25	68	53	55	28	78	51
Grassland reseeding	85	63	80	80	78	43	80	73
Fodder production	88	70	78	70	75	43	55	68
Livestock diversification	75	70	85	50	73	55	55	66
Improved animal breeds	88	75	85	45	85	68	68	73
Animal and herd management	68	50	68	68	63	53	68	62
Animal diseases and health control	88	80	80	55	75	70	78	75
Improved feeding practices	70	63	78	50	80	60	63	66
Manure management	58	40	70	38	60	58	60	55
	73	**58**	**76**	**59**	**71**	**52**	**68**	**65**

(continued)

TABLE ES.10: (Continued)

	Inadequate access to finance including inputs and credits	Inadequate access to markets	Limited implementation capacity (awareness, skill, training, and education)	Land tenure issues	Research	Inadequate access to infrastructure (roads, storage facilities, and ICT)	Public policy	Average
Integrated catchment management								
Small-scale irrigation	83	63	73	68	70	65	60	69
Rainwater harvesting	65	38	65	40	38	50	53	50
Terracing	40	20	83	73	58	48	53	53
Gully control	78	35	88	65	53	60	60	63
Flood control	68	25	73	60	50	63	60	57
Check dams	65	28	73	63	53	65	65	59
Afforestation/reforestation	73	40	88	88	60	68	70	69
Grassland rehabilitation	80	35	73	78	50	55	65	62
	69	**35**	**77**	**67**	**54**	**59**	**61**	**60**
Aquaculture								
Improved stocks	80	78	78	40	75	63	63	68
Production intensification	78	70	83	53	73	60	60	68
Better feeding practices	78	75	85	38	65	60	63	66
Improved water use efficiency and pond management	75	65	85	45	70	78	68	69
Diseases control	85	78	83	38	78	55	68	69
	79	**73**	**83**	**43**	**72**	**63**	**64**	**68**
Average	**71**	**54**	**75**	**54**	**65**	**54**	**63**	

Low High

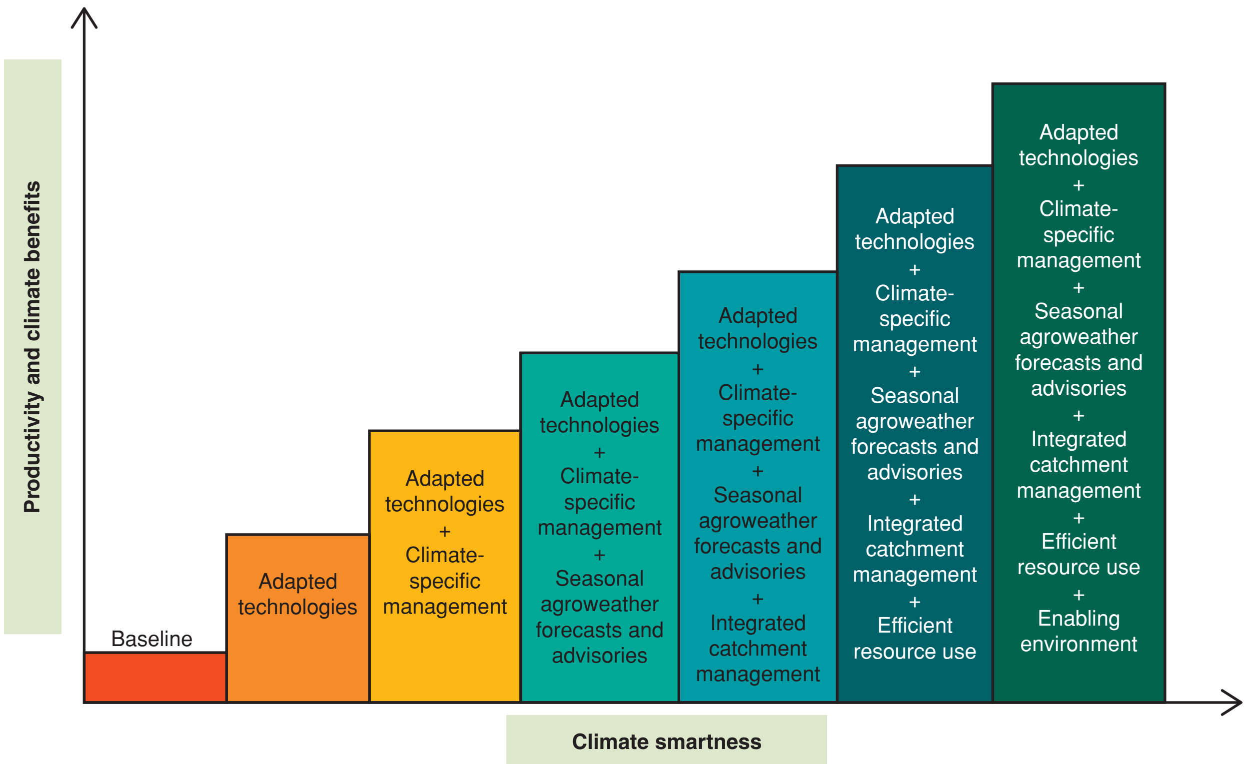
Source: Based on stakeholders' ranking.

Note: ICT = information and communication technology; IPM = integrated pest management. Importance of factors for adoption was first rated as 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; and 5 = Very high. Thereafter, scores for each factor were averaged over the number of respondents and expressed as a percentage. Higher scores indicate that it is more critical and urgent to address a factor (or enabling condition) for effective CSA implementation in Lesotho.

CSA investment needs

29. **To determine Lesotho's CSA investment needs, emphasis was placed on integrating proven CSA technologies that will minimize trade-offs and capitalize on synergies between CSA pillars as exemplified in figure ES.8 where successive addition of CSA technologies leads to an overall increase in productivity and climate benefits derived from the agricultural system.** Climate modeling indicates that yield variability is primarily due to rainfall deficits, implying that there is need for stress-resistant, higher yielding crop varieties, and greater cropping intensity to meet food demand. Increasing cropping intensity implies that expanding efficient irrigation and agricultural water management technologies is a key part of the CSAIP in Lesotho. In addition to improved water use efficiency, strengthening the adaptive capacity of smallholder farmers to adjust and modify their production systems

FIGURE ES.8: RELATIONSHIP BETWEEN CSA BENEFITS AND CLIMATE SMARTNESS OF TECHNOLOGIES



Source: Modified from CCAFS (2014). This figure builds on the premise that CSA technologies are context-specific. Adapted technologies refer to those that are proven to be suitable to the local context. Climate-specific management comprises a set of practices that address the climate vulnerability of farming in the locality.

to minimize the potential future impacts from climate variability will require solutions that improve soil health, and increase farm productivity. Regional demand for fruit and vegetables is likely to increase as urban populations grow, incomes rise, and the popularity of healthy diets increases. Higher production and sales of high value crops would also deepen domestic agricultural markets, generate rural employment and improve nutrition. Lastly, implementation of sustainable landscape management encompassing interventions from the micro-catchment scale[4] managed largely by communities, to wider development among multiple sectors concerned with productive and nonproductive land uses will help optimize ecosystem functions and services.

30. **Given the above consideration, four thematic areas have been identified and validated with stakeholders as priority areas for the CSAIP investments (box ES.1).** They are:

- Improve water management in rainfed and irrigated agriculture;
- Scale up CSA technologies for crops, livestock, and aquaculture;
- Promote market access for farmers; and
- Support sustainable landscape and integrated catchment management.

31. **Total CSAIP financial costs for the RL scenario amount to about US$268 million over a 5-year investment period, corresponding to investment costs of about US$54 million per year.** For the CZ scenario, the total CSAIP costs are about US$208 million over the same period, or about US$42 million per year (table ES.11). The Internal Rate

[4] The within-field systems of water harvesting are called **micro-catchment** systems. A micro-catchment consists of small structures such as pits, holes, basins, and bunds formed for surface runoff water collection from within the cropped area.

BOX ES.1: BRIEF DESCRIPTION OF THE LESOTHO CSAIP COMPONENTS

Component 1: Improve Water Management in rainfed and irrigated agriculture.

Enhanced and efficient water management is a key factor for adaptation and increasing the efficiency of other CSA measures. The CSAIP will promote off- and on-farm investments in hydraulic infrastructure to restore and improve water distribution and reduce losses, improve water use efficiency, and increase and regulate water access management and governance for household consumption and agriculture production, particularly in areas of high agricultural potential. The CSAIP investment activities will include: sustainable water management practices such as micro-irrigation, water harvesting; modernization of hydraulic infrastructures, and strengthening institutions for effective agricultural water management.

Component 2: Scale up CSA technologies for crops, livestock, and aquaculture.

This CSAIP component will promote integrated soil fertility management; agroforestry; and conservation agriculture. For livestock, the CSAIP will finance three key interventions: improving access to better livestock breeds, improving animal nutrition, and improving access to animal health services. For aquaculture, the CSAIP will focus on improved stocks, production intensification, better feeding practices, and improved water use efficiency in the ponds.

Component 3: Promote market access for farmers.

Activities to be supported under this component include: development of Agriculture Clusters Service Enterprises; development of Market Hub Enterprises; aggregation of smallholder farmers into upgraded commodity value chains; piloting weather index insurance to manage risks; and promoting food quality standards. The component will also support the development of integrated climate information services through public private partnership.

Component 4: Support sustainable landscape and integrated catchment management.

This component will finance structural and vegetative measures of sustainable landscape management. The structural measures include terracing; gully control; flood control; and a check dam, a small, temporary dam constructed across waterways to reduce erosion by decreasing water flow velocity. The vegetative measures include afforestation/reforestation; and grassland rehabilitation. In addition, the component will finance the modernization of land administration through digital land registry and titling, spatial data infrastructure development, and capacity building for land administration.

TABLE ES.11: CSAIP INVESTMENT COSTS (US$, THOUSANDS PER YEAR)

Components	RL	CZ
1. Improve water management in rainfed and irrigated agriculture	14,944	18,382
2. Scale up CSA technologies for crops, livestock, and aquaculture	15,473	9,793
3. Promote market access for farmers	5,882	4,272
4. Support sustainable landscape and integrated catchment management	17,207	9,210
Total amount per year	**53,505**	**41,658**
Total over the complete investment period (5 years)	**267,525**	**208,288**

Source: Authors

of Return (IRR) for the RL scenario is 13 percent, increasing to 73 percent when carbon benefits are factored into the investment. For the CZ scenario, the investment rate of return is 32 percent but increases marginally to 34 percent with the inclusion of carbon benefits.

32. **Appropriate delivery methods are required for the CSAIP investment to support adoption and generate the desired benefits.** Six delivery methods that were considered with respect to the investment components and their roles in breaking key adoption barriers are indicated in table ES.12. All the delivery mechanisms focus on addressing implementation capacity which is the most critical CSA adoption barrier in the country. Except for agricultural research and innovation, the delivery mechanisms also address farmers' access to finance and

TABLE ES.12: ROLE OF DELIVERY MECHANISM IN ADDRESSING CONSTRAINTS TO CSA ADOPTION

Delivery mechanisms	Implementation capacity	Access to finance and markets	Inadequate research	Infrastructure	Land tenure
Efficient irrigation technologies and institutions	Establishment of irrigation institutions and strengthening their capacity through technical assistance and training	Higher and better agricultural produce from irrigation help to deepen agricultural markets		Investment in irrigation infrastructure will increase productivity and market access. This will, in turn, attract private investment, enhance job creation and stimulate growth.	
Pluralistic extension services and FFS	Increase the knowledge and skills of farmers, farmer aggregators, agro-processors, agro-dealers, and national and district level extension staff in proven CSA technologies.	Farmer aggregators and other service providers can help connect farmers to relevant markets.	Feedback from extension and FFS can stimulate further research and ameliorate yield-limiting constraints.		
Market linkages	Horizontal alliance helps to shift smallholder thinking from subsistence farming to agribusiness by training farmers to identify crops with potential for commercialization, grow them profitably, and establish relations with market agents.	Improved legal and regulatory framework for commercial agriculture helps improve access to market.	Public investment can be used to leverage private investment in agricultural research including developing improved seeds and seedlings, and IPM measures tailored to local conditions.	Public-private partnership can help address underinvestment, poor infrastructure, deficient services, low visibility, and insufficient funding.	

(continued)

TABLE ES.12: (Continued)

Delivery mechanisms	Implementation capacity	Access to finance and markets	Inadequate research	Infrastructure	Land tenure
SLM through participatory approaches	Participatory element of SLM and landscape approaches facilitates knowledge exchange between farmers and community members.	Large mitigation benefits from landscape restoration could open up opportunities from carbon finance.			The delivery method includes modernizing land titling and administration that helps to improve tenure security and proper land market functioning. Secure land tenure incentivizes CSA adoption.
Agricultural research and innovation	Combining agricultural research innovation with extension will help enhance farmers' capacity to implement integrated CSA solutions.		Improved crop and livestock breeding, increased yields, disease resistance, abiotic stress tolerance, and nutrition.		
Digital solutions and services	ICT-based agroweather, agronomic, and market advisories can be used to facilitate learning through feedback (bidirectional information flow) between farmers and advisories providers.	ICT tools can facilitate buyer—seller matching and market transactions for agricultural commodities. ICT also promotes financial inclusion. Market information systems will help reduce information costs.			Digitizing and documenting land rights in ways that are supported by local stakeholders enhances transparency and provides incentives for CSA adoption, sustainable land use, and intensification.

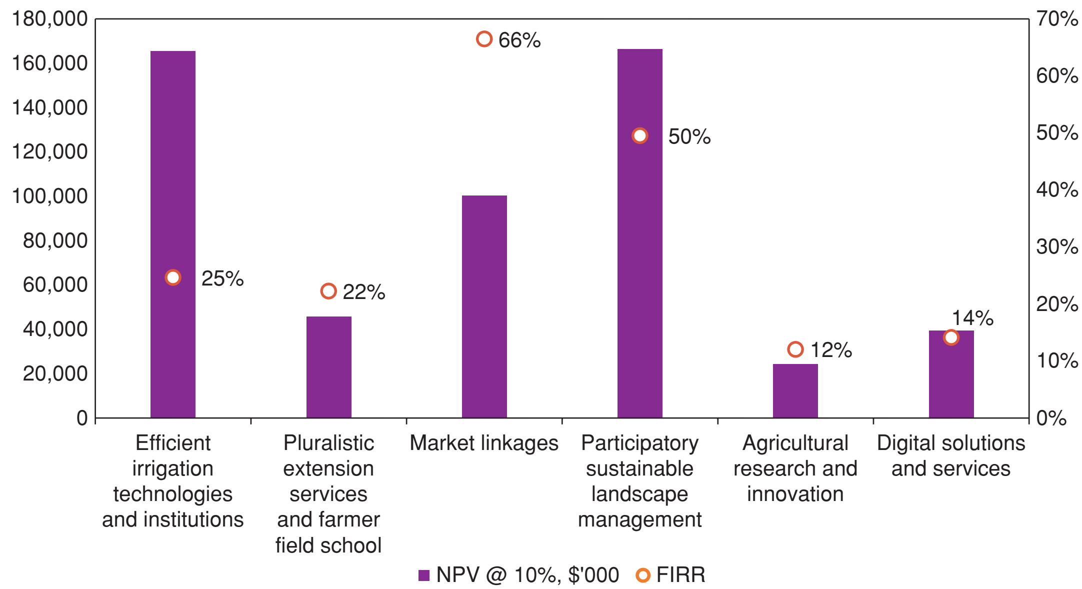
Source: Authors

Note: CSA = climate-smart agriculture; FFS = Farmer Field School; ICT = information and communication technology; SLM = sustainable land management.

markets. The application of digital technology can facilitate learning, market access, and regularization of land rights that will encourage CSA adoption.

33. **Figure ES.9 indicates that Net Present Values (NPVs) of the delivery methods are positive, suggesting that they all generate positive cashflow ranging from $24 million for agricultural research and innovation to $166 million for Participatory Sustainable Landscape Management.** This confirms the financial viability of investing in the delivery mechanisms. The costs of the delivery mechanisms are covered by the benefits, and there is an excess. The IRRs are above the discount rate of 10 percent, ranging from 12 percent for agricultural research and innovation to 66 percent for market linkages. The IRRs further provide confidence in the profitability of the delivery mechanisms.

FIGURE ES.9: NET PRESENT VALUE AND INTERNAL RATE OF RETURN OF LESOTHO CSAIP DELIVERY MECHANISMS



Source: Authors

Prioritization of scenarios and investment decision

34. **Prioritizing CSA practices that are adapted to a country's context is a key step toward optimizing the productivity and climate benefits of the practices.** Table ES.13 demonstrates that comparison over 13 indicators shows that the RL scenario performs better on 6 indicators (46 percent), while CZ performs better on 7 indicators (54 percent). Six important lessons emerge for effective scaling up of CSA in the country:

- Though commercialization is more profitable, it requires larger farm size. It is more appropriate for medium-size, emerging farmers and requires strong market-oriented agricultural policies for it to be successful.
- Furthermore, commercialization would require more private initiative and resources, for instance in developing the agricultural value chain and well-functioning land markets. This could constitute a serious barrier given Lesotho's nascent private sector.
- Commercial agriculture generates more stable jobs but will also require a transformational shift in the farming systems and may be challenging given the current level of implementation capacity.
- Though less profitable, climate-resilient agriculture delivers 10 times carbon benefits as commercial agriculture. Thus, climate-resilient agriculture could potentially benefit from climate finance. Climate-resilient agriculture is also more effective in controlling soil erosion.
- Climate-resilient agriculture is 30 percent costlier for the public sector but is easier to implement and not affordable for small farmers. It is more tailored toward adapted technologies, landscape resilience and sustainable agricultural intensification that the average smallholder farmer can practice.

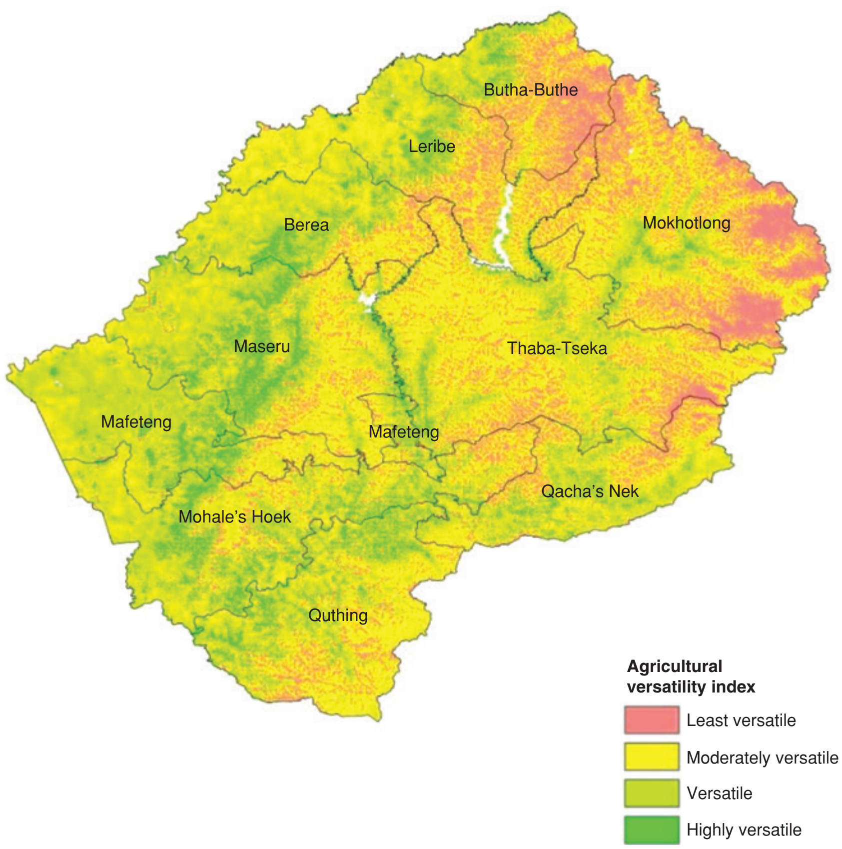
35. **Climate-resilient farming seems more feasible given the above considerations.** Alternatively, Lesotho may opt for climate-resilient farming and sustainable landscape management in zones more prone to soil erosion, suitable for afforestation and farmer-managed natural regeneration of vegetation, and where less fertile land needs restoration and replenishment. Commercial agriculture can be practiced in more fertile areas that are suitable for potato, orchards, and vegetables. Aquaculture development is more suitable to the lowlands due to warmer temperatures. In figure ES.10, the most productive lands in Lesotho are the versatile and the highly versatile land classes that can be preferentially allocated to commercial agriculture.

TABLE ES.13: COMPARISON OF INDICATORS UNDER THE TWO SCENARIOS

	Commercialization	Resilient Landscape
Net household income US$ per year	1,233	698
Increase in crop yields over historical (%)	60	70
Cropland area (ha)	132,247	153,482
Livestock production (ton)	38,849	45,765
Erosion control: gross erosion (Mt per year)	39	35
Food availability[5] (kcal/capita/day)	675	649
Export potential	moderate	none
GHG mitigation: carbon balance tCO_2-eq	−2,521,976	−26,228,494
Job creation	39,378	27,862
Economic internal rate of return (EIRR) %	32	13
Carbon benefits (US$ million)	2–17	36–282
EIRR % with carbon benefits	32–34	16–73
Financial cost (US$ million)	208	268

Source: Authors. Green color indicates that a scenario performs better; orange color indicates otherwise.

FIGURE ES.10: LESOTHO AGRICULTURAL VERSATILITY MAP



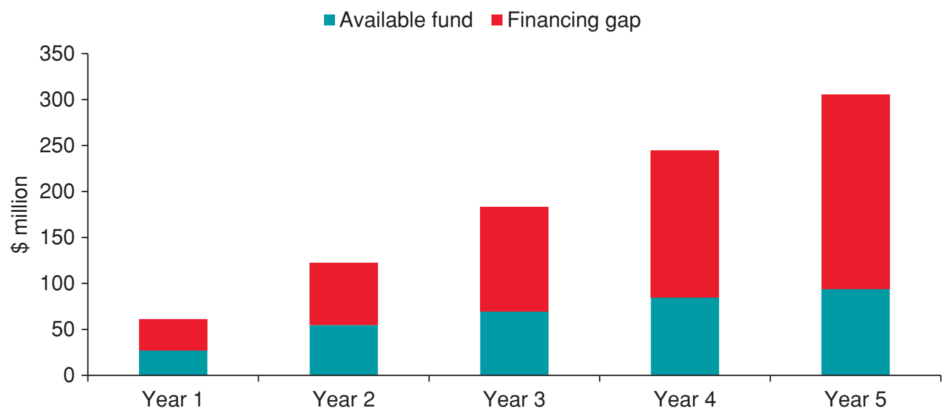
Source: Authors

[5] This measures food calories from national production.

Financing the investment plan

36. **Assuming Lesotho pursues the RL pathway, the cumulative financing gap amounts to US$34 million in year 1, increasing to US$211.5 million by year 5 (figure ES.11).** In estimating the CSAIP financing gap, the report considered existing agricultural projects with CSA-related expenditures and the duration of such projects.[6] The annual financing gap was then estimated as the difference between annual cost of CSAIP and available funds supporting CSA-related expenditures.

FIGURE ES.11: CUMULATIVE ANNUAL PROPORTION OF FUNDS UNDER EXISTING AGRICULTURAL PROJECTS AND CSAIP FINANCING GAP



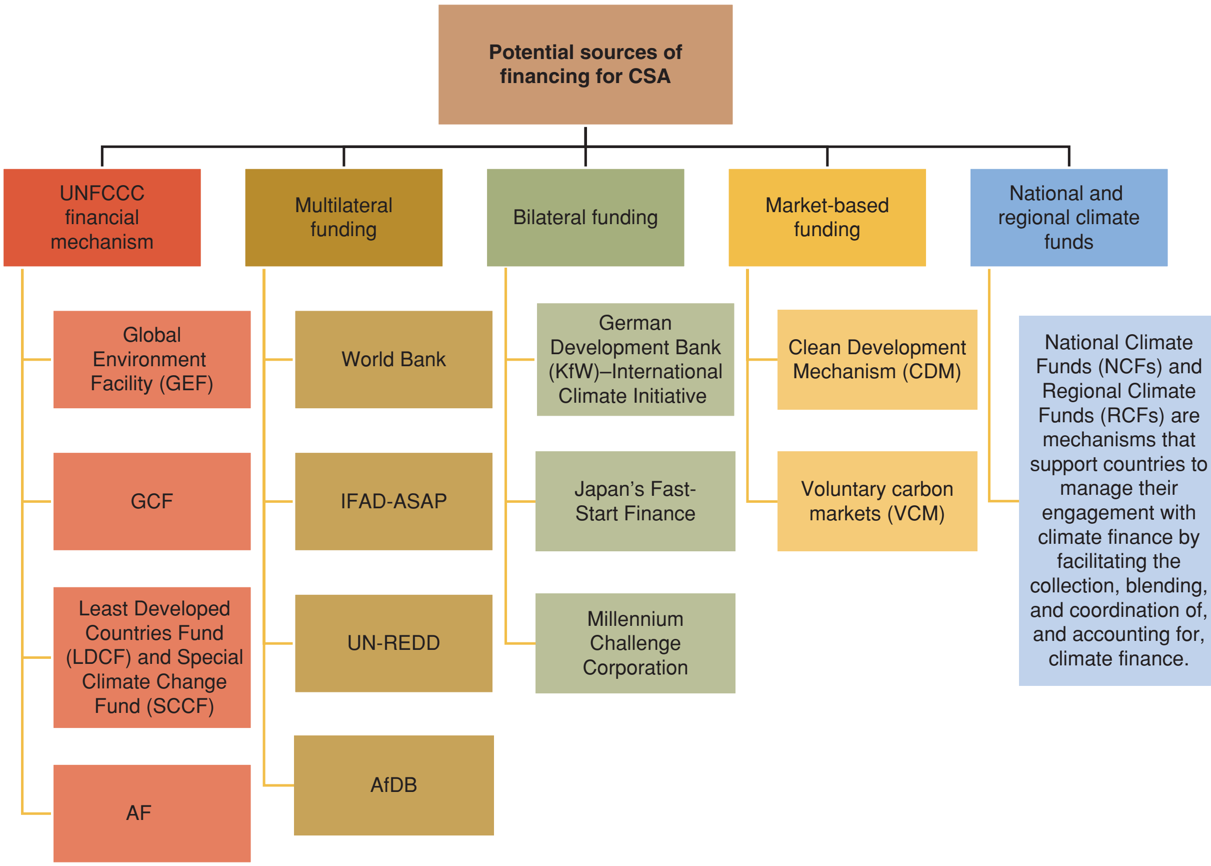
Source: Authors

37. **Lesotho can benefit from climate finance given its vulnerability to climate risks.** Climate finance refers to all financial flows that help achieve climate change adaptation and mitigation objectives. It can be instrumental in supporting Lesotho's agriculture sector in three main ways. The first way is meeting the gap in financing or increasing the attractiveness of an investment to leverage financing from other sources. The second way is reducing risks associated with an agriculture project either by reducing the overall financing requirement or through providing climate finance in the form of risk mitigation instruments, such as guarantees. The third way climate finance could support Lesotho's agriculture sector is using it to finance interventions that systematically reduce the transaction cost associated with CSA at the sector level. The sources of climate finance can be public, multilateral, bilateral or private (figure ES.12), but for climate finance to be effective in achieving its goals, strengthening the link between financial institutions and farmers is important.

38. **Lesotho CSAIP may benefit from the use of blended finance, that is, the use of public sector finance to crowd in or scale up private investment for the CSAIP (table ES.14).** Blended finance can be particularly effective in catalyzing investments in sectors where perceived risk is higher than actual risk, which is especially true for new sectors and projects with which investors are unfamiliar. Blended finance can also help deliver enhanced development impacts. In the case of the six delivery mechanisms, the following financing strategies are proposed.

[6] The total cost of existing projects is $142 million with about 42 percent funded by the World Bank.

FIGURE ES.12: SOURCES OF FINANCE FOR CSA IMPLEMENTATION



Source: Adapted from http://csa.guide.

Note: AF = Adaptation Fund; AfDB = African Development Bank; ASAP = Adaptation of Smallholder Agriculture Program; IFAD = International Fund for Agricultural Development; UNFCCC= United Nations Framework Convention on Climate Change; UN-REDD = United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation.

TABLE ES.14: POTENTIAL SOURCES OF FUNDING FOR CSAIP DELIVERY MECHANISMS

Delivery mechanisms	Possible sources of finance
Efficient irrigation technologies and institutions	IFAD, IFC, IDA, set up PPPs with assistance of development partners
Pluralistic extension services and FFS	IFAD, AfDB
Market linkages	IFC, MCC, set up PPPs with assistance of development partners, GCF, other climate funds
Participatory SLM	NDC Partnership, GEF, UNCCD, European Commission, GCF, UNDP
Agricultural research and innovation	BMG, AfDB, IDA
Digital solutions and services	GFDRR, IDA, set up PPPs with assistance of development partners

Source: Authors

Policy recommendations

39. **Scaling up CSA in Lesotho will require changes in policy and environment.** Policy actions to support effective delivery of CSA in Lesotho are outlined below.

1) **Establish nationally owned CSA Program**

40. **CSA requires judicious policy management: proper coordination between agencies across different sectors at central and local levels.** CSA needs to shift beyond development practitioners to involve government agencies more often. Nationally owned climate-smart agricultural policies and action frameworks tend to increase the adoption of CSA technologies. Lesotho's national CSA program should also incorporate sustainable landscape management approaches for better management of agricultural production and ecosystem services. This will involve multidisciplinary teams from agriculture, forestry, soil conservation, water, and rangeland management.

2) **Improve knowledge management systems**

41. **Several climate-smart technologies are knowledge-intensive, and promoting their adoption will require well-designed, inclusive, and innovative knowledge management systems.** The priorities are to strengthen farmers' knowledge of CSA practices, facilitate sharing the techniques, and provide the greatest support to local and indigenous knowledge systems, such as the Machobane Farming System. This will result in more robust knowledge systems and farmer-led approaches. The use of co-learning and co-management strategies involving scientists and farmers is a way to do this. Scientific experts and farmers working closely together will, in turn, lead to mutual accountability.

3) **Foster equitable access to land**

42. **Secure land rights are necessary for climate-smart agriculture, providing incentives for local communities to manage land more sustainably.** Customary land rights and gender equality need to be recognized. Fast, effective, and low-cost approaches involving the use of satellite images, global position systems, and computerized data management technologies to access, register, and administer land rights are needed. Improving land governance—the way land rights are defined and administered—can be the missing link between land availability and sustainable agricultural development.

4) **Establish Strategic Food Reserve Agency**

43. **Lesotho could establish a Food Reserve Agency to support food security policies and social safety net mechanisms.** The Food Reserve Agency would help ensure a reliable supply and meet local shortfalls in the supply of agricultural commodities critical to food security. The Agency can also help the country meet food emergencies caused by drought, floods, hail, or any other natural disasters, manage food storage facilities, stabilize food prices, and provide relevant market information and agricultural credit facilities to small-scale farmers.

5) **Realign agricultural support to promote CSA**

44. **There is a need to realign agricultural support to break adoption barriers and promote CSA.** It is vital that government policies and investments address the demand and supply sides of agricultural input use. Reversing land degradation and improving soil health in Lesotho will require increased but targeted use of fertilizers and other inputs. This, in turn, will require building sustainable private sector-led input markets. However, progress in improving input distribution systems is likely to be unsustainable without strong, effective demand for the inputs. Effective demand can only be assured if farmers have access to reliable markets to sell their products at a profit. Thus, both demand- and supply-side interventions are needed to strategically break the adoption barriers associated with climate-smart practices. Examples of demand-side interventions are improving farmers' ability to purchase inputs and providing them with risk management tools. Examples of supply-side interventions include improving road and rural infrastructure to lower transport costs and developing market information system to reduce information cost.

6) **Strengthen agricultural research and extension**

45. **The goals of climate-smart agriculture cannot be met without policies and initiatives that encourage agricultural innovations and research, and establish stronger linkages between farmers, climate-smart supply chains, and markets.** There is need to strengthen research and establish partnership with CGIAR and other international research institutes to develop high-yielding, stress-tolerant, climate-ready varieties that are adapted to Lesotho's environment. Development of heat-tolerant varieties is of importance given the projected increase in

warming for Lesotho. Agricultural extension services should be upgraded to catalyze the agricultural innovation process and bring the actors together, coordinate and create networks, facilitate access to information, knowledge and expertise, and provide technical backstopping.

7) **Create enabling environment for private sector**

46. **Introducing policies and incentives that provide an enabling environment for private sector investment can increase overall investment.** Public investment can be used to leverage private investment in research and development, establish agroforestry, promote afforestation, and develop improved seeds and seedlings. Bundling agricultural credit and insurance together and providing different forms of risk management—such as climate information services, index-based weather insurance, or weather derivatives—are areas of private investment that can be encouraged through public policy and public-private partnerships.

8) **Build capacity to access climate finance**

47. **Lesotho faces a financing gap in the agriculture sector with low capacity to access climate finance.** Critical areas that need capacity development include identifying funding gaps and needs; assessing public and private financing options; developing payment for ecosystem services programs; developing bankable investment plans, project pipeline, and financing propositions; and developing financially viable opportunities for effective private sector engagement.

Table ES.15 provides information on specific measures under each policy option, responsible authorities, and time frame for implementing the measures.

CSA and the World Bank agenda in Lesotho

48. **Scaling up CSA has been a focus of the World Bank's work throughout much of the developing world, and many of the lessons gleaned from one region apply to others.** It is an integral part of development partners' larger agriculture work program in the country. This larger work program includes the Smallholder Agriculture Development Project (SADP) supported by the World Bank and the International Fund for Agricultural Development (IFAD) which is designed to enhance climate resilience and promote commercialization and nutrition diversity. SADP is also supporting the development of an irrigation master plan to assist the government in its efforts to define strategic priorities for improving the irrigation subsector. The Master Plan will identify a pipeline of high priority irrigation investments for support from government, private sector, and other development partners. The World Bank is also supporting the Agriculture Productivity Project for Southern Africa (APPSA) that seeks to increase the availability of CSA technologies to farmers in Lesotho in addition to establishing the Center of Excellence in horticulture in Southern Africa. IFAD is financing the Wool and Mohair Promotion Project (WAMPP) with the goal of boosting the economic and climate resilience of poor, smallholder wool and mohair producers to adverse effects of climate change in the Mountain and Foothill Regions of Lesotho. The European Union recently produced a set of reports for Integrated Catchment Management in Lesotho. The reports covered catchment development plans, institutional settings, and legal issues for effective catchment management. The Millennium Challenge Corporation (MCC) is also supporting Lesotho to build institutional capacity in the use, uptake and customization of data to enhance effective policy planning, coordination, and execution in different sectors including transport, irrigated agriculture, climate change, integrated catchment management, water, and health. The activities aim to build capacity in Lesotho's government agencies in cooperation with research centers, private sector and civil society organizations. The Private Sector Competitiveness and Economic Diversification Project (PSCED) supported by the World Bank is assisting Lesotho in building an enabling business environment, leveraging private investment support, providing access to finance to increase productivity, and increasing market opportunities in Lesotho's horticulture subsector. In addition, the World Bank has supported analytical work to identify strategies to unlock the potential of Lesotho's private sector in creating jobs and improving the competitiveness the horticulture subsector as well as another analytical work that specifically deals with linking smallholder vegetable farmers to markets. Another aspect of World Bank's work program is the Lesotho

TABLE ES.15: LESOTHO CSA POLICY MEASURES AND TIME FRAME FOR IMPLEMENTATION

	Time frame	Responsible authorities
Establish nationally owned CSA Program		
(i) Establish Lesotho CSA Program to guide implementation of CSA and landscape approaches, strategies, practices and technologies	Short	Department of Planning and Policy Analysis of the Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Forestry, Range, and Soil Conservation
(ii) Update irrigation policy and support policy planning for mainstreaming CSA	Medium	Department of Planning and Policy Analysis of the Ministry of Agriculture and Food Security
(iii) Introduce evidence-based policies and institutional strengthening for CSA	Short–Medium	Department of Planning and Policy Analysis of the Ministry of Agriculture and Food Security
Develop knowledge management system		
(i) Establish CSA Knowledge Portal	Medium–Long term	Department of Agricultural Research; Department of Crop Services; Department of Livestock all of the Ministry of Agriculture and Food Security; Lesotho Meteorological Services; National University of Lesotho
(ii) Promote inclusive Climate Information Services and Advisories Dissemination Platform	Medium–Long term	Department of Field Services; Lesotho Meteorological Services; Ministry of Science and Communications; ICT Service Providers
(iii) Document MFS practices and integrate with modern science	Short	Department of Field Services; Department of Agricultural Research; Machobane Agricultural Development Foundation; National University of Lesotho
Foster equitable access to land		
(i) Develop cost-effective approaches for managing land rights	Medium	Land Administration Authority
(ii) Document different types of land rights supported by stakeholders	Medium	Land Administration Authority
(iii) Identify opportunities for commercial farming	Short	Land Administration Authority; Department of Soil and Water Conservation; Lesotho National Development Corporation
(iv) Link land rights to land suitability, soil carbon and other key parameters of land use using satellite imageries	Medium	Land Administration Authority; Department of Soil and Water Conservation
Establish Strategic Food Reserve Agency		
(i) Set up Food Reserve Agency and define functions: administer the strategic food reserves, facilitate market development, and manage warehouse/storage facilities	Medium	Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Finance; National Disaster Management Authority
(ii) Awareness building on the role of the Agency	Short	Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Finance; National Disaster Management Authority
(iii) Build and manage warehouses and storage facilities for national seed and grain reserve	Medium–Long	Ministry of Agriculture and Food Security; National Disaster Management Authority
(iv) Subsidize seed and grain storage for qualifying farmers	Long	Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Finance; National Disaster Management Authority

(continued)

TABLE ES.15: (Continued)

	Time frame	Responsible authorities
Realign agricultural support to promote CSA		
(i) Policy reform to align agricultural support to promote CSA	Short	Ministry of Agriculture and Food Security; Ministry of Planning; Ministry of Finance
(ii) Establish inputs e-voucher system	Short–Medium	Ministry of Agriculture and Food Security; Ministry of Planning; Ministry of Finance
(iii) Develop market information systems to reduce information costs	Short–Medium	Department of Field Services of the Ministry of Agriculture and Food Security; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
Strengthen agricultural research and extension		
(i) Establish partnership with international research institutes and develop high-yielding, stress-tolerant, climate-ready varieties	Long term	Department of Agricultural Research, Department of Field Services, all of the Ministry of Agriculture and Food Security; Lesotho Agricultural College, Ministry of Agriculture and Food Security; National University of Lesotho
(ii) Upgrade agricultural extension services to facilitate access to information and improved technical backstopping	Short–Medium	Department of Field Services, Department of Agricultural Research, Ministry of Agriculture and Food Security
Create enabling environment for private sector		
(i) Introduce policies and incentives that provide an enabling environment for private sector investment	Short	Ministry of Agriculture and Food Security; Lesotho National Development Corporation; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
(ii) Encourage private financial service providers to tailor instruments that enable farmers who adopt CSA practices to overcome adoption barriers	Medium	Ministry of Agriculture and Food Security; Lesotho National Development Corporation; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
(iii) Promote PPP and design innovative risk management products (bundling credit and weather index insurance)	Medium–Long term	Ministry of Agriculture and Food Security; Lesotho National Development Corporation; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
Build Capacity to Access Climate Finance		
(i) Build capacity to identify funding gaps and needs; assess public and private financing options	Long term	Ministry of Agriculture and Food Security; Ministry of Finance; Ministry of Development Planning
(ii) Develop financially viable opportunities for effective private sector engagement	Long term	Ministry of Agriculture and Food Security; Ministry of Finance; Ministry of Development Planning
(iii) Develop results-based financing/payment for ecosystem services programs	Long term	Ministry of Agriculture and Food Security; Ministry of Finance; Ministry of Development Planning

Source: Authors
Note: Short term = 1–2 years; Medium term = 2–5 years; Long term = greater than 5 years

Agriculture Public Expenditure Review designed to identify measures to improve the quality of public expenditures in agriculture. CSA through agroforestry, integrated soil fertility management, and conservation agriculture (CA) is a focus of an important World Bank partnership with the International Center for Tropical Agriculture (CIAT) and other partners to support the incorporation of CSA into national planning through the Lesotho CSA Profile. These together are part of the larger context of this work on the CSAIP in Lesotho.

I.

Introduction

49. **The Kingdom of Lesotho is a small, mountainous, landlocked country in Southern Africa with a population of 2.2 million.** It is one of the poorest countries in Southern Africa, with high levels of poverty and inequality. Income inequality in Lesotho is among the 20 percent highest in the world (World Bank, 2019). An estimated 49.7 percent of the population lives below the national poverty line, and 24.1 percent fall below the extreme poverty line (Government of Lesotho, 2019). Rural areas, heavily dependent on subsistence and semi-subsistence agriculture, account for 66 percent of the population and 80 percent of all people living below the poverty line (World Bank 2019). A wide (22 percent) poverty gap, high rates of unemployment, wide prevalence of human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS), and climate vulnerability further constrain the scope for inclusive growth and improvements in living standards. Gross domestic product (GDP) per capita is estimated at US$1,181 (2017) and when adjusted by purchasing power parity is equivalent to 16 percent of the world's average. The country is an open economy, traditionally centered on trade, with textiles, water, and diamonds as its main exports. Lesotho is a member of the Southern African Customs Union (SACU), the Southern African Development Community (SADC), and the Common Monetary Area all of which create strong opportunities for regional trade. As a member of the Common Monetary Area, its currency is pegged to the South African rand.

50. **Lesotho has prioritized agriculture as one of the key pillars for economic growth.** Realizing the inherent unsustainability of its economic model, Lesotho has endorsed a new template for development. The recently completed National Strategic Development Plan (NSDP) II 2018/19–2022/23 seeks to pursue inclusive, sustainable growth and private sector-led employment creation. The Government of Lesotho (GoL) has identified four productive sectors, namely agriculture, manufacturing, tourism and creative industries, and technology and innovation as potential sectors for job creation and inclusive economic growth under a new growth path led by the private sector.

51. **Agriculture plays a significant role in Lesotho's economy.** Over 70 percent of the country's population lives in rural areas and depends, directly or indirectly, on agriculture for employment and livelihood. The sector has potential to increase food security, reduce rural poverty, and generate both on- and off-farm employment opportunities. Main crops include maize, sorghum, and wheat which are planted as monocrops on 85 percent of the country's arable land which comprises 10 percent of Lesotho's total land area. Livestock contributes 75 percent of the total agricultural output, including semi-intensive and intensive production of pigs and poultry, as well as extensive (free range) production of goats and sheep on rangelands in the foothills and highland areas. Sheep and goats, which dominate the livestock sector, are reared mainly for wool and mohair.

52. **Lesotho's agricultural output is one of the lowest in Southern Africa, hampered by underperforming yield, limited arable land, and suboptimal input use.** Average maize yield in Lesotho is about 0.7 ton per ha, less than 20 percent of the Southern African average of 4.2 ton per ha. Lesotho's agricultural sector suffers from low levels of productivity and commercialization which has made the country heavily dependent on food imports to meet domestic consumption needs. Despite 70 percent of the rural population being engaged in some form of agricultural activity, the sector contributes only 6 percent to the national GDP. The farming system is characterized by limited

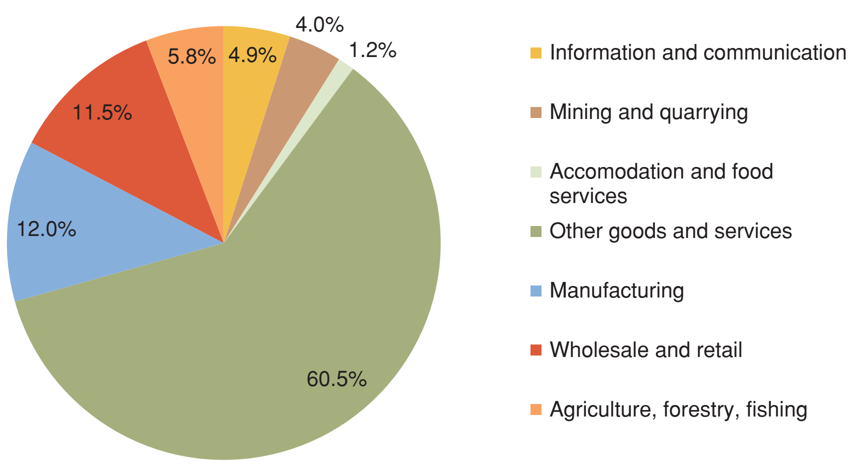
diversification[7] (primarily cereal production) and extensive livestock grazing. Productivity challenges in the sector include limited size of arable land[8] with land holding less than 1.0 ha for several farming households, outdated farm technologies and farm management practices, limited technical expertise, and suboptimal use of inputs. About 32 percent of farming households use inorganic fertilizers, while the application of insecticides is even lower (8 percent). Less than 2 percent of the country's arable land is irrigated, implying strong reliance on rainfed crop production that limits the growing season and yields. Weak rural infrastructure, a rudimentary rural advisory system, and limited access to credit and investment capital further compound agricultural productivity.

The 2018 Household Budget Survey/ Continuous Monitoring Survey (HBS/CMS) shows that only 5 percent of farming households took loans for agricultural activities such as purchase of inputs or equipments, with neighbors (47 percent), money lenders (21 percent), and relatives (11 percent) as the predominant sources of loans for the farming households. Commercial banks provided the highest average amount of loan for farming activities (US$2650), followed by insurance companies (US$875), and money lenders and microfinance institutions that each provide an average loan of US$465.

53. **Lesotho is traditionally a net importer of food and agriculture products.** The country is highly reliant on food imports from neighboring South Africa, and only wool and mohair make a significant contribution to exports and national incomes. Between 2009 and 2013, wool contributed about 55 percent to the total agricultural exports on average, wheat flour 25 percent, and maize flour 11 percent. The value of total agricultural exports for crops and livestock on average over 2009–2013 was US$6.6 million. From 2012 to 2016, imports of food and agriculture products increased at a compound annual growth rate (CAGR) of 14.7 percent, from US$220 million to US$380 million. During this period, exports increased at a CAGR of 77.9 percent, from US$4 million to US$38 million. Although growth of exports outpaced imports over the same period, in terms of absolute value, imports were 10 times larger than exports. Given this trend, the food and agriculture products trade balance has also increased, recording a CAGR of 12.2 percent from 2012 to 2016. Lesotho's negative food trade balance as of 2016 was US$342 million.

54. **Climate change poses major challenges to the development of Lesotho's agricultural sector.** The Inter-governmental Panel on Climate Change (IPCC) categorizes Lesotho as one of the countries highly vulnerable to the impacts of climate

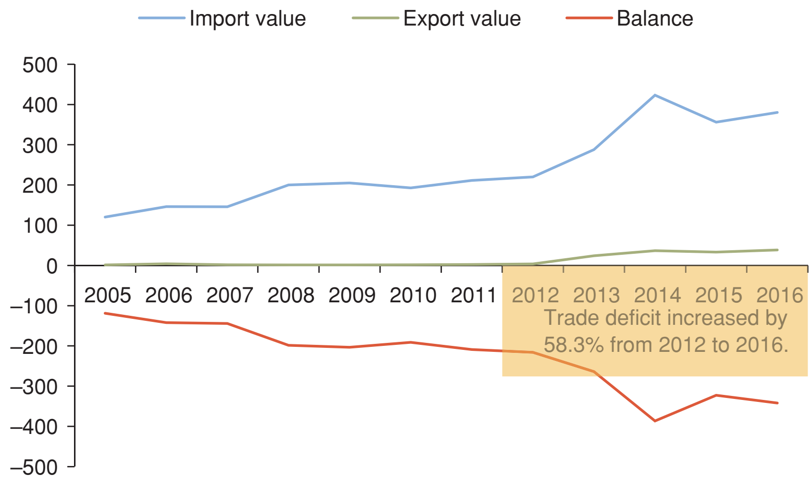
FIGURE 1.1: SECTOR-WISE PERCENTAGE CONTRIBUTION TO LESOTHO GDP



Source: National Accounts of Lesotho 2007–2016 (No 31:2017)

[7] Diversification typically refers to strategies and techniques to produce different agricultural products (horizontal diversification), engage in multiple value-added activities (vertical diversification), or exit the agricultural sector and engage in nonfarm activities.
[8] While the agricultural land area of 2.36 million ha accounts for 78 percent of the total land area, only 357,000 ha (12 percent) is suitable for crop production. Most agricultural land is mountain pasture, suited for extensive livestock production—which accounts for 75 percent of the total value of agricultural output (Food and Agriculture Organization Corporate Statistical Database [FAOSTAT]).

FIGURE 1.2: LESOTHO FOOD AND AGRICULTURE TRADE BALANCE (US$, MILLIONS)



Source: FAOSTAT

change. The country has a temperate climate with subalpine characteristics and experiences regular droughts, floods, frosts, snow, hailstorms, and strong winds. The El Niño-Southern Oscillation (ENSO) phenomenon particularly affects the climate variation in Lesotho (World Bank Group 2016). High intraseasonal and interannual rainfall variability, with frequent droughts, has often resulted in delayed planting or farmers not planting at all, reduced seed germination due to hardened soil and lack of water, crop failures, deterioration of rangelands and pastures, water scarcity for livestock, and increased food prices of staple grains such as maize (CIAT and World Bank Group 2018). Chronic droughts have also negatively affected the livestock sector, resulting in rangeland degradation and limiting the carrying capacity of pastoral land.

55. **Drought, severe frost, excessive rainfall, and pests and disease outbreaks are key production risks leading to average annual losses of US$28 million, corresponding to 2 percent of Lesotho's GDP.** Production shocks have considerable impacts on household and national food security and an overall destabilizing effect of the economy. The drought of the 2015–16 growing season was the most severe on record putting over 534,000 people at risk of food insecurity. The current rain-fed crop production system with its focus on maize at the expense of diversification to more drought-tolerant crops (sorghum, millet, and cowpeas) increases vulnerability to climatic shocks. The crop production system also makes limited use of climate-smart agriculture (CSA) technologies such as new varieties, conservation agriculture (CA), intercropping, integrated pest management (IPM), and water harvesting technologies, all of which limit productivity.

56. **Lesotho is also a hotspot of severe land degradation.** The annual cost of land degradation in Lesotho is estimated at US$57 million, equivalent to 3.6 percent of the country's GDP.[9] Massive soil erosion and loss of scarce agricultural land have resulted in extremely low agricultural productivity levels: average sales of agricultural output are US$195 while average profits are US$132 per growing season. Cereal yields average less than 1 ton per ha, failing to meet the SADC Regional Indicative Strategic Development Plan (RISDP) target of achieving at least 2,000 kg per ha (ReSAKSS 2016). Consequently, marketable surplus remains low. The 2018 Household Budget Survey/Continuous Monitoring Survey (HBS/CMS) shows that only 1 percent of farming households in the poorest quintile produce primarily for sale compared to 5 percent in the wealthiest quintile. Urban farmers are twice as likely to produce for sale compared to rural dwellers, indicating the importance of proximity to markets and access to credit in farmers' commercial orientation. Furthermore, literacy level markedly influence farmers' commercial orientation with only

[9] https://www.unccd.int/sites/default/files/inline-files/Lesotho.pdf.

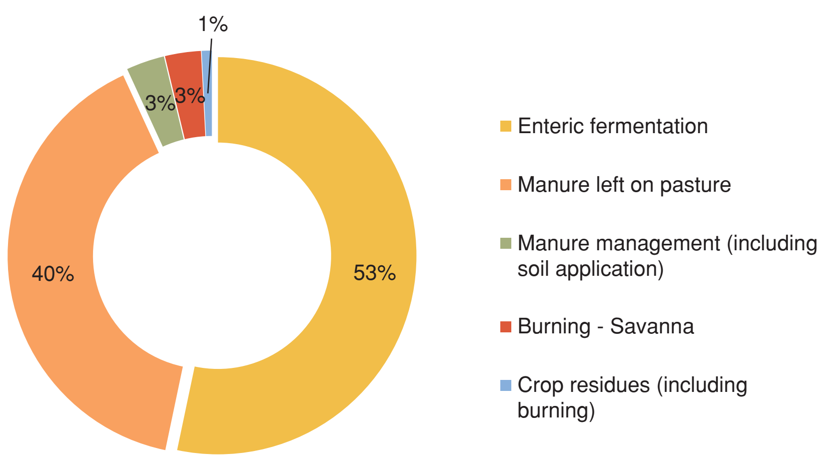
2 percent of farming households without formal education producing primarily for sale compared to 9 percent for farming households with a university education. Low private sector development further constrains commercialization. Private sector activity in Lesotho is dominated by microenterprises, with a marked absence of the small and medium enterprises that drive economic growth and job creation in most countries.[10] The erratic and severe weather patterns and land degradation reinforce the need to mainstream climate resilience in Lesotho's agricultural sector.

57. **The agricultural sector is the second largest greenhouse gas (GHG) emitter in the country accounting for 35 percent of national emissions, while energy (64 percent of national emissions) is the largest emitter.** The total annual GHG for Lesotho, including emissions from land use, land-use change, and forestry is 1.2 million tons of CO_2 equivalent (tCO_2eq) (figure 1.3). Within the agricultural sector, livestock overwhelmingly accounts for most emissions at 93.9 percent of agricultural emissions with cropping accounting for just 6.1 percent of agricultural emissions. Within the livestock subsector, enteric fermentation (53 percent of agricultural emissions) and manure left on pastures (40 percent) are key GHG emitters, while in the crop subsector, savannah burning for agricultural purposes (3 percent) is the largest emitter.

58. **Lesotho is undertaking critical measures to build a commercial and climate-resilient agricultural sector.** Recognizing the significant role of agriculture in its overall economic growth agenda, NSDP II (2018/19–2022/23), which prioritizes the development of the agricultural sector, identifies three broad areas of strategic action: (a) sustainable commercialization and diversification of agriculture, (b) a well-functioning agri-food system, and (c) rehabilitation of rangelands and wet lands. Priorities for action within these areas include (a) improved technology and infrastructure (including irrigation and CSA), (b) increased production of high-value crop and livestock products, (c) the development of institutional frameworks for producer and industry organizations, (d) building the capacity of farmers to benefit from these institutions, and (e) the development of value chains and agricultural markets. The NSDP II also calls for scaling up current nutrition systems toward strengthening human capital and expanding the use of water harvesting for irrigation. Gender and climate change are indicated as critical cross-cutting issues.

59. **Several policies and strategies, including Vision 2020, National Climate Change Policy (2017), Lesotho Food and Nutrition Policy (2016), and Lesotho Zero Hunger Strategic Review (LZHSR) accord high priority to scaling up climate-smart**

FIGURE 1.3: LESOTHO AGRICULTURE GHG EMISSIONS SOURCES (100% = 1.224 MILLION tCO_2eq)



Source: FAOSTAT.

[10] A survey of registered business enterprises in 2015 shows that of the 9,625 registered business enterprises, 75.6 percent were microenterprises (1–4 employees) and 37.5 percent had a turnover of less than LSL 1 million (approximately US$70,000). Only 15 percent of the enterprises surveyed were small to medium (5–50 employees), and only 4.3 percent had a gross revenue of LSL 1–5 million (US$70,000–350,000). This pattern is even more evident in agro-processing and agribusiness. Five large enterprises dominate the food and beverage sector, with few medium-size enterprises or microenterprises.

practices and actions to promote agricultural adaptation and increased food security, achieving zero hunger by 2030, ensuring access to adequate food and healthy diets all year round, ending malnutrition, doubling smallholder productivity and incomes, and eliminating food loss and waste (table 1.1).

60. **The World Bank and other development partners have provided substantial support to the development of Lesotho's agriculture sector over the past decade.** Through the first phase of the Smallholder Agricultural Development Project (SADP) co-financed with IFAD, as well as Private Sector Competitiveness and Economic Diversification Project (PSCED), the World Bank has provided financial and technical assistance to improve commercialization and competitiveness. SADP is providing training and competitive grants to smallholder farmers for improving marketable surplus in several value chains, including horticulture (fruit and vegetable production), poultry, piggery, and dairy. The project is also supporting the development of an irrigation master plan to assist the government in its efforts to define strategic priorities for improving the irrigation subsector in terms of alignment with agriculture growth potential and economic and environmental sustainability objectives. The PSCED is assisting in building an enabling business environment, leveraging private investment support, providing access to finance to increase productivity, and increasing market opportunities in Lesotho's horticulture subsector. IFAD is financing the Wool and Mohair Promotion Project (WAMPP) with the goal of boosting the economic and climate resilience of poor, smallholder wool and mohair producers to adverse effects of climate change in the Mountain and Foothill Regions of Lesotho. The World Bank is also supporting the Agriculture Productivity Project for Southern Africa (APPSA) that seeks to increase the availability of CSA technologies to farmers in Lesotho. In addition, the World Bank has supported analytical work to unlock the potential of Lesotho's private sector in creating jobs and improving the competitiveness the horticulture subsector (World Bank Group 2018b), as well as another analytical work that specifically deals with linking smallholder vegetable farmers to markets (Reva 2019). Another analytical review is the Lesotho Agriculture Public Expenditure Review designed to identify measures to improve the quality of public expenditures in agriculture (Giertz et al. 2019). The World Bank is also working with several development partners in the agricultural sector. The European Union recently produced a set of reports for Integrated Catchment Management in Lesotho. The reports covered catchment development plans,

TABLE 1.1: THE MAINSTREAMING OF CLIMATE CHANGE WITHIN AGRICULTURE-RELATED POLICIES IN LESOTHO

	Climate Change	Productivity	Resilience	Mitigation	CSA
Vision 2020 (2000)	✓	✓	✓		✓
Lesotho National Forestry Policy (LNFP) (2008)	✓			✓	✓
NSDP (2012)	✓		✓		
National Agricultural Investment Plan (NAIP) (2014)	✓	✓	✓	✓	✓
Lesotho's Intended Nationally Determined Contributions (INDC) (2015)	✓			✓	
Lesotho National Nutrition Policy and Strategy (LNNPS) (2016)	✓	✓	✓		
National Seed Policy (NSP) (2016)	✓	✓	✓		
National Climate Change Policy (NCCP) (2017)	✓	✓	✓	✓	✓
Nationally Determined Contributions (NDC) (2017)	✓	✓	✓	✓	✓
LZHSR (2018)	✓	✓	✓		✓
NSDP II (2019)	✓	✓	✓	✓	✓

Source: Based on synthesis of various Lesotho government documents.

institutional settings, and legal issues for effective catchment management. The Millennium Challenge Corporation (MCC) is also supporting Lesotho to build institutional capacity in the use, uptake and customization of data to enhance effective policy planning, coordination, and execution in different sectors including transport, irrigated agriculture, climate change, integrated catchment management, water, and health. The activities aim to build capacity in Lesotho's government agencies in cooperation with research centers, private sector and civil society organizations.

61. **The World Bank has also supported the preparation of the Lesotho CSA Profile, which recommends country-specific CSA practices that can help the country adapt to and mitigate climate change.** The Lesotho CSA Profile documents Lesotho's agricultural context, climate change vulnerabilities and impacts, promising CSA technologies and their current level of adoption, finance mechanisms for scaling up the technologies, and institutional and policy entry points for effective delivery of CSA investments. The CSA Profile is the primary document for policy discussions and for initiating dialogue with the government on the imperatives of CSA prioritization and planning in the country.

62. **This report builds on the CSA Profile by developing a CSAIP that can assist the Government of Lesotho (GoL) in filling knowledge gaps and identifying critical investments to transform Lesotho's agriculture to a productive, resilient, and low-emissions sector.** The main audience of the report is agricultural policy makers and the technical staff working on agriculture and food security and other related programs in the Ministry of Agriculture and Food Security (MAFS) and the Ministry of Forestry, Range and Soil Conservation. In addition, the report can serve as an important reference document for the Ministry of Development and Planning, the Ministry of Finance, and development partners. An earlier version of this report has significantly supported the preparation of SADP II whose development objective is to support the increased adoption of CSA technologies, enhanced commercialization, and improved dietary diversity in Lesotho. The remainder of the report is organized as follows. Chapter 2 describes the approach used in preparing the CSAIP, including the methodology applied at the household and agricultural sector

BOX 1.1: KEY FINDINGS FROM LESOTHO CSA PROFILE

Conservation agriculture (CA) is the most widely promoted climate-smart agriculture (CSA) practice, although other practices such as keyhole gardens, small-scale irrigation, organic manure application and the use of tunnels (greenhouses) are common. Traditional practices that are adapted to local conditions—such as Machobane—also exist and have potential to be integrated into modern CSA practices, hence improving acceptability among rural households.

There is a need to scale up agroforestry in meeting the country's goals related to improving forest cover, while at the same time enhancing the food security, nutrition, and resilience of households. The integration of stone fruits (peaches and nectarines) and other fruit trees into existing cropping systems could be an option.

For livestock production, the main climate-smart practices include fodder production, as well as rangeland rehabilitation and management, but these are practiced at very limited scale. Given the country's energy needs, particularly in off grid rural communities, biogas energy development using livestock manure could be an option. The adoption of improved (including both heat- and cold-tolerant) breeds of cattle, goats and merino sheep will also be important for improving the resilience and productivity of the local production of meat, milk, wool and mohair, while reducing greenhouse gas emissions per unit of produce. At present, the country imports most of its meat and support to a low carbon, more productive and highly resilient meat industry in Lesotho is required. Animal health management and improved veterinary services will also be crucial to improve production quality and enhance resilience of the livestock sector.

levels. Chapter 3 presents the results of an analysis of the financial and economic viability of adopting CSA practices at the household/farm level, while chapter 4 presents the impact of CSA adoption at the sector level and evaluates the extent to which CSA implementation could help achieve Lesotho's CSA goals. Chapters 3 and 4 are the building blocks upon which the investment plan described in chapter 5 is formulated. Chapter 5 also assesses CSA adoption constraints and highlights strategies to break the adoption barriers. The chapter concludes with possible sources of financing for the investment.

II.

Methodology

63. **The CSAIP approach is an integrative framework for supporting a country's agriculture and climate change goals.** It comprises in-depth literature review, stakeholder engagement, expert and key informant interviews, and quantitative modeling, which are encapsulated in four key steps tailored to the country's context. As shown in figure 2.1, Step 1 is the identification of agriculture sector goals and strategies through a process of stakeholder engagement and review of key policy documents. This is followed by Step 2 that entails the development of scenarios through stakeholder consultation, including the identification of critical factors that can interfere with the achievement of goals identified in Step 1. In Step 3, quantitative and qualitative analyses are conducted based on the inputs from Steps 1 and 2. Results of the analyses in Step 3 are used to assess the extent to which Lesotho's CSA goals articulated in Step 1 could be achieved. The final Step 4 evaluates and prioritizes CSA strategies to the specific country's context. The implementation steps are described below.

Step 1: Identify agriculture sector goals, targets, and strategies

64. **A collaborative, stakeholder-driven process took place in Maseru in May and October 2018 to identify visions, goals, and strategies and to prioritize a handful of promising climate-smart technologies and strategies for Lesotho's agriculture sector.** The stakeholders included staff from the Ministry of Agriculture and Food Security, Department of Agricultural Research, Ministry of Forestry, Range and Soil Conservation, Ministry of Water, Ministry of Planning, National University of Lesotho, Lesotho Agricultural College, Lesotho Meteorological Services, Disaster Management Authority, Food and Agricultural Organization of the United Nations (FAO), World Food Program (WFP), Lesotho National Farmers Union (LENAFU) and farmer members, the private sector and civil society organization (Annex 1). The process built on the Lesotho CSA Profile that was also based on detailed consultation across Lesotho's agriculture sector stakeholders and developed a 'normative vision' of the sector factoring in national development plans and targets. Working backward from this normative vision, sector targets and priority strategies were identified that connected the normative vision with the present situation of Lesotho's agricultural sector (table 2.1).

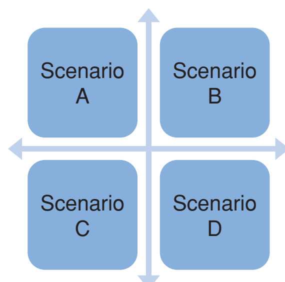
65. **The unique environment of Lesotho necessitates agricultural methods and practices that consider the realities of the relatively dry, high-altitude environment of the country.** Despite the current low agricultural productivity and high influx of food imports into Lesotho, stakeholders felt that the situation could be reversed if policy makers and farmers could commit to diversify production and prioritize commercialization of the agricultural sector. The future of maize production received considerable attention from participants. While fertilizer subsidy contributes 15 percent to maize production, much of Lesotho's agroecology has been found to be unsuitable to produce maize (annex 4). Thus, the cost of maize production in the country is significantly higher than the cost of importation from South Africa. Therefore, diversification from maize to other commodities was among the goals cited by all stakeholders. With proper policies and enough investment in key value chains for which the country has a distinct competitive advantage, the stakeholders felt that Lesotho could be a net exporter of some agricultural products.

66. **The CSA goals articulated by the stakeholders reveal that the roles of agriculture as a source of food security and as a source of environmental**

FIGURE 2.1: THE CSAIP DEVELOPMENT PROCESS

I. Sector Goals and Strategies
Stakeholder consultation and review of policy documents used to identify agriculture sector vision, targets, and strategies

II. Scenario Development
Stakeholder consultation to identify agricultural development pathways and key uncertainties which can impede the achievement of sector goals



III. Quantitative and Qualitative Analyses	
Quantitative analysis: Design Lesotho Agriculture Sector Model (LesAgMod) and determine impacts of CSA on sector goals and indicators: • LesAgMod analysis with no climate change and with climate projections • Outcome Indicators include crop areas, livestock units, yield, production, food availability and trade, soil erosion, pest infestation, GHG emissions, and job creation	Literature review and expert consultation: To assess the enabling environment and innovative delivery mechanisms needed to support CSA adoption
Quantitative analysis: CBA to assess effects of CSA on household-level indicators (gross margins, net margins and net incremental benefits)	Expert consultation to validate assessments

IV. Prioritization and Evaluation
CSA strategies are evaluated according to key indicators including sector and household level impacts. CSA investment needs: • Scaling up CSA and assessing economic costs and benefits; carbon valuation • CSA adoption constraints • Improving the enabling environment for CSA implementation • Financing the investment plan

Source: World Bank

TABLE 2.1: NORMATIVE VISION FOR CSA IN LESOTHO

CSA Pillar	Vision
Productivity	By 2050, increase yields and profits by a factor of 2.5 by diversifying from maize production to other agricultural commodities, while enhancing food and nutrition security.
Resilience	By 2050, have a resilient and diversified agricultural sector with improved and sustainable capacity to respond to climate variability and land degradation.
Mitigation	By 2050, increase agricultural productivity, while simultaneously maintaining low GHG footprint.

Source: Stakeholders consultation workshop.

services converge in fundamental ways (table 2.2). Productivity can be increased through the adoption of climate-smart practices that sequester carbon.[11] The carbon that is removed from the atmosphere and captured in soils and plant biomass is the same carbon that makes agricultural soils more fertile, and that leads to higher profit margins for producers. Higher carbon content enables the soil to make more water and nutrients available to support crop growth and increases the resilience of farmland, reducing both the need for fertilizer applications and susceptibility to land degradation.

67. **The CSA targets that were developed with stakeholders and evaluated in this report focus on increasing agricultural productivity, enhancing resilience, and reducing emissions (table 2.3).** All five targets focus on productivity, the central goal of most agricultural policies, while two targets each focus on enhancing climate mitigation and resilience. In reality, most CSA technologies can generate substantial resilience and mitigation co-benefits if production is well managed (World Bank Group 2018a). A number of strategies were identified as vital to achieving the specified targets. These are clustered into three groups: climate resilience and nutrition security, commercialization, and capacity development strategies (table 2.4).

68. **These strategies were incorporated in the design and are key project activities of the second phase of SADP.** They include proven solutions that increase farm productivity and crop diversification through the adoption of climate-resilient seed varieties (short maturity and drought-, heat-, and pest-resistant species), and market-oriented crops with a clear potential for income security derived from the integration of smallholders to value chains. The strategies also include agronomic practices that enhance climate resilience at the farm and catchment levels and measures to improve soil health through the adoption of climate-smart practices to improve soil fertility and soil nutrient management and promote soil carbon sequestration. In addition, the strategies focus on enhancing water security at the farm level through cost-effective irrigation technologies that foster a more productive and

TABLE 2.2: CSA GOALS FOR LESOTHO

Productivity	Resilience	Mitigation
Increase yields of major staples by a factor of 2.5.	70% of arable land are planted to stress-tolerant crops; 70% of livestock breeds are climate-smart.	Reduce livestock emissions intensity by 25% compared to business as usual.
Increase land area devoted to biofortified crops by 60%.	60% of cropland is under CA and agroforestry; 60% of rangeland is rehabilitated or under improved management system.	CSA practices are adopted by 70% of farmers.
Reduce losses across agricultural value chains including postharvest losses to less than 5%.	Increase forest cover to 10% to total land area.	Increase investment in agricultural research and extension to 10% of agricultural budget.
Increase agricultural exports by a factor of 2.5.	Increase land under irrigation to 70% of irrigation potential.	—

Source: Stakeholders consultation workshop.

[11] Carbon sequestration, the process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils, can help reverse soil fertility loss, limit GHG concentrations in the atmosphere, and reduce the impact of climate change on agricultural ecosystems and people.

TABLE 2.3: LESOTHO CSA TARGETS

No.	Targets for long-term vision	Policies to which targets most closely align	CSA pillars addressed
1	Increase yields of major staples by a factor of 2.5.	NAIP (2014); LZHSR (2018)	P
2	Double income of smallholder farmers.	LZHSR (2018)	P, R
3	Increase agricultural exports by a factor of 2.5.	NAIP (2014)	P, R
4	Reduce agricultural GHG emissions by 25%.	INDC (2015, 2017)	P, M
5	Reduce livestock emissions intensity by 25%.	INDC (2015, 2017)	P, M

Source: Stakeholders consultation workshop.
Note: P = Productivity; R = Resilience; and M = Mitigation.

TABLE 2.4: STRATEGIES FOR ACHIEVING LESOTHO CSA GOALS

Climate resilience and nutrition security	Commercialization	Capacity development
Crop diversification	Agricultural value chain	Agricultural research and extension
Stress-tolerant crop and livestock breeds	Commodity standards	Knowledge development
Biofortified crops	Warehouse receipt system	Integrated weather and market advisories using Big Data and information and communication technology (ICT)
CSA practices at the farm level	Greenhouse agriculture	—
Landscape approaches	Market infrastructure development	—
Cost-effective irrigation	—	—

Source: Stakeholders consultation workshop.

efficient use of water for agriculture, reducing the risks associated with intra- and inter-seasonal climate variability. Biofortification was mentioned as an effective and economical strategy to enhance nutrition security by boosting the content of essential nutrients in crops, particularly staples that sustain Lesotho's population.

69. **Stakeholders acknowledged the need for policy makers and resource managers to manage trade-offs across space, time, and sectors when addressing challenges related to poverty, food security, environmental degradation, and climate change.** The multiple services provided by land interact in complex ways, leading to positive and negative impacts as the production of one ecosystem service increases.[12] Synergy results when the production of more of an ecosystem service leads to more of another, whereas trade-offs, the more frequent outcomes, occur when the production of one ecosystem service decreases the supply of another. Conversion to agricultural land presents a trade-off to society because the same land that is used for providing essential food, feed, fiber, and biofuels could store large amounts of carbon in soils and biomass in its natural state and thus mitigate climate change. Globally, the expansion of croplands to satisfy the needs of a growing population with changing diets is causing a costly loss in carbon stocks in natural vegetation and soils (West et al. 2010).

70. **Agriculture in Lesotho has suffered major setbacks due to overreliance on rainfall, which is insufficient in most areas.** Provision of irrigation is critical for addressing climatic risks in Lesotho's agriculture; however, the subsector is beset with challenges. Despite the ready availability of water from the mountains, only 2,600 ha of arable land have been developed for irrigation. Poor management and inadequate maintenance have reduced the area under irrigation, with only an estimated 1,200 ha currently under irrigation. The modernization of national water resource management policies and institutions has been slow, and physical infrastructure has deteriorated due to lack of public funds for maintenance. Many pump stations are no longer operational, and existing headworks and reservoirs have silted up. On-farm irrigation systems have also deteriorated due to ill-defined property rights over infrastructure and weak local capacity for management. There are few effective community-based irrigation management systems and poor links between the existing institutions and the local public institutions responsible for water management. This combination of limited budgetary resources and an inadequate policy and institutional framework hamper the ability to maintain the existing infrastructure as well as expand irrigation. Combating the effects of climate change and increasing productivity toward food security and commercialization will require sustained efforts to provide adequate, reliable, and timely delivery of irrigation to Lesotho's crop and livestock farmers.

71. **Diversifying from cereals monocropping to cereal-legume intercropping and higher-value horticulture can enhance incomes and climate resilience.** Development of high-value cash crops—such as fruits and vegetables and potato, and dairy and small-scale pig and poultry production—offer opportunities for moving from uncompetitive maize monocropping to a more diversified production base, which is more responsive to climatic risks. Lesotho's higher altitude, potential for early season production, and access to cheap water and labor combine to create favorable conditions and comparative advantage for the production and export of vegetables, fruits, and seed potato. Regional demand for fruits and vegetables is increasing as urban populations grow, incomes rise, and the popularity of healthy diets also increases. Higher production and sales of these high-value crops would also deepen domestic agricultural markets, generate rural employment, and improve nutrition. However, as commercial vegetable production currently ranges from 100 ha to 600 ha (depending upon rainfall) and commercial potato production is less than 500 ha, achieving diversification and commercialization will need a much broader base. Government support, private investment, and external financing will be critical for diversification and commercialization.

[12] Ecosystem services refer to the benefits we derive from nature and functioning ecosystems. They are grouped into four broad categories: provisioning, such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as nutrient cycles and oxygen production; and cultural, such as spiritual and recreational benefits (http://www.millenniumassessment.org/documents/document.356.aspx.pdf).

72. **A more diversified production base, with greater emphasis on horticulture and livestock production, also offers a means to increase dietary diversity and reduce child malnutrition.** Lesotho's high rates of child malnutrition are attributed to poverty, low dietary diversity, and inadequate consumption of fruits and vegetables. Limited dietary diversity affects all children—only 23 percent of children have minimum dietary diversity and 11 percent have a minimum acceptable diet. Fruit and vegetable availability were estimated at 128 g in 2013, compared with the World Health Organization (WHO) recommended daily intake of 400 g. Increased horticulture and livestock production would contribute to improved nutrition by (a) increasing the availability of fruits and vegetables as well as protein-rich foods and (b) improving incomes and thereby resources for increased access to a more diverse diet (World Bank Group 2019).

73. **Complementing diversification is the need to improve market access to smallholder farmers.** Smallholder farmers in Lesotho have limited access to profitable, value-added markets, and in the absence of critical supporting functions, such as infrastructure and service provision, they struggle to shift from subsistence farming to more productive forms of exchange. There is need to support horizontal and vertical alliances that would result in the integration of a greater number of smallholder producers in potentially remunerative agricultural value chains, incentivize contract farming, build mutually rewarding partnerships between farmers and private agri-businesses, and drive enterprise operations toward more lucrative domestic and export markets.

Step 2: Scenario development

74. **Scenario development helps define specific pathways to achieve the proposed vision and goals, evaluate those outcomes considering future uncertainties, and then determine resilient and robust outcomes.** It is a stakeholder-driven process to test the plausibility of identified agriculture sector goals and serves as a "reality check" to the outcomes given future uncertainties and other constraints. For instance, the process might ask what a diversified agricultural production system should look like, what types of resources would be needed to achieve CSA goals, and how might climate change and other external factors hinder or support those development pathways.

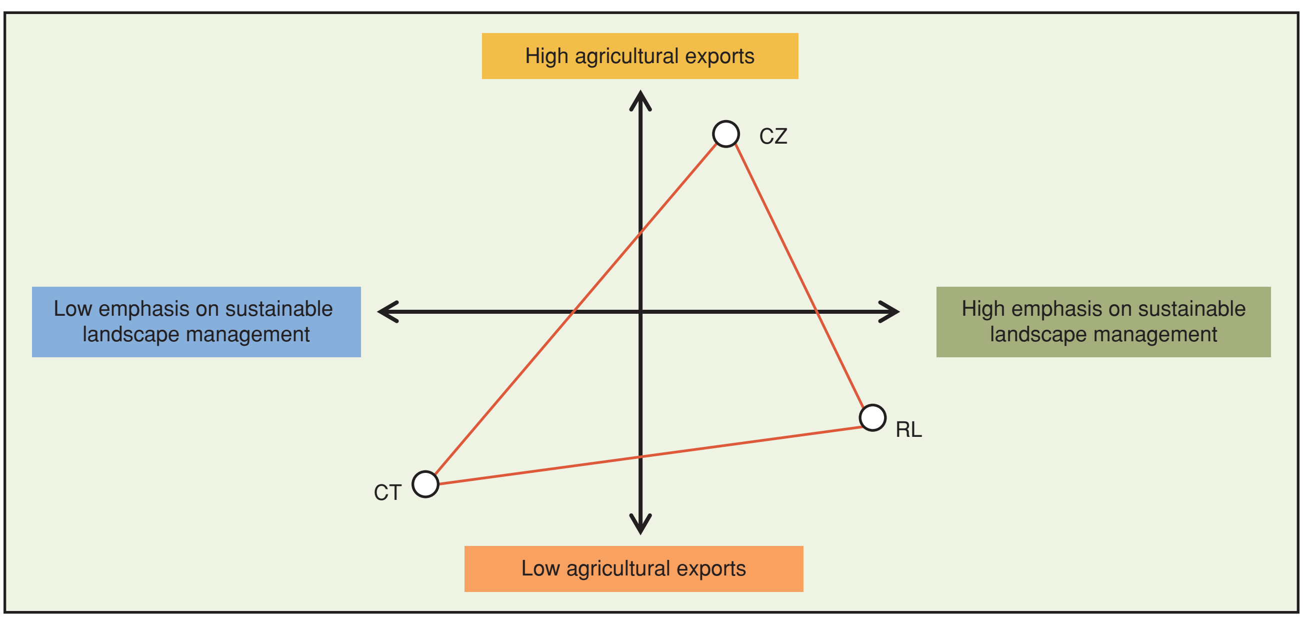
75. **Scenarios are useful tools to explore uncertain futures in socioecological systems, such as the agricultural sector, that typically faces high levels**

of risks and uncertainties. Scenarios differ from predictions, forecasts, and projections in that they describe alternative futures under different sets of assumptions given our current understanding of the way drivers of land use interact to affect the agricultural system. A crucial element of scenarios is the ability to capture both qualitative and quantitative elements that define future conditions. Environmental scenarios typically use narratives to represent qualitative scenario elements. Such narratives provide voice to the qualitative factors that shape development, such as values, behaviors, and the role of institutions, while modeling (Step 3 of the CSAIP process) offers empirically based insights into the subset of socioeconomic and biophysical factors that are amenable to quantification (Raskin 2005). Combining both qualitative and quantitative scenario components, in the form of narratives and empirical modeling results, has become a common approach in global environmental change assessments (Alcamo 2008).

76. **Two major drivers that may influence agricultural development in Lesotho are agricultural trade and sustainable landscape management.** The report developed three land-use scenarios for 2010 to 2050 that consider these main drivers and trends for agricultural land-use change identified during the Lesotho CSA Profile development and stakeholder workshops. The scenarios' definitions were also supported with official statistics and information available from Food and Agriculture Organization of the United Nations (FAO) databases. Narratives are built along two axes of agricultural trade and sustainable landscape development: the first axis represents emphasis on exports versus national food self-sufficiency (and hence low exports), while the second axis depicts short-term economic growth orientation with low emphasis on sustainable landscape management versus long-term economic growth orientation with strong focus on landscape sustainability. Lesotho is surrounded by the Republic of South Africa (RSA), which provides the main context of Lesotho's agricultural sector. Thus, RSA's agriculture and trade policies de facto become Lesotho's policies. South Africa has an open economy with fully liberalized agriculture markets. Due to international market integration, RSA's commercial agriculture sector produces high-quality and relatively cheap goods, which present stiff competition for Lesotho's own products. Any development of Lesotho's agriculture sector will therefore need to be closely aligned with conditions and developments in RSA (GoL 2014).

77. **The CT scenario generally follows the current development pathway and ongoing tendency of market liberalization but with relatively**

FIGURE 2.2: POSITIONING OF SCENARIOS ON THE AXES OF DRIVERS OF AGRICULTURAL LAND CHANGE



Source: Authors based on stakeholders consultation workshop.

low ambition toward sustainable landscape management. A general assumption under the CT scenario is for agricultural land under cultivation to grow through agricultural extensification and for production to keep pace with the current annual population growth rate of about 1.3 percent. The total planted area would grow throughout the study horizon to keep pace with population growth through 2050, with a similar crop and livestock portfolio that is generally observed currently. Such magnitude of agricultural production has been observed in Lesotho in past years and is thus a reasonable target for the CT scenario. The CT is characterized by rainfed subsistence farming, cereals monocropping, extensive livestock grazing, and suboptimal use of modern inputs.

78. **The CT scenario implies continued support for the dominant, historical cropping system generally characterized by maize monoculture, where there is an assumption that the land under crop production has an increasing trend to keep up with population growth.** To achieve this outcome, price support and subsidy must increase, and this implies an increasing social cost. In this scenario, maize, wheat, sorghum, and beans continue to be the primary crops, while sheep and goat production for wool and mohair remain vital. Agriculture continues to be dominated by small-scale rain-fed cereal production and extensive animal grazing. The contribution of the animal sector remains about double that of the crop subsector. Despite the prevalence of these agricultural practices, it is generally considered unsustainable and insufficient to feed the country's population, implying a high social cost. Vegetable production continues to be mostly subsistence, with home gardening of rural households estimated at more than 70 percent. Most home gardens are rain-fed but supplemented with irrigation from household or community domestic water supplies. Total cropped area increases from about 195,000 ha in 2010 to about 210,000 ha by 2050. Food imports continue to be important to meet consumer demands, and improved food self-sufficiency targets are mostly unmet. Two other scenarios deviate from the CT scenario and are referred to as the CZ and RL scenarios.

79. **The CZ scenario even prioritizes a high degree of market liberalization following trends in neighboring RSA and taking into consideration agricultural commodities for which Lesotho has distinct comparative advantage.** The proximity to RSA provides a great market opportunity for Lesotho, as RSA is the source of foreign direct investment while also providing access to modern technology and markets. Furthermore, the free trade environment within SACU—the biggest market in Africa—makes Lesotho relatively attractive to regional and global companies seeking access to regional markets. The scenario assumes high ambitions for international cooperation, market liberalization, and increased agricultural exports as a main strategy to graduate from the United Nations (UN) ranking of least developed countries.

80. **A main strategy under the CZ scenario is to enhance regional integration.** Closer regional integration with SADC members should help Lesotho remove some supply-side constraints by enlarging markets, generating economies of scale in agriculture research and policy development and public good provision, and facilitating greater trade integration with the global economy (NSDP 2012). The scenario implies a reduction in price support for field crops, notably maize, where deficits are assumed to be met by imports, supported through investments in more profitable commodities, most notably potato, vegetables, and orchard products on the crops side and animal products on the livestock side of agriculture. Given the high production costs of these more commercially viable commodities (potato, orchards, and vegetables), the expansive use of land for growing grain crops—most notably maize—is put in check.

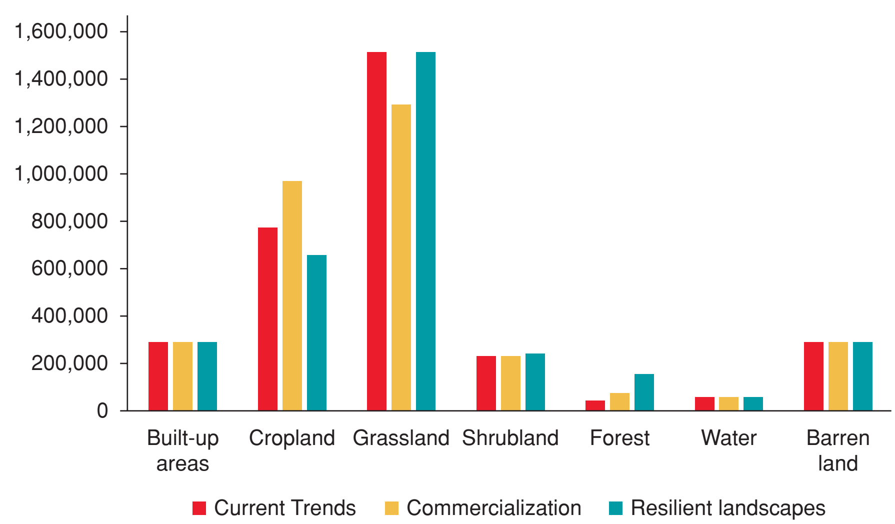
81. **In contrast, the RL scenario assumes a lower priority to market liberalization but prioritizes a land management system that empowers smallholders with ambitions toward sustainability, socioeconomic resilience, and low ecological impact from economic growth.** Improvements in agricultural productivity will not be possible unless stern efforts are made to reduce land degradation and associated loss of natural resources. Indigenous knowledge (IK) is increasingly recognized as important in developing mitigation and adaptation strategies for climate change. Thus, the RL scenario focuses on integrating scientific knowledge with Machobane Farming System (MFS), a traditional farming practice with high adaptability

and resilience to climate change. MFS is an intensive cropping system, using crop rotation, relay cropping, and intercropping practices with the application of manure and plant ash to conserve soil moisture and replenish soil fertility (Mekbib et al., 2011). MFS is based on five technical principles that are rooted in sustainable ecological intensification: perennial vegetation cover, cropping pattern adapted to the varying climate, use of organic fertilizers, natural pest control, and relay intercropping that allows for staggered harvesting of crops throughout the year. Production practices that conserve soil while improving its structure and fertility are prioritized. High yielding, pest resistant varieties are introduced. Similarly, incentives are provided that enable livestock owners to adopt climate-smart livestock technologies and rangeland management practices. Complementing rangeland resources management with improved fodder production helps relieve pressure from overstocked and overgrazed rangelands under the RL scenario.

82. **A main strategy to graduate from the least developed country status under the RL scenario is supporting smallholders, investing in sustainable landscape management, and building institutions to enhance landscape resilience.** The scenario identifies and builds upon local practices and incorporates modern scientific knowledge to adapt and improve the practices to meet new and emerging challenges under climate change. RL scenario implies more balanced cereal production, with maize still grown, but with an emphasis also on the drought-tolerant attributes of sorghum. Winter wheat still is important, but there is more balance with other crops such as potato, vegetables, and orchards. This scenario, too, implies a drastic reduction in cropland area with more emphasis on sustainable intensification of agriculture.

83. **Within the context of Shared Socioeconomic Pathways (SSPs),[13] the CT scenario corresponds to SSP2, a "middle of the road" pathway where trends broadly follow their historical patterns; the RL scenario parallels SSP1, a "taking the green road" pathway of sustainability—focused growth and equality; and CZ resembles SSP5, a "taking the highway" pathway of rapid and unconstrained growth in economic output and energy use.** The scenario narratives have been translated into demand for land use and land cover based on a variety of data, including statistical information from the Lesotho Bureau of Statistics, information from various agricultural plans from government ministries, stakeholder consultation,

FIGURE 2.3: PROJECTED DISTRIBUTION OF NATIONAL LAND COVER BY 2050 (HA)



Source: Authors

[13] SSPs were formulated by global environmental change researchers to capture a set of plausible potential future socioeconomic developments that could shape the future in the absence of climate change and climate policies (O'Neil et al. 2017). These socioeconomic developments are used to explore how societal choices will affect GHG emissions and, therefore, how well the goals of the Paris Agreement could be met.

and peer-reviewed literature. The demand for built-up area was based on UN projections of average annual urbanization rate of 2.85 percent for all scenarios. Water and barren land were kept static for all the scenarios. Grassland is projected to decline under the CZ scenario but occupy the same extent under the CT and RL scenarios. The management regime under the latter will however be improved with climate-smart practices. The overall impact of land management is expected to lead to an increase in forest cover to 2.5 percent of total land area under the CZ scenario and 5 percent under the RL scenario. Currently, maize monocropping is a prevalent system but is unsustainable and insufficient to feed the country's population. Thus, productive diversification from maize to other crops and livestock is an important strategy under both the CZ and RL scenarios. Despite an increase in available cropland for the CZ scenario, the shift away from land-intensive production of maize as a smaller share of total planted area means that degraded rangeland can be restored and perhaps can accommodate other production systems, such as silviculture and agroforestry. The full sets of assumptions for computing the land covers under the scenarios are presented in annex 2. The proportions of cropland occupied by major crops grown in Lesotho are dictated by the objectives highlighted in the narrative scenario. The relative proportion of crops is assumed to remain as current under the CT scenario but deviates substantially for the CZ and RL scenarios due to diversification from maize.

Step 3: Quantitative and qualitative modeling

84. Quantitative modeling was performed to assess the productivity and climate benefits of CSA at household and sectoral levels under a changing climate. This step combined two quantitative approaches—cost-benefit analyses (CBAs), a bottom-up, farm-level perspective that assesses the desirability of CSA technologies and practices at the household and farm levels, and the development of the Lesotho Agricultural Sector Model (LesAgMod) that takes a countrywide, spatial perspective to assess the potential impacts of CSA technologies on the achievement of agriculture sector goals. The quantitative modeling was further supplemented with qualitative assessment of CSA adoption factors in the country.

CBAs for assessing the financial and economic profitability of CSA

85. The CBA includes a financial and economic analysis to determine the profitability of adopting CSA at the household and sectoral levels. The analysis provides answers to two key questions:

1) **What is the financial viability of CSA practices for a household?**
2) **How do the anticipated costs needed to scale up CSA compare to the anticipated economic benefits?**

86. A financial analysis was undertaken to determine financial viability and incentives for an average household to adopt CSA. This was done by assessing the net incremental benefits accruing to a household following the adoption of CSA practices compared to maintaining the conventional farming practices. Second, an economic analysis was used to assess the economic and societal benefits of adopting CSA and to establish the economic rationale for the public sector to support farmers' adoption and scaling up of CSA. Indicators for the CBAs are presented in table 2.5.

87. Additional analyses were carried out to assess the economic benefits for households adopting CSA, public good benefits accruing from climate mitigation, and the expected public sector investments to effectively scale up CSA in Lesotho. For the economic analysis, households' financial net incremental benefits were evaluated at economic prices and aggregated across the projected number of CSA adopters. To assess the public good benefits, EX-ACT was used to evaluate the climate mitigation potential of CSA technologies. EX-ACT enables calculation of the net carbon balance, that is, the difference between gross GHG emissions under conventional practices and gross emissions under CSA practices. The net carbon balance was then valued at low and high shadow prices of carbon (LSP and HASP, respectively) to express climate mitigation in monetary terms.[14] The shadow price

[14] http://globalpractices.worldbank.org/climate/SitePages/Greenhouse%20Gas%20Accounting%20-%20Shadow%20Price%20of%20Carbon.aspx.

TABLE 2.5: OUTCOME INDICATORS OF THE CBA

Indicator	Definition
Financial analysis	
Gross margins	Gross margins represent total revenues from crop production minus total production or variable costs excluding labor.
Net margins	Net margins are calculated as the gross margins, but factor labor costs into total production costs.
Net incremental benefits of adoption	This represents the expected financial returns for households generated by the adoption of CSA activities as compared to conventional farming methods.
Economic analysis	
Net carbon balance	The net carbon balance is the difference between GHG gross fluxes under CSA adoption and under conventional farming practices. Results are given in tCO_2eq. Positive numbers represent sources of CO_2e emission while negative numbers represent carbon sinks. This is valued at a shadow price of carbon and included in the economic analysis as public good benefits. The value is assessed with the Ex-Ante Carbon Balance Tool (EX-ACT).
Net present value (NPV)	The NPV is the difference between the present (discounted) value of cash inflows and the present value of cash outflows over a period.
Economic internal rate of return (EIRR)	The EIRR is the discount rate at which the calculated NPV equals zero. A high EIRR provides confidence in the profitability of an investment.

of carbon indicates the carbon price consistent with achieving the core objective of the Paris Agreement of keeping temperature rise below 2°C. To assess the public expenditure needed to support CSA adoption at the sectoral level, information was sourced from previous investment projects in Lesotho, literature and information sourced by government institutions, independent research entities and nongovernmental organizations (NGOs), and international institutions.

88. **The CBA was based on the comparison between "with" and "without" CSA investments scenarios.** The "without CSA investments" scenario is consistent with the CT scenario, while the "with CSA investments" scenarios consider the implementation of the following CSA options consistent with the RL and CZ scenario narratives. The "with CSA investments" scenarios are based on the hypothesis that farming households will adopt a combination of CSA-related practices, namely:

- Crop diversification (for example, inclusion of different crops in the rotations and in the farming systems, expansion of vegetable and fruit production and expansion of livestock-related activities);
- Adoption of improved crop varieties that are more productive, are drought- and stress-tolerant, capable of competing with weeds, and resistant to pests and diseases;
- Improved use of fertilizer through integrated soil fertility management combining inorganic and organic fertilization with adapted varieties;
- Improved water use efficiency due to access to cost-efficient small-scale irrigation systems;
- Focused intensification of livestock production based on improved feeding (for example, more concentrates, adding certain oils or oilseeds to the diet, improving pasture quality) and breeding management practices (for example, increasing productivity through breeding and better management practices): increasingly adopted for cattle (including dairy) and sheep;
- Some households will be able to engage in aquaculture production due to the improved water management activities promoted under the CSAIP. Cultivation of medicinal plants (*Rosa canina*) and mushroom production will be introduced on communal land subject to reforestation and forest regeneration activities. Last, the use of horses and donkeys as animal draft power sources and transport means will generate an extra source of income at household level; and

- Soil conservation technologies, such as CA and its three pillars (rotation with legumes, minimum tillage, and mulching), aimed at improving soil structure and fertility, thus reducing erosion and overall land degradation and increasing crop yields.

89. **The CBA adopts an interdisciplinary approach, considering agronomic, economic and environmental aspects associated with CSA implementation.** Different data sources have therefore been used. Raw data from the Agriculture Production Survey (APS) 2016-7 (and 2015-6 for data not available in 2016-7; for example, yields of selected crops) have been used to determine quantities and costs of the inputs used in crop and livestock management. Cropland area and crop yields have also been derived from Food and Agriculture Organization Corporate Statistical Database (FAOSTAT). Such information refers to "conventional" farm management (that is, business as usual). Yields reported therefore represent the actual yields. The attainable yields were sourced from the Department of Agricultural Research and have been used to calibrate the yields under the CSA-improved management options. Additional data sources include: household level Census 2009 dataset, previous investment programs in the agriculture sector of Lesotho (or in the Region), and available literature. Information about the proposed components of the CSAIP (discussed in chapter 5) have been validated with the Lesotho stakeholders.

90. **The robustness of the economic benefits was determined through a sensitivity analysis incorporating variations of key variables.** The sensitivity analysis considers the performance of the investment options under different scenarios, including changes in the flow of benefits and costs, changes in the adoption rate, and changes in crop yields. Detailed assumptions for the CBA are provided in annex 3.

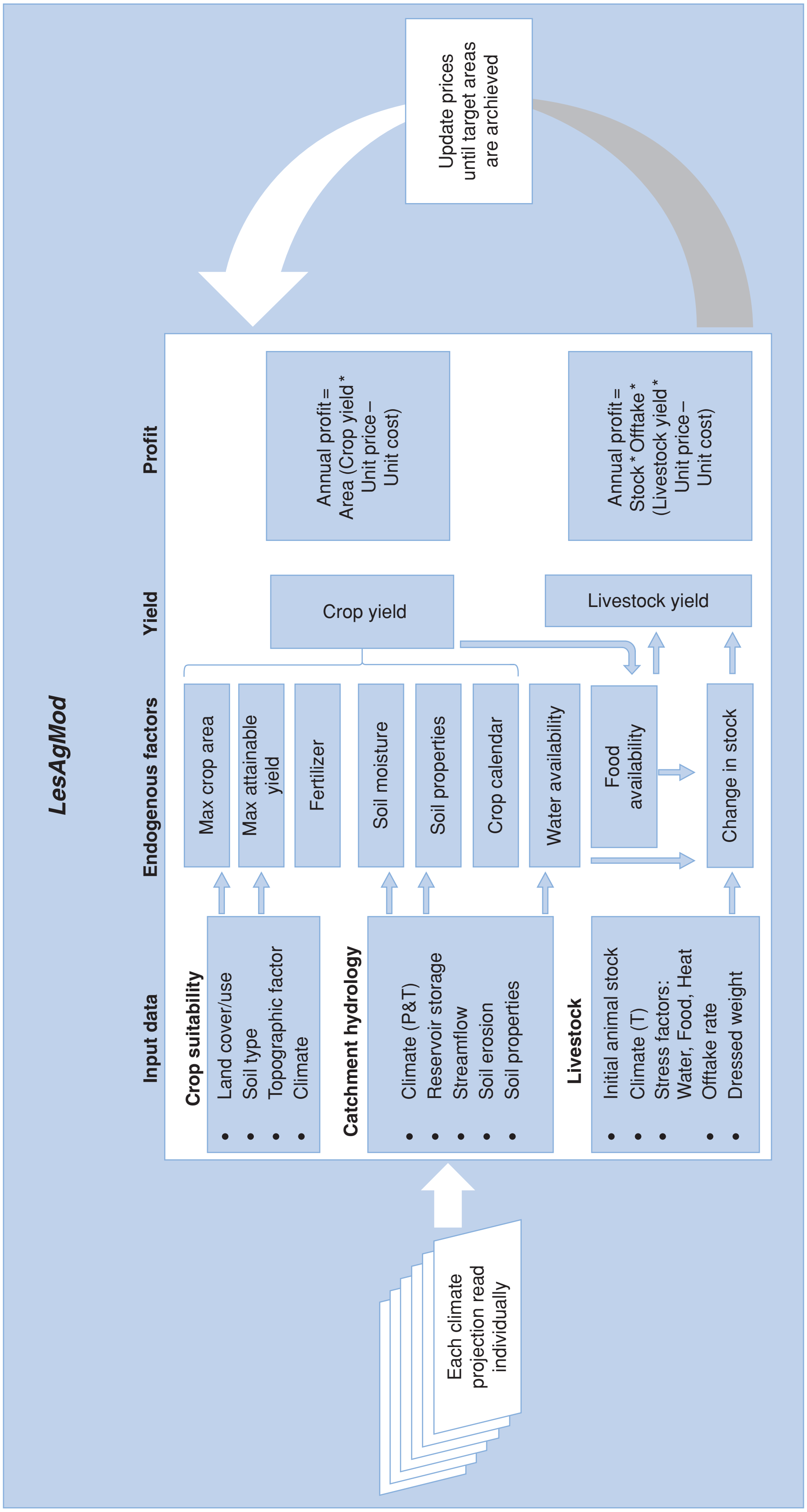
The LesAgMod approach for assessing agricultural sector goals

91. **LesAgMod was purposefully designed to assess the potential impacts of CSA technologies on Lesotho's agricultural sector under changing climate conditions.** LesAgMod is a spatially explicit, monthly time step model designed to reflect the current water and agricultural systems of Lesotho (figure 2.4). It was used to explore alternative agricultural pathways and investment priorities within the context of the CSA normative vision and scenario-building processes. The model couples agricultural, water, soil nutrients, and land-use practices and climate change scenarios to assess key vulnerabilities of the agricultural sector and employs a profit maximization approach to estimate changes in land-use and cropping patterns over time.

92. **LesAgMod enables stakeholders to better understand how changing climate patterns and other factors may affect agriculture within Lesotho and explore the implications of alternative strategies that seek to reduce vulnerabilities and create opportunities, particularly for the rural poor.** The model assesses the sensitivity of water and agricultural management to changes in natural and managed landscapes. The model was developed at a spatial scale appropriate to simulate major hydrologic flows; represent major demographic, land-use, and cropping trends; and evaluate the effects of water and land management. The model runs on a monthly time step to simulate hydrological process, crop growth, consumptive water demand, and water allocation decisions.

93. **LesAgMod took as its starting point a water resources assessment tool that was developed under the Lesotho Water Security and Climate Change Assessment Project (World Bank Group 2016) using the Water Evaluation and Planning (WEAP) decision support system.** This legacy model included agricultural crop production measured as potential yield based solely on soil moisture deficits. Land-use, land cover, and cropping patterns were based on historic data and only varied based on external or exogenous assumptions of future conditions. Livestock were not included in the revenue maximization but are modeled statically in terms of herd size and product output. In this report, LesAgMod was modified for CSAIP to better represent and evaluate Lesotho's agricultural sector. This included refining the model to include factors of production beyond soil moisture that affect agriculture output such as nutrient availability, soil properties, and input costs. The model includes

FIGURE 2.4: SCHEMATIC REPRESENTATION OF LESOTHO AGRICULTURAL SECTOR MODEL

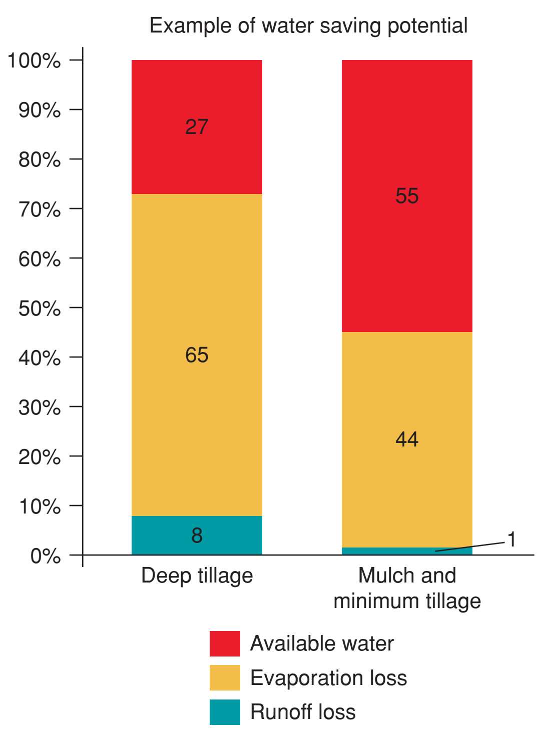


Source: Authors

fertilizer application, soil organic content, and nitrate content to estimate yield as well as input costs and commodity prices to calculate revenue maximization. LesAgMod was also updated to include livestock production, their derived products, and their factors of production.

94. **From a modeling perspective, the practical implementation of CSA includes improvements in soil water efficiency and enhanced soil health allowing cropping pattern substitutions and prioritizing crop production in regions where land characteristics and soil properties are most favorable.** An example of how CSA improves yield is contrasting more traditional, deep tillage approaches to CA that include minimum soil disturbance (deep tillage) for weed control, mulching, and intercropping of maize and beans. Under the traditional practice, total evaporative loss is much higher compared with CA practices that include residue retention, mulching, and minimum tillage, with soil water column loss reduced to 45 percent. LesAgMod calculates crop yields, changes in livestock populations, and GHG emissions on an annual basis. The model is formulated as a maximization of net profit (that is, revenue minus cost) for the producer, which assumes that farmers respond to a price signal in terms of their planting and livestock decisions. Price remains an exogenous variable, but area planted becomes endogenous and can thus vary over time in response to an external price signal and/or constraint to production, such as land and water availability, changes in the costs of production, and so on. Production and market value change over time as a function of changes in planted area and yield. In this study, the agricultural economic analysis was conducted over a 40-year period from 2010 to 2050.

FIGURE 2.5: ILLUSTRATIVE EXAMPLE OF WATER-SAVING POTENTIAL OF CSA PRACTICES



Source: Lininger et al. 2011

95. **The narrative scenarios prescribe the adoption levels for the various CSA practices that include CA, fertilizer application rate, irrigation, and improved crop varieties.** CA is a set of management practices that is characterized by minimum soil disturbance and permanent soil organic cover (either crop residues or cover crops). CA has been shown to enhance soil physical properties, including increased infiltration, soil water retention, and organic content, which in turn lead to improved yields. The LesAgMod captures these effects directly through its hydrologic and crop yield routines that consider these input parameters. For example, minimizing soil disturbance and managing crop residue and tilling practices results in higher soil organic matter and reduction in sheet flow and soil erosion. In LesAgMod, these soil treatments result in increasing soil water holding capacity, higher soil organic content, and less overall field runoff, enhancing soil moisture and increasing crop yield. For each of the scenarios, we have assumed a rate of adoption of these practices, which are assumed to be adopted linearly over the period of the analysis (2010 through 2050). Each narrative scenario was run for a set of future climate projections. The climate projections are assumed to be an exogenous (external) factor that has an influence on crop and livestock productivity. Thus, each of the selected climate change projections was run for each of the narrative scenarios, resulting in 30 unique simulations.

TABLE 2.6: LESAGMOD OUTCOME INDICATORS

Indicators	Definition
Cropped area, yield, and production	Crop production is determined for each of the 74 sub-catchments as the product of the yield estimate within the sub-catchment and the estimated cropped area, which in turn is dependent on the crop suitability and management practices, market prices which reflect demand, and the conditions and cost associated with land conversion to agricultural purposes to expand production.
Livestock production	LesAgMod estimates livestock production as a function of the number of heads of each commodity (cattle, chicken, dairy cows, goats, pigs, and sheep), annual offtake rate for each commodity, and their average yield measured in kg per animal.
Food availability	Crop products for food, livestock feed, bioenergy, and fiber are used as indicators for food security of a growing population. The analysis uses kilogram availability per capita to measure food security.
Export potential	Export potential of agricultural commodities targeted for commercial development is estimated in terms of their output quantity. The model assesses imports or exports as a share of domestic consumption, which is assumed to be proportional to historic production and population.
GHG emissions	LesAgMod accounts for GHG emissions from crops and livestock as CO_2 equivalent, including fertilizer use and emissions from livestock, including enteric and manure for livestock and fertilizer for crops; emissions from biomass removal from conversion of forest and natural land to cropland or below-ground carbon sequestration, which might occur with no tillage and agroforestry practices; or emissions from burning of biomass.
Soil erosion (ton per ha per year)	High precipitation intensity on poorly managed soils can lead to the loss of soil organic content. The impact on cropped agriculture is the reduction in water holding capacity of soils and loss of soil fertility leading to reduced yields. Where soil erosion is mitigated, soil fertility improves leading to higher soil moisture content and less water stress on crops.

Source: Authors

96. **The outcome indicators from LesAgMod application are presented in table 2.6.** Production and market value change over time as a function of changes in planted area and yield.[15] Due to variability in climate and biophysical features, such as soil properties and slope gradient, some areas of the country are more suitable, and therefore more profitable, for growing certain crops than other areas. The difference in land suitability leads LesAgMod to preferentially allocate crops to different parts of the landscape (annex 5). For this reason, the model tends to substitute crops by removing production in some parts of the landscape and concentrating their production in parts that are more favorable to their growth.

Step 4: Prioritize CSA strategies and determine investments

97. **The final step synthesizes results from the previous steps and evaluates CSA strategies and the investments necessary to scale up CSA in the country.** It also analyzes the potential barriers to implementing CSA and how the investment plan could potentially help in breaking the barriers. It focuses on proven delivery mechanisms tailored to different aspects of the CSAIP and their strategic importance in addressing the constraints associated with CSA adoption. Step 4 also includes policy recommendations to support effective delivery of CSA in Lesotho.

[15] For each of the narrative scenarios, the LesAgMod was run iteratively, where prices for each commodity were adjusted to determine the level of price that would be necessary to meet the objective of the narrative scenario. Additionally, these prices were estimated under the assumption of the historic climate of 1948 through 1988 repeating itself for 2010 through 2050, where there is assumed to be no anthropogenically attributed climate change. The estimated future prices were used to infer the level of investment and/or the cost to society to achieve the outcome of each scenario. As an example, in 2010, the market price of maize was about US$0.40 per kg. Meanwhile, maize yields have been historically low, and despite these low yields, maize still represents more than 60 percent of the planted area and total production year after year in Lesotho. This implies a high cost in absolute terms and a high cost to society in general. Most maize production has traditionally been from small landholders with few economies of scale to boost production. Production costs from a social perspective are thus quite high. Arguably, it makes more sense for Lesotho to focus its agricultural production on those commodities for which it has a comparative advantage, import maize on the open market, and forgo some portion of its domestic production. Since LesAgMod is set up to maximize revenue, for Lesotho to maintain historic levels of maize production in the future, the implied price of maize must be higher than the historic value to reflect the higher social cost of its production. If real prices are used for the full period of analysis from 2010 through 2050, then LesAgMod will gradually take maize out of production by planting less area, since from a revenue maximization perspective, it is not profitable to grow maize.

III.

CSA Impacts at the Household Level

98. **This chapter evaluates the benefits of CSA adoption relative to conventional farming practices at the household level.** The results indicate that climate-smart crop and livestock production are more profitable than conventional practices. The results also show that societal benefits of climate-smart crop production are higher than the private benefits derived by individual farmers. Even though improved land management technologies generate private and public benefits, their adoption faces many barriers. These barriers must be effectively addressed through the CSAIP interventions.

99. **Net margins gained under the CSA adoption are systematically higher than those obtained under conventional farming.** Favorable net margins suggest that the households will have the capacity to cover the costs of adopting CSA practices. Overall, household incomes will increase because of the CSAIP interventions. The increase is much higher under the CZ scenario compared to the RL scenario (table 3.1) due to the increase in average farm size from 0.5 ha to 2.5 ha, intensification of cereals production, and the expansion of high-value crops (potato, vegetables, and fruits). Switching from CT to CZ farming system will be more profitable but will require more private investments; switching from CT to RL farming system will be less profitable but will be more affordable for the smallholders.

100. **Crop and livestock production under CSA are several times more profitable than conventional practices.** The annual net income of the representative household is about thrice higher under the RL scenario and about five times higher under the CZ scenario.[16] Potato is 28 percent more profitable, wheat 2.5 times more profitable, peas 3 times more profitable, and maize and sorghum 4 times more profitable under CSA than conventional practices (table 3.2). Compared to agroforestry, CA is estimated to generate about 2.5 times private benefits to farmers, while the private benefits of mushroom and *Rosa canina* (Rosehip, a medicinal plant) are about the same. Climate-smart livestock production is also more profitable than conventional techniques by a factor ranging from 1.3 for goat and sheep to about 2 for dairy and poultry, and about 4 for pig (table 3.3).

101. **Societal benefits of climate-smart crop production are higher than the private benefits derived by individual farmers.** For every US$100

TABLE 3.1: INCOME FROM CROP PRODUCTION FOR THE REPRESENTATIVE HOUSEHOLD AND FARMER GROUP

	Without CSA investments, CT	With CSA investments	
		CZ	RL
		US$ per year	
Gross income	424	7,524	842
Net income (after labor)	251	6,167	698

Source: Authors

Note: It is assumed that in the RL scenario, households will have 0.5 ha available for farming, while in the CZ scenario, they will become more commercially oriented and will be able to expand their cropland to 2.5 ha, for instance, through farmer aggregation (farmer groups) promoted under the scenario.

[16] For the CZ comparison, the gross income was prorated by dividing by 5 since farm size under CZ is 5 times that of RL.

TABLE 3.2: INCOME BENEFITS FROM ADOPTION OF CSA PRACTICES

Financial												
Crops	**Conventional management**						**CSA-improved practices**					
	Gross margin		**Net margin**		**Production costs (including labor)**		**Gross margin**		**Net margin**		**Production costs (including labor)**	
	LSL per ha	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**
Maize	4,256	312	2,006	147	3,090	226	14,092	1,032	8,348	611	8,802	644
Maize (CA)	—	—	—	—	—	—	11,367	832	6,225	456	7,343	538
Maize (Agroforestry)	—	—	—	—	—	—	9,504	696	2,562	188	10,393	761
Sorghum	5,826	426	1,295	95	5,455	399	9,704	710	5,182	379	7,568	554
Wheat	5,139	376	988	72	5,204	381	10,283	753	2,438	178	11,962	876
Peas	5,739	420	1,839	135	5,131	376	13,466	986	6,112	447	10,888	797
Green Beans	—	—	—	—	—	—	70,258	5,143	26,577	1,946	53,423	3,911
Tomato	—	—	—	—	—	—	116,767	8,548	97,427	7,132	67,573	4,947
Potato	57,171	4,185	53,422	3,911	30,426	2,227	73,963	5,415	68,300	5,000	51,200	3,748
Rosa canina	—	—	—	—	—	—	12,762	934	2,650	194	26,656	1,951
Mushrooms	—	—	—	—	—	—	2,843.97	208.97	2,832	207	47,799	3,499
Apples	—	—	—	—	—	—	35,025	2,564	29,085	2,129	17,392	1,273
Peaches	—	—	—	—	—	—	17,320	1,268	11,380	833	14,845	1,087
Economic												
Cereals & legumes	**Conventional management**						**CSA-improved practices**					
	Gross margin		**Net margin**		**Production costs (including labor)**		**Gross margin**		**Net margin**		**Production costs (including labor)**	
	LSL per ha	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**	**LSL per ha**	**US$ per ha**
Maize	4,560	334	2,872	210	2,623	192	14,600	1,069	10,292	753	8,202	600
Maize (CA)	—	—	—	—	—	—	12,023	880	8,167	598	6,464	473
Maize (Agroforestry)	—	—	—	—	—	—	11,176	818	5,557	407	8,413	616
Sorghum	6,208	454	2,810	206	4,469	327	9,322	682	5,930	434	7,819	572
Wheat	5,557	407	2,443	179	4,234	310	9,821	719	3,937	288	11,591	849
Peas	6,111	447	3,186	233	4,330	317	14,642	1,072	9,126	668	9,206	674
Green Beans	—	—	—	—	—	—	77,193	5,651	44,432	3,253	41,836	3,063
Tomato	—	—	—	—	—	—	138,061	10,107	123,556	9,045	54,372	3,980
Potato	—	—	—	—	—	—	88,792	6,500	84,545	6,189	44,318	3,244
Rosa Canina	67,328	4,929	64,516	4,723	25,901	1,896	18,596	1,361	11,012	806	21,057	1,541
Mushrooms	—	—	—	—	—	—	3,065	224	3,057	224	49	4
Apples	—	—	—	—	—	—	40,422	2,959	35,967	2,633	14,151	1,036
Peaches	—	—	—	—	—	—	20,568	1,506	16,113	1,180	12,166	891

Source: Authors

TABLE 3.3: INCOME BENEFITS FROM ADOPTION OF IMPROVED FEEDING AND BREEDING MANAGEMENT PRACTICES FOR LIVESTOCK

Financial										
Livestock species	Conventional management									
	Gross margin (before labor)		Net margin (after labor)		Production costs (including labor)		IRR	NPV @ 10%	Average stock size	Unit net margin
	LSL per year	US$ per year	LSL per year	US$ per year	LSL per year	US$ per year	%	LSL	Heads	US$ per head per year
Cattle	6,618	484	2,778	203	10,752	787	13	2,878	16	13
Dairy cows	21,849	1,600	17,369	1,272	14,676	1,074	42	61,440	40	32
Goat	33,758	2,471	20,800	1,523	46,400	3,397	23	51,224	476	3
Sheep	44,088	3,227	22,884	1,675	84,700	6,201	12	16,354	613	3
Pig	45,209	3,310	26,009	1,904	82,591	6,046	22	85,726	128	15
Poultry	23,797	1,742	16,117	1,180	58,770	4,302	23	53,864	894	1
Financial										
Livestock species	CSA-Improved practices									
	Gross margin (before labor)		Net margin (after labor)		Production costs (including labor)		IRR	NPV @ 10%	Average stock size	Unit net margin
	LSL per year	US$ per year	LSL per year	US$ per year	LSL per year	US$ per year	%	LSL	Heads	US$ per head per year
Cattle	20,901	1,530	16,677	1,221	13,008	952	44	62,878	31	39
Dairy cows	44,654	3,269	38,382	2,810	19,327	1,415	52	139,494	52	54
Goat	52,270	3,827	31,066	2,274	69,107	5,059	29	93,173	547	4
Sheep	82,973	6,074	61,769	4,522	168,465	12,333	20	131,606	1,285	4
Pig	149,991	10,980	125,031	9,153	152,725	11,180	37	487,608	160	57
Poultry	32,782	2,400	22,798	1,669	64,991	4,758	26	81,118	1,036	2
Economic										
Livestock species	Conventional management									
	Gross margin (before labor)		Net margin (after labor)		Production costs (including labor)		IRR	NPV @ 10%	Average stock size	Unit net margin
	LSL per year	US$ per year	LSL per year	US$ per year	LSL per year	US$ per year	%	LSL	Heads	US$ per head per year
Cattle	4,418	323	1,538	113	13,216	967	4	–5,794	16	7
Dairy cows	5,635	412	2,275	167	16,882	1,236	10	–254	40	4
Goat	44,987	3,293	35,268	2,582	44,330	3,245	78	121,220	476	5
Sheep	44,088	3,227	28,185	2,063	79,399	5,813	22	65,458	613	3
Pig	36,605	2,680	22,205	1,626	65,703	4,810	24	79,158	128	13
Poultry	29,555	2,164	23,795	1,742	50,547	3,700	42	107,326	894	2

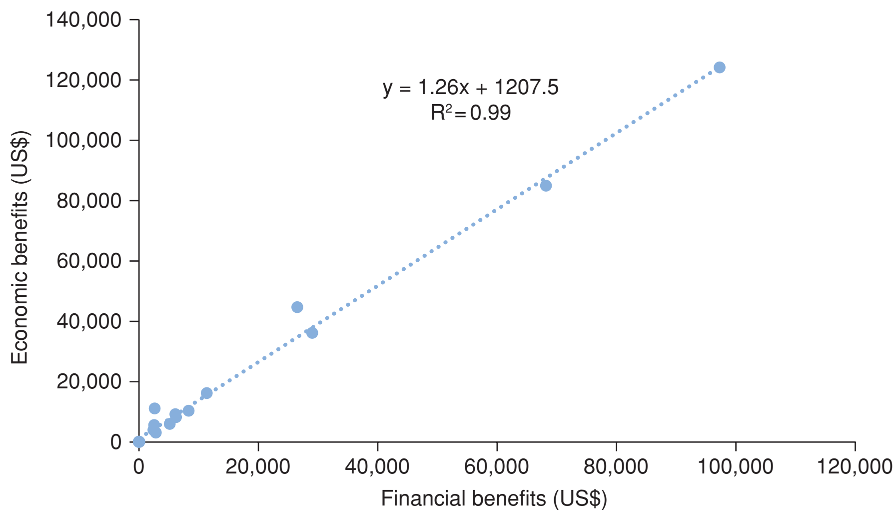
(continued)

TABLE 3.3: (Continued)

Livestock species	Economic									
	CSA-Improved practices									
	Gross margin (before labor)		Net margin (after labor)		Production costs (including labor)		IRR	NPV @ 10%	Average stock size	Unit net margin
	LSL per year	US$ per year	LSL per year	US$ per year	LSL per year	US$ per year	%	LSL	Heads	US$ per head per year
Cattle	9,849	721	6,681	489	13,864	1,015	25	19,711	31	16
Dairy cows	17,720	1,297	13,016	953	23,157	1,695	30	40,755	52	18
Goat	59,301	4,341	43,398	3,177	63,806	4,671		172,656	547	6
Sheep	88,391	6,471	72,488	5,307	138,200	10,117	31	200,500	1,285	4
Pig	121,423	8,889	102,703	7,519	122,132	8,941	38	407,385	160	47
Poultry	39,480	2,890	31,992	2,342	55,251	4,045	44	144,575	1,036	2

Source: Authors
Note: IRR = Internal rate of return; NPV = net present value.

FIGURE 3.1: RELATIONSHIP BETWEEN ECONOMIC AND FINANCIAL BENEFITS FROM CSA FARM BUDGETS



Source: Authors

the farmer profits from CSA adoption, the society benefits an additional US$26 through subsidies or transfer payments (figure 3.1). The ratio between financial and economic net margins depends on the contribution of different inputs and outputs to the overall farm budgets. For example, for cattle beef and dairy production, economic net margins are lower than financial net margins because of imported feed, medicines, and vaccines. For goat and sheep production, economic net margins are higher because of wool exports. On the other hand, the economic net margins are higher than the financial net margins for all crops because of the lower cost of labor, which constitutes the biggest cost in crop management. The only exception is maize under agroforestry for which importation of tree seeds/seedlings is key. CSA also generates carbon sequestration, biodiversity conservation, and other public goods that accrue to society but not to the farmers engaged in market transactions alone. However, only the estimation of carbon sequestration is included as shown in chapter 5. In addition, CSA can create jobs that could stimulate Lesotho's rural economy (see chapter 4).

102. **The potential for aquaculture development has recently increased and could represent an interesting investment for the private sector as indicated by the profitability of the economic model presented in table 3.4.** Fish farming plays a very important role in the development of the fisheries sector in Lesotho. In the current structure of CSAIP costs, aquaculture investments are included only to a limited extent, and only a small number of fish farmers is assumed. The aquaculture model considered in the current analysis refers to the most consolidated production system, that is, warm-water fish farming in the lowlands. The model includes production of common carp, also known as trout (*Cyrprinus carpio*), which is one of the main species produced. It describes the individual fish farmer system, where farmers who have abundant water near their farmland or have water stored for other purposes utilize it for fish farming.

103. **However, farmers face higher production costs—for improved seeds, fertilizers, and other inputs—which may represent an adoption barrier to CSA implementation.** CSAIP is expected to overcome such barriers and facilitate adoption (see chapter 5). Labor costs are a key determinant of the financial and economic results shown in the activity models. They represent an important component of total production costs. Most farmers rely on family labor only. The analysis does not differentiate between family and external labor but evaluates both using the average cost incurred to hire external laborers (which is used as a proxy of labor value). In general, CSA implementation implies an increase in the overall labor requirements, and this may represent an adoption barrier.[17]

TABLE 3.4: BENEFITS FROM AQUACULTURE PRODUCTION

Financial	Net margin start-up	LSL 4,177	US$306
	Net margin non-start-up	LSL 69,526	US$5,090
Economic	Net margin start-up	LSL 3,381	US$248
	Net margin non-start-up	LSL 56,279	US$4,120

Source: Authors. The estimates correspond to a pond size of 600 m^2 with 3,600 fingerlings. Each cycle of 6 months produces 2.1 tons of fish or 4.2 tons of fish per year.

104. **Additionally, the CSAIP promotes a set of sustainable land management (SLM) measures to protect against erosion and provide other ecosystem services:**[18]

- Terraces and other physical measures—bench terraces, vegetated soil bunds, and stone bunds
- Flood control and drainage measures—rock catchment water harvesting and runoff/ floodwater farming
- Gully control measures—gully erosion management, reshaping of gully erosion through integration of silt fences, erosion blankets and brush packing, stone wall check dams
- Reforestation and natural regeneration of vegetation cover

105. **The unit costs of such measures vary, depending on the intensity of input use, mainly labor.** Most of the measures require establishment costs as well as yearly maintenance costs and are reported in table 3.5 and included in the overall CSAIP costs (chapter 5).

[17] In some models, for example, potato and sorghum, it was assumed that producers could switch to tractor land preparation in the "with CSA investments" scenario. However, the low access to tractors and consequent reliance on manual labor is currently a major constraint to agriculture, especially for potato which is highly labor-intensive. Such constraints are considered by allocating only a small amount of land to potato production. In addition, to reflect the difficulty of getting increased access to tractors for cultivation, the reduction in labor requirements for land preparation also considers the possibility of using animal draft power, given also the expanded size of the livestock subsector in the CSIP investments. However, the implications on the labor market are not considered in this report.

[18] SLM is the implementation of land-use systems and management practices that enable humans to maximize the economic and social benefits from land while maintaining or enhancing the ecosystem services from land resources. SLM practices include technologies and approaches to increase land quality. The practice must be site-specific because different areas will require different interventions. For example, tree planting may be an SLM practice in one area but not in another because the practice may negatively affect downstream water availability. SLM technologies include agronomic, vegetative, structural, and management measures, while SLM approaches include ways and means of support that help introduce, implement, adapt, and apply technologies in the field.

TABLE 3.5: COSTS OF SLM OPTIONS

Activity	Unit of measure	Unit cost
		US$
1. Terraces and other physical measures		
Bench terraces		
Establishment costs, 5 years	ha	387
Maintenance costs, twice per year	ha	102
Vegetated soil bunds		
Establishment costs, 15 month(s)	ha	231
Maintenance costs, once per year	ha	24
Stone bunds		
Establishment costs, 36 month(s)	ha	45
Maintenance costs, once per year	ha	16
2. Flood control and drainage measures		
Rock catchment water harvesting		
Establishment costs, 5 years	Community	144,555
Maintenance costs, once per year	Community	799
Runoff/floodwater farming		
Establishment costs, 30 month(s)	ha	72
Maintenance costs, once per year	ha	153
3. Gully control measures		
Gully erosion management		
Establishment costs, 15 month(s)	ha	869
Maintenance costs, once per year	ha	85
Reshaping of gully erosion through integration of silt fences, erosion blankets and brush packing		
Establishment costs, 15 month(s)	ha	141,343
Maintenance costs, once per year	ha	220
Stone wall check dams		
Establishment costs, 15 month(s)	ha	129
Maintenance costs, once per year	ha	56
4. Reforestation and natural regeneration of vegetation cover		
a. Training of village NRM committees in grasslands rehabilitation and plant nurseries	Community	2,000
b. Establishment of community nurseries	Community	3,000
c. Input packages for community nurseries	Community	1,200
d. Tree planting and grasslands management on communal areas	Community	5,000

Source: Authors

IV.

CSA Impacts at the Sector Level

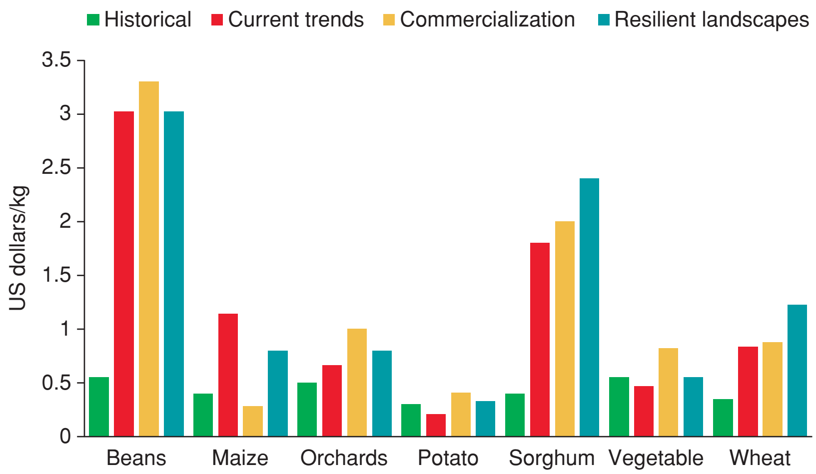
106. **This chapter presents the results of key agricultural sector indicators for the narrative scenarios and in the context of future climate change.** Performance indicators include crop production, livestock production, food availability, and GHG emissions. The chapter also evaluates the feasibility and implications of meeting the CSA targets developed during the stakeholder consultation. The key findings are as follows:

- Climate is a major determinant of crop yield variability. Very dry conditions can suppress yields, leading to low productivity. The variability of yield and thus production from year to year can be extreme and is primarily due to rainfall deficits leading to soil moisture stress and reduced rangeland productivity.
- There is an urgent need to increase production to meet caloric food demand. To prevent cropland expansion to natural vegetation, sustainable agricultural intensification strategy is required for narrowing the agricultural yield gap. Constraints that must be overcome include weather-induced yield variability, soil fertility constraints, pest infestation, and market accessibility.
- Subject to narrowing yield gaps and improving the enabling environment for CSA adoption, Lesotho can prioritize orchards, vegetables, and potato for exports.

4.1 Crop prices for the scenarios

107. **For maize to maintain a 60 percent share of cropland, under the CT scenario, the subsidized price by 2050 was estimated at US$1.14 per kg or 2.85 times the historic price.** Likewise, given the low profitability of beans, a high price is necessary to maintain its production, which was found to be more than five times the market price.

FIGURE 4.1: HISTORICAL COMMODITY PRICES (BLUE) AND THE ESTIMATED PRICES BY 2050 TO ACHIEVE PRODUCTION LEVELS ENVISIONED UNDER THE NARRATIVE SCENARIOS



Source: Authors

All the narrative scenarios give some priority to beans production. The prices for wheat, sorghum, and orchards are higher, while those of potato and vegetables are slightly lower. This is consistent with the observed trends, where potato and vegetable production has increased in market share and thus has a higher social value. To maintain the share of potato and vegetables at the historic levels, the future input price should be reduced; otherwise a disproportionate amount of potato and vegetables would be grown, which is inconsistent with the CT scenario.

108. **Under the RL scenario, support for maize is maintained through subsidies reflected in its higher relative price but not at the level of the CT scenario.** Sorghum and wheat prices are both higher, as are orchards and beans, suggesting that price subsidy or input support is still necessary to achieve this diversified portfolio. A broad goal is a diversified agricultural sector markedly different from the common wheat-maize monocropping system, which despite its prevalence is unsustainable and insufficient to feed the country's population. The RL scenario assumes a smaller share of maize supported by a larger share of more drought-tolerant sorghum. Wheat production increases since it still fits into the cropping system, as it is traditionally a winter variety. A significant benefit of the RL scenario is that the total planted area is reduced, allowing for more efficient systems including agroforestry systems and production practices that focus on soil conservation and soil health improvements. Similarly, incentives are provided that enable livestock owners to adopt climate-smart livestock technologies and improve rangeland management practices.

109. **Under the CZ scenario, all crops targeted for increased production to enhance diversification and resilience would require price increases.** This is consistent with the high degree of market liberalization pursued under the scenario taking into consideration agricultural commodities for which Lesotho has distinct comparative advantage. Increased agricultural exports are a main strategy of this scenario; monocropping of cereals is deemphasized, and thus, the price of maize is reduced to 70 percent of the historic price. Table 4.1 shows that sorghum is still supported at a high level, with a price multiplier of 5, as the narrative maintains an interest in sorghum production, but the high price multiplier suggests that it is not a socially preferable commodity, rather a reliable, drought-tolerant commodity. To continue to grow some wheat and beans given the dramatic increase in the higher-valued crops, the price multiplier for wheat and beans is 2.5 and 6, respectively. This scenario implies increased investment in potato, orchards, and vegetables with potential to export, with the relative prices about double the historic value.

TABLE 4.1: RATIO OF THE COMMODITY PRICES FOR THE ALTERNATIVE SCENARIOS RELATIVE TO THE HISTORICAL PRICES BY 2050

	CT	RL	CZ
Beans	5.5	5.5	6.0
Maize	2.85	2.0	0.7
Orchards	1.33	1.6	2.0
Potato	0.7	1.1	1.35
Sorghum	4.5	6.0	5.0
Vegetable	0.85	1.0	1.5
Wheat	2.4	3.5	2.5

4.2 Planted areas under no climate change

110. **For the CT scenario, the price support and subsidies are maintained for maize and wheat monocultures.** Area planted with maize increases by about 30 percent, from 120,000 ha to about 140,000 ha. The scenario implies the historical portions of crops are generally maintained and the total cropped area increases to keep up with population growth (table 4.2). The CZ scenario implies a large increase in the production of commercial crops: potato, vegetables, and orchards. In the RL scenario, potato still are a large share of the total production but only grow to about 8,600 ha. While the area of maize decreases, the area of sorghum is generally maintained, and the area of wheat grows by about 50 percent to yield a more balanced production of the main grain crops.

TABLE 4.2: DISTRIBUTION OF CROPS UNDER THE SCENARIOS BY 2050

Crops	CT		CZ		RL	
	ha	%	ha	%	ha	%
Maize	137,000	62	24,000	21	44,000	36
Sorghum	22,000	10	18,000	16	23,000	19
Beans	21,000	10	14,500	13	12,000	10
Wheat	21,000	10	20,000	17	24,300	20
Potato	9,000	4	15,000	13	8,600	7
Fresh vegetables	5,500	2	11,000	10	5,500	4
Orchards	4,500	2	12,000	10	5,000	4
Total	**220,000**	**100**	**114,500**	**100**	**122,400**	**100**

4.3 Livestock units

111. **While the normative vision approach modifies input prices for crops to infer production costs, it applies a prescriptive approach for changes in livestock.** Within the LesAgMod, baseline growth numbers were adjusted such that animal numbers grew at a rate enough to achieve the targets listed in table 4.3. No changes were made to offtake rates, which imply that in cases where numbers decrease over time, the baseline growth rate is exceeded by the offtake rate. These baseline growth rates are reflective of the level of investment through agricultural support that would be required to achieve the targets (table 4.4).

TABLE 4.3: ANNUAL LIVESTOCK GROWTH RATES (PERCENT)

	CT	CZ	RL
Cattle	1.24	0.90	1.50
Dairy	1.40	1.75	1.75
Sheep	1.25	1.70	1.60
Goats	0.45	0.90	0.80
Chicken	1.50	1.75	1.85
Pigs	1.50	1.90	1.50
Horses	0.25	0.25	0.50
Donkeys	0.25	0.25	0.50

TABLE 4.4: TARGET LIVESTOCK NUMBERS AND LIVESTOCK UNITS FOR EACH NARRATIVE SCENARIO

Livestock	CT		CZ		RL	
	No.	LSU	No.	LSU	No.	LSU
Cattle	600,000	300,000	540,000	270,000	690,000	345,000
Dairy	100,000	50,000	90,000	45,0000	115,000	57,500
Sheep	1,600,000	160,000	1,920,000	192,000	1,840,000	184,000
Goat	825,000	82,500	990,000	99,000	948,750	94,875
Chicken	906,000	9,060	951,000	9,510	1,041,900	10,419
Pigs	100,000	20,000	115,000	23,000	100,000	20,000
Horses	50,000	25,000	50,000	25,000	65,000	32,500
Donkey	80,000	24,024	80,000	24,024	96,000	28,829
Total	**4,261,000**	**670,584**	**4,736,000**	**1,092,534**	**4,896,650**	**773,123**

112. The target populations set under the RL scenario reflect the largest increase in the number of livestock units over the 2010 levels, with over 105,000 livestock units added by 2050. Livestock units increased by 19,000 and 38,500 under CT and CZ scenarios, respectively. An increase in the number of livestock units implies an increase also in their density. According to FAO, since 1980, densities for "major livestock types" have averaged about 0.27 livestock units (LSU) per ha (coefficient of variation [CV] = 0.08) on 2.3 million ha (CV = 0.01) of rangeland (FAO 2019). With changes in land use assumed with each of the narrative scenarios, livestock densities would remain relatively unchanged under the CT scenario. Densities would increase slightly to 0.28 LSU per ha and 0.30 LSU per ha for CZ and RL scenarios, respectively. These densities are within the range of those observed historically. However, to meet the improved rangeland objectives under the RL scenario, it would be necessary to increase densities further, which may be achieved through the adoption of CSA agroforestry strategies.

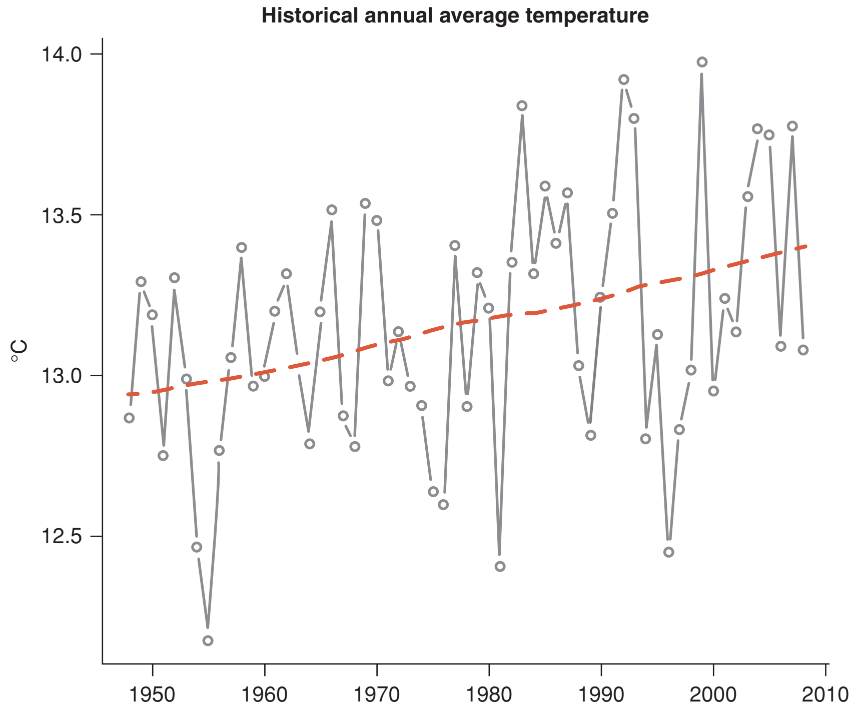
4.4 Climate projections

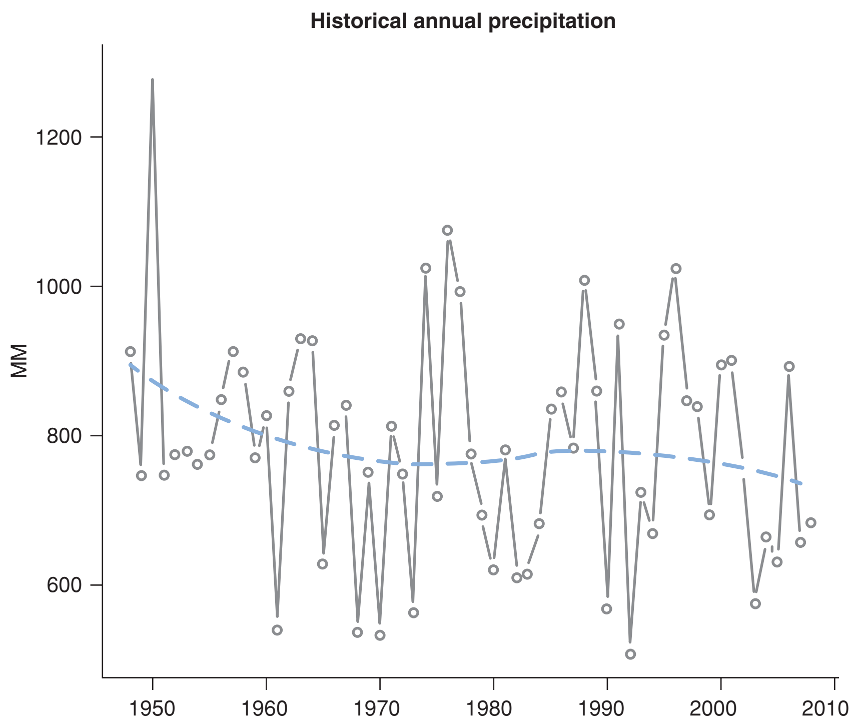
113. Analysis of precipitation and temperature trends in Lesotho over 1950 through 2010 suggests a slight decreasing trend in precipitation and an increase in temperature. The precipitation trend appears to be biased by a large precipitation event around 1950, while there appears to have been about a 0.5°C average warming over the country for the 60-year period. The historical annual average precipitation over Lesotho is about 760 mm. Figure 4.2 shows the range of future climate change from a collection of over 144 Global Circulation Model (GCM) projections over Lesotho for 2040 to 2050 relative to 1990 to 2000. The projected increase in air temperature derived from the GCMs ranges from no change to about 1.0°C above the historical average, with the greatest projected warming nearing 2°C for this averaging period. Considering all the future climate projections, the average precipitation decreases by about 5 percent. Of the 144 climate projections, 84 or 60 percent have below-average precipitation, with the range of projected precipitation change including both an increase and decrease of about 20 percent or 160 mm annually. Two climate scenarios show annual increase in precipitation greater than 20 percent. The red marks in figure 4.3 show the GCM projections used for this study and were selected to reflect a range of possible future climate variability, with 5 of the 10 climate scenarios suggesting generally drier and warmer conditions till 2050. The climate projections included scenarios that ranged from about a 15 percent decrease in annual average precipitation to a 5 percent increase in precipitation, while the average annual temperature increase of the future projections is more than 2°C when the averaging period is 2035 through 2065 to represent the 2050 warming relative to the historic period. More important than the changes in the annual mean are the characteristics of each scenario, such as length and intensity of droughts.

Figure 4.4a shows the annual average temperature estimated as the difference (°C) and precipitation change estimated as a ratio for the historic 30-year period from 1980 through 2010 and the future 30-year period of 2035 through 2065. These averaging periods were used to reflect the average change at the 2050 mid-century mark based on the 10 climate models used in the study and indicated by the red marks in figure 4.3. A 30-year averaging interval is commonly used to represent mean climate change to smooth out internal variability of the climate system. The temperature change at mid-century is more than 2°C for most part of Lesotho, while the average projected precipitation change is not large, with the mean value less than 1.0 and much drier conditions generally projected for the western side of the country. The bottom-left map is the standard deviation of the ratio of the future and current annual precipitation. It indicates the magnitude of the range of change among the 10 GCMs used in the study. Again, the western region suggests less precipitation with greater variability.

114. Table 4.5 summarizes the attributes of the historic climate period (1948–1998) and the 10 climate change projections (2001–2050). Generally, the future drought and wet spell attributes of the climate projections do not differ significantly from those of the historic climate. The longest dry spell length is 16 years (CanESM2), which is four years longer than the historic, while the Commonwealth Scientific and Industrial Research Organization (CSIRO) projection is the shortest over this period. The maximum number of consecutive dry years is the HadGEM2 model at eight years, while the CSIRO-Mk3 model has the longest wet spell length at seven years.

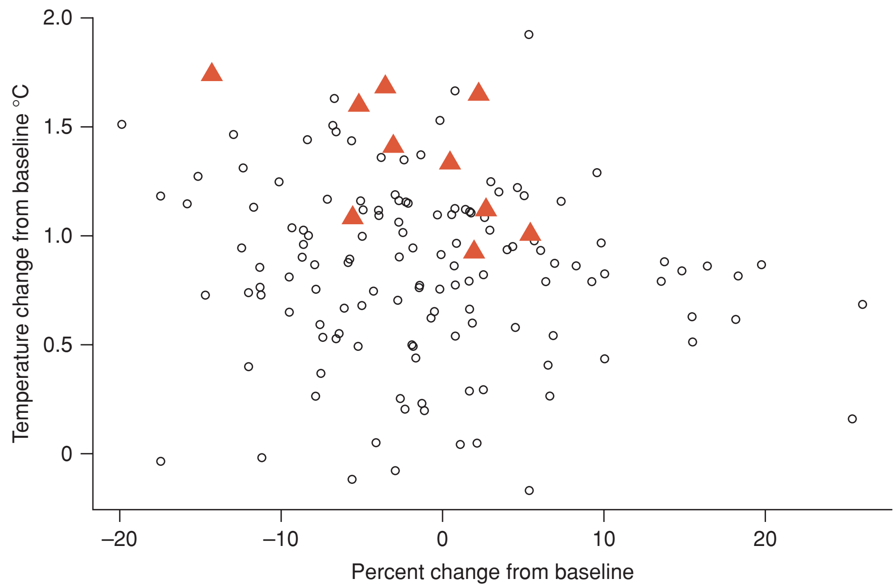
FIGURE 4.2: HISTORIC AVERAGE ANNUAL TEMPERATURE AND TOTAL ANNUAL PRECIPITATION OVER LESOTHO





Source: Sheffield 2006

FIGURE 4.3: SUMMARY OF TEMPERATURE AND PRECIPITATION CHANGE FOR THE 30-YEAR AVERAGING PERIOD OF 1980–2010 RELATIVE TO THE 30-YEAR AVERAGING PERIOD OF 2035–2065 FOR 121 CLIMATE PROJECTIONS



Source: Authors

Note: The 10 GCMs selected for the analysis are highlighted by red marks.

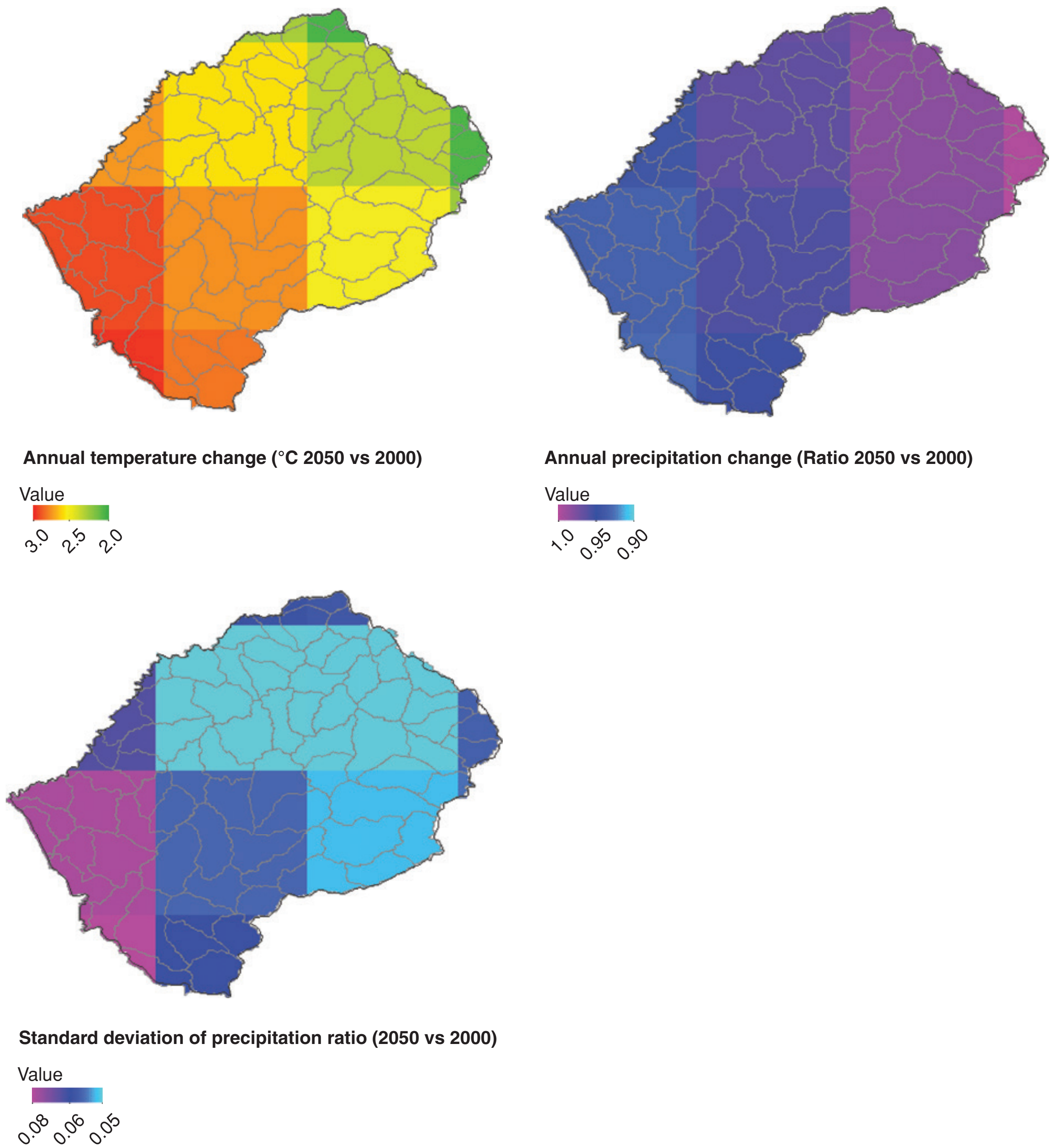
TABLE 4.5: DRY AND WET SPELL ATTRIBUTES OF THE HISTORIC AND CLIMATE PROJECTIONS

No.	GCM	Avg.	Wet Spells	Dry Spells	Wet Length	Dry Length	Avg. Dry	Avg. Wet	Max. Dry	Max. Wet
1	Historic	793	11	12	23	27	2.3	2.1	7	3
2	ACCESS1-0_run1_rcp85	808	13	14	25	25	1.8	1.9	4	5
3	CanESM2_run1_rcp85	705	15	16	22	28	1.8	1.5	3	2
4	CCSM4_run1_rcp85	843	12	13	22	28	2.2	1.8	5	3
5	CSIRO-Mk3-6-0_run1_rcp85	723	8	9	27	23	2.6	3.4	4	7
6	GFDL-CM3_run1_rcp85	788	11	12	21	29	2.4	1.9	6	0
7	GFDL-ESM2M_run1_rcp85	787	13	14	25	25	1.8	1.9	3	5
8	HadGEM2-CC_run1_rcp85	782	12	13	22	28	2.2	1.8	8	3
9	MIROC-ESM_run1_rcp85	757	11	12	22	28	2.3	2	7	4
10	MIROC5_run1_rcp85	833	13	14	21	29	2.1	1.6	6	4
11	NorESM1-M_run1_rcp85	813	10	11	23	27	2.5	2.3	6	5
	Average (excluding historic)	**785**	**12**	**13**	**23**	**27**	**2**	**2**	**5**	**4**

Source: Authors

Note: Avg = Average annual precipitation (mm); Wet Spells = Number of occurrences where there are at least two consecutive years where the annual precipitation is above average; Dry Spells = Number of occurrences where there are at least two consecutive years where the annual precipitation is below average; WetLength = Number of years of above- average precipitation; Dry Length = Number of years of below- average precipitation; Avg. Dry = Average number of consecutive dry years; Avg. Wet = Average number of consecutive wet years; Max. Dry = Maximum number of consecutive years of below- average precipitation; and Max. Wet = Maximum number of consecutive years of above- average precipitation.

FIGURE 4.4: PROJECTED MID-CENTURY (2035 TO 2065) AVERAGE TEMPERATURE AND PRECIPITATION CHANGE



Source: Authors

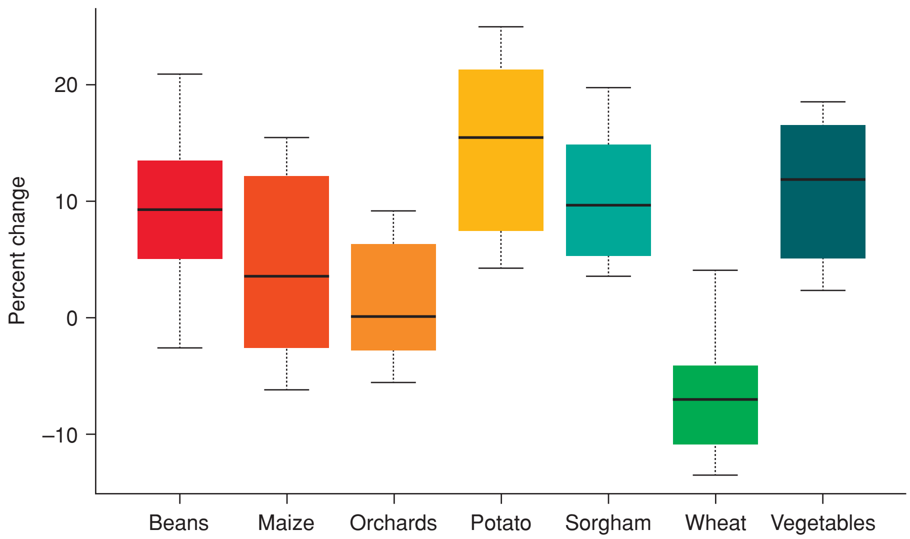
Note: Temperature is in °C while precipitation is the change in the average (top-right) and standard deviation (bottom-left) of the precipitation ratio of the mid-century and historic climate (1980 through 2010).

4.5 Crop yields

115. **On average, climate change generally increases yields for Lesotho's major crops.** The warmer temperatures extend the growing season supported by mostly adequate moisture regimes. By extending the growing season, grain filling stages are increased that may otherwise have been curtailed by cooler temperatures. Wheat is the exception, which shows a general decline, with reduced winter and spring soil moisture that results in suppressed yields. Since the future narrative scenarios encompass a wide range of CSA adaptation and actions within the context of future climate change, it is difficult to isolate the impacts of climate change on crop yield alone. Therefore, LesAgMod was run for 2010–2050 using a static land-use and cropping pattern and CSA practices based on historic conditions to isolate the relative impacts of climate change on crop yield alone. Figure 4.5 indicates the percentage change in yields for the 10-year period 2010–2020 relative to the 10-year period 2040–2050 averaged for all 10 climate projections. Note that a 10-year averaging period is quite short to draw conclusions, as a particularly dry or wet period that had high yields could bias the result.

116. **The projected changes in yield under climate change are summarized in figure 4.5 and table 4.6.** The minimum projected impact of climate change

FIGURE 4.5: AVERAGE CHANGE IN CROP YIELDS DUE TO CLIMATE CHANGE



Source: Authors

TABLE 4.6: PROJECTED IMPACTS OF CLIMATE CHANGE ON CROP YIELDS (%)

Crops	Minimum	First quartile	Median	Third quartile	Maximum
Beans	–2	5	9	13	21
Maize	–6	–2	3	12	15
Orchards	–5	–2	0	6	9
Potato	4	8	15	21	25
Sorghum	3	6	10	14	20
Wheat	–14	–11	–7	–4	4
Vegetables	2	6	12	15	18

Negative Positive

Source: Authors

on yield is negative for wheat (15 percent decrease), maize (6 percent decrease), orchards, (5 percent decrease) and beans (2 percent decrease). On average, potato has the largest positive impact with 15 percent increase in yield, followed by vegetables (12 percent increase), sorghum (10 percent increase), and beans (9 percent), suggesting that crops would generally benefit from global warming in Lesotho. The warmer temperatures extend the growing season supported by mostly adequate moisture regimes. By extending the growing season, grain filling stages are increased that may otherwise have been curtailed by cooler temperatures. Wheat is the exception, which shows a general decline, with reduced winter and spring soil moisture that results in suppressed yields. The maximum projected positive impact of climate change on yield ranges from 4 percent for wheat to 25 percent for potato.

117. **The RL and the CZ scenarios show the influence of the CSA practices on yield, with the RL scenario having the highest level of CSA adoption resulting in higher yields compared with the CZ scenario.** The ratios in figure 4.6 are all greater than 1, indicating an increase in yield relative to historical for all scenarios under climate change. Relative to the CT scenario, the overall benefit of the CSA practices on yield under climate change is modest. The year-to-year variability of yield is primarily due to soil moisture deficits and heat stress. Potato and vegetables show the greatest increase in yield overall, benefiting from CSA practices, including the increase in application of nitrogen fertilizers.

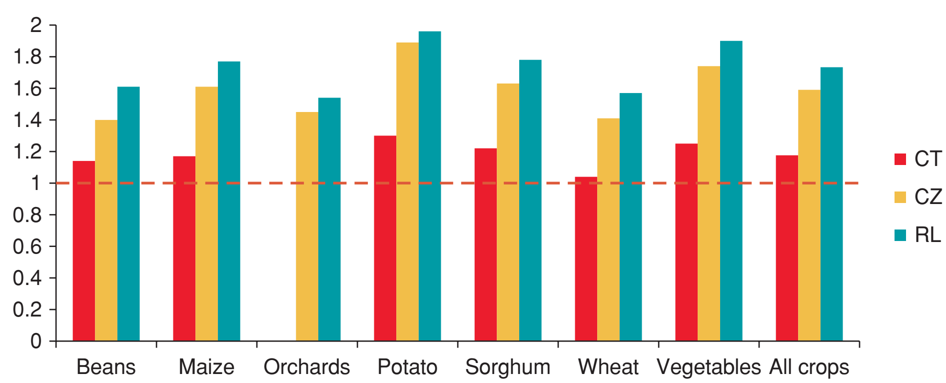
118. **Despite predicted yield improvements, this report shows that Lesotho is unlikely to meet the CSA target of increasing yields of major staples by a factor of 2.5.** There is need for further research to develop high-yielding, stress-tolerant, climate-ready varieties that are adapted to Lesotho's environment. Stress-tolerant germplasms are one component of CSA that, when used in combination with other components, can sustainably increase production and resilience of agriculture systems. Development of heat-tolerant varieties is of importance given the projected increase in warming for Lesotho. The Agriculture Productivity Project for Southern Africa (APPSA) in Lesotho could collaborate with ongoing research at the International Maize and Wheat Improvement Center (CIMMYT) on heat-tolerant varieties to generate species and cultivars adapted to Lesotho's context.

4.6 Production

4.6.1 Area under cultivation for the narrative scenarios

119. **A major key to making agriculture climate-smart is increasing land-use efficiency through higher productivity, thereby reducing the need for clearing more land for agricultural production.** Adoption of CSA leads to a reduction in the estimated cropland requirement by 20 percent for the RL scenario and 30 percent for the CZ scenario relative to historical requirements. On the other hand, the CT

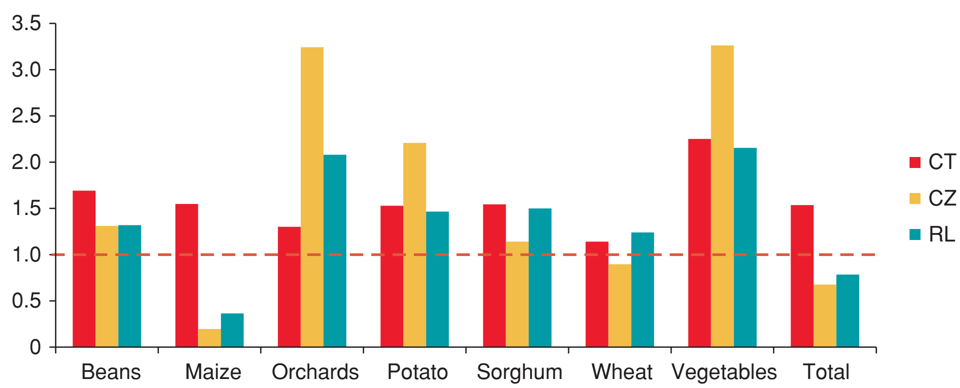
FIGURE 4.6: RATIO OF CROP YIELDS UNDER CLIMATE CHANGE VERSUS HISTORICAL BY 2050



Source: Authors. Ratios above 1 show that relative to historical, cropland extent will increase. On the other hand, ratios below 1 indicate that cropland extent will decrease relative to historical.

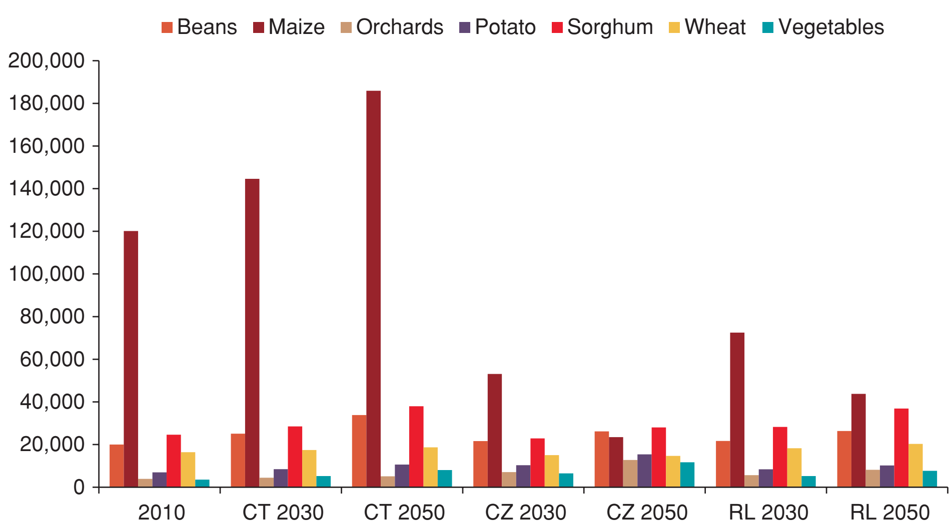
scenario shows cropland expansion by 50 percent (figure 4.7). The estimated cropland area under the scenarios by 2050 are 300,280 ha for CT, 153,480 ha for RL, and 132,250 ha for CZ. Figure 4.8 summarizes the total area planted for each crop in 2010, in 2030, and in 2050 for each narrative scenario, averaged for all climate projections. Note that because 2010 represents the starting point for the analysis, the planted area is common for all narrative scenarios and climate projections. For the CT scenario, the area under cultivation for all crops increases, which is consistent with the goals of that narrative. The area of maize increases considerably when climate change is considered. When LesAgMod is forced with the historic climate, the total area under maize cultivation by 2050 is about 140,000 ha (not shown), whereas the area under maize cultivation is more than 180,000 ha or 28 percent greater when the model is forced with the climate projections. In contrast, the cultivated area of maize for the RL and CZ scenarios shows considerable declines, consistent with the goals of those narratives. These later scenarios prioritize diversity and higher-valued crops, resulting in a smaller cropped agricultural footprint across the landscape of Lesotho. The RL scenario results in a more diversified cropping pattern, with more balanced grain production that includes sorghum and wheat, while the CZ scenario greatly

FIGURE 4.7: RATIO OF CROPLAND EXTENT UNDER CLIMATE CHANGE VERSUS HISTORICAL BY 2050



Source: Authors

FIGURE 4.8: CROPLAND EXTENT FOR THE NARRATIVE SCENARIOS AVERAGED FOR ALL THE FUTURE CLIMATE PROJECTIONS



Source: Authors

reduces maize area and intensifies the cultivation of vegetables, orchards, and potato.

4.6.2 *Crop production for the narrative scenarios under climate change*

120. **Total food production under climate change is estimated to increase fourfold to sixfold for the scenarios relative to historical production (figure 4.10).** The estimated total production was 496,000 tons for CT, 590,000 tons for RL, and 742,000 tons for CZ. The proportion of maize production decreases from 30 percent for CT to 3 percent for CZ. Potato is the most dominant crop accounting for 43 percent under CT, 54 percent under RL, and 62 percent under CZ scenario. The production of orchards under CZ doubles that of the CT scenario (table 4.7).

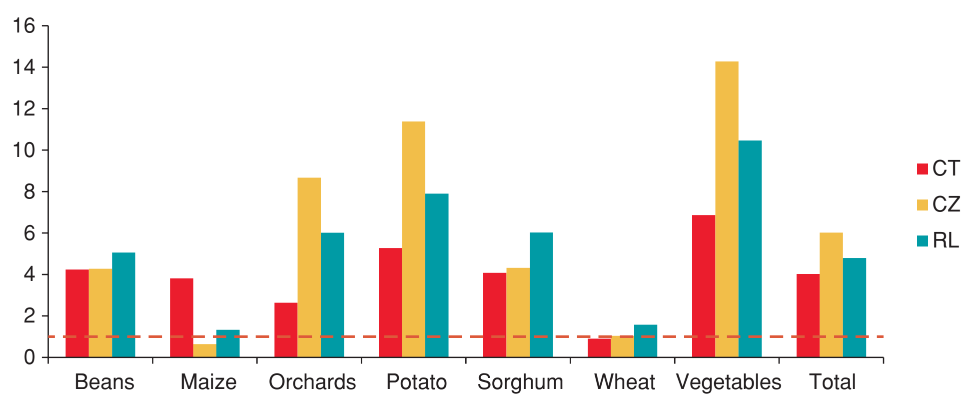
121. **The efficiency of CSA practices in minimizing conversion of natural vegetation to cropland is evident in the production of the RL and CZ scenarios.** Basically, less land is used to produce more crop output. Note that this increase in production is also due to the increased utilization of nitrogen-based fertilizers, an imperative for Lesotho to boost crop yields. For the RL scenario, maize area under cultivation will decrease to 44,000 ha by 2050, while maize production will increase to 51,000 tons by 2050 under climate change. Orchards area under cultivation has increased by 50 percent while production has more than doubled. Potato still are a large share of the total mass of production, but only grow to about 10,000 ha, with their total mass output more than doubling. Sorghum remains important in the diversification strategy of the RL scenario, with its production increasing and exhibiting robustness in terms of increased production relative to the historic (no climate change) scenario. The CZ scenario implies a large increase in production, particularly for potato, vegetables, and orchards. The high tonnage of potato reflects its relatively high density, although its area planted has grown from about 7,000 ha in 2010 to more than 13,000 ha by 2050.

TABLE 4.7: CROP PRODUCTION AND THEIR PROPORTIONS FOR THE SCENARIOS UNDER CLIMATE CHANGE

	CT		CZ		RL	
	ton	%	ton	%	ton	%
Beans	10075	2	10169	1	12020	2
Maize	146770	30	24536	3	51172	9
Orchards	17555	4	57692	8	40000	7
Potato	214100	43	461743	62	320493	54
Sorghum	18015	4	19098	3	26631	5
Wheat	18418	4	21160	3	32125	5
Vegetables	70881	14	147415	20	107993	18
Total	**495815**	**100**	**741813**	**100**	**590433**	**100**

Source: Authors

FIGURE 4.9: RATIOS OF CROP PRODUCTION BY 2050 UNDER CLIMATE CHANGE FOR THREE SCENARIOS VERSUS HISTORICAL CROP PRODUCTION



Source: Authors. Ratios above 1 show that relative to historical, crop production will increase. On the other hand, ratios below 1 indicate that crop production will decrease relative to historical.

4.6.3 Livestock production

122. **While modeling results suggest steady increases of livestock over time, these changes are occasionally moderated by variability in climate and water supply.** However, these effects are modest. The effects of climate and water supply reliability are more pronounced when looking at net production of livestock, because stresses caused by heat and scarcities of food and water have a larger influence on reducing the productivity of livestock than on increasing mortality.

4.7 Food availability and trade

123. **Food calorie intake in Lesotho is 2,447 kcal per capita per day, implying a calorie deficit of 11 percent compared to the recommended average of about 2,750 kcal per capita per day.** National food production contributes only 34 percent of Lesotho's per capita calorie intake (table 4.8) with more than half of per capita food calories derived from maize. Lesotho relies heavily on food imports from RSA, exporting only a small percent of its national production. While imports are 30 percent more than total national production, only about 2 percent of national production is exported. Per capita food rates have been modestly low and would benefit from increased production.

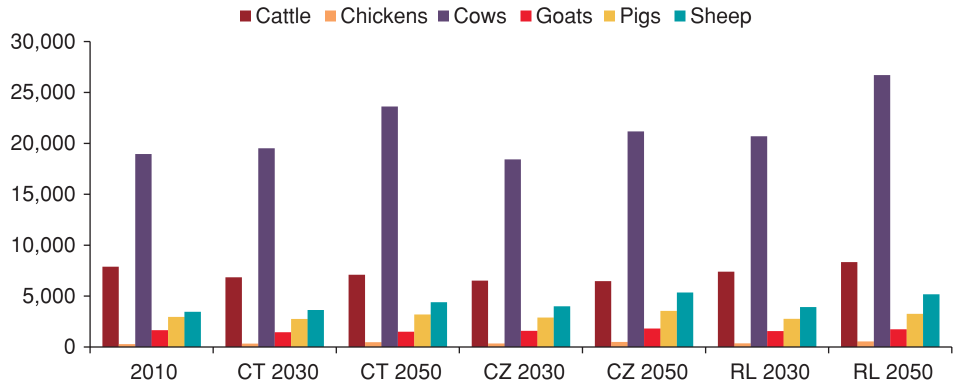
124. **Within the context of the CZ scenario, some nationally produced agricultural commodities, such as vegetables, orchards, and potato, could serve Lesotho's export market.** Assuming population will grow to 3 million by 2050 and current food calorie shortfalls will be met through national production, figure 4.11 indicates that calories potentially derived from national production by 2050 could increase by a factor ranging from 3.6 for potato to 10.2 for vegetables. Within this context, the CZ scenario prioritizes the development of an agricultural export sector. Potato would grow to nearly 462,000 tons by 2050, and Lesotho could target 200,000 tons for national consumption, doubling the historical requirement of 100,000 tons. Thus, more than 260,000 tons could be available for export. Likewise, vegetable and orchard production are shown to grow at rates exceeding population growth rates and could also be used for exports, in addition to making food calorie intake grow to

TABLE 4.8: AVERAGE HISTORIC IMPORTS, EXPORTS, AND NATIONALLY PRODUCED CROP SUBSECTOR COMMODITIES AND THE KCAL PER CAPITA PER DAY PROVIDED BY EACH OF THOSE COMMODITIES FOR 2000–2010

	National production (ton)	Import (ton)	Export (ton)	Net (ton)	Calorie intake (kcal per capita per day)	National production as proportion of consumption (%)	Calorie (kcal per capita per day) from national production
Beans	17,000	83,000	2,000	98,000	370	17	64
Maize	96,000	213,000	2,000	307,000	1,350	31	422
Orchards	16,000	5,000	0	21,000	20	76	15
Potato	100,000	8,000	0	108,000	95	93	88
Sorghum	22,000	7,000	0	29,000	100	76	76
Wheat	17,000	83,000	2,000	98,000	370	17	64
Vegetables	26,000	17,000	0	43,000	12	60	7
Livestock	27,000	8,000	0	35,000	130	77	100
Total	**321,000**	**424,000**	**6,000**	**739,000**	**2,447**		**836**

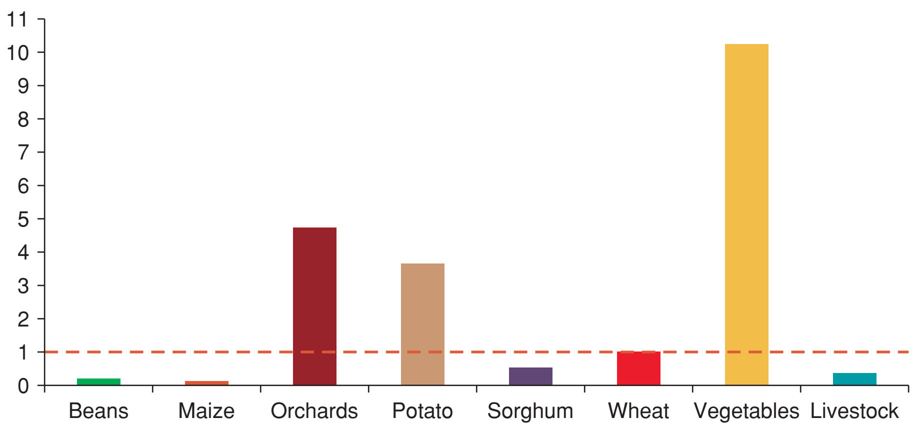
Source: FAOSTAT. Food items were converted to calories using Lesotho food composition table.

FIGURE 4.10: LIVESTOCK PRODUCTION (TONS) FOR THE NARRATIVE SCENARIOS AVERAGED FOR ALL THE FUTURE CLIMATE PROJECTIONS



Source: Authors

FIGURE 4.11: RATIOS OF CALORIES POTENTIALLY DERIVED FROM NATIONAL FOOD PRODUCTION BY 2050 UNDER CLIMATE CHANGE FOR THE CZ SCENARIO VERSUS CALORIES FROM HISTORICAL (2000–2010) NATIONAL PRODUCTION



Source: Authors. Orchards, potato and vegetables can be prioritized for export. Ratios above 1 show that relative to historical, calories derived from national production will increase. On the other hand, ratios below 1 indicate that calories derived from national production will decrease relative to historical.

more acceptable standards of around 2,750 kcal per capita per day. To improve nutritional quality, Lesotho could also step up its biofortification efforts to cover beans, maize, wheat, and sorghum. Biofortification, a technique that uses conventional breeding methods to produce more nutritious crops—with a higher content of vitamin A, zinc, iron, or other micronutrients than standard crop varieties—could contribute to healthier diets in Lesotho.

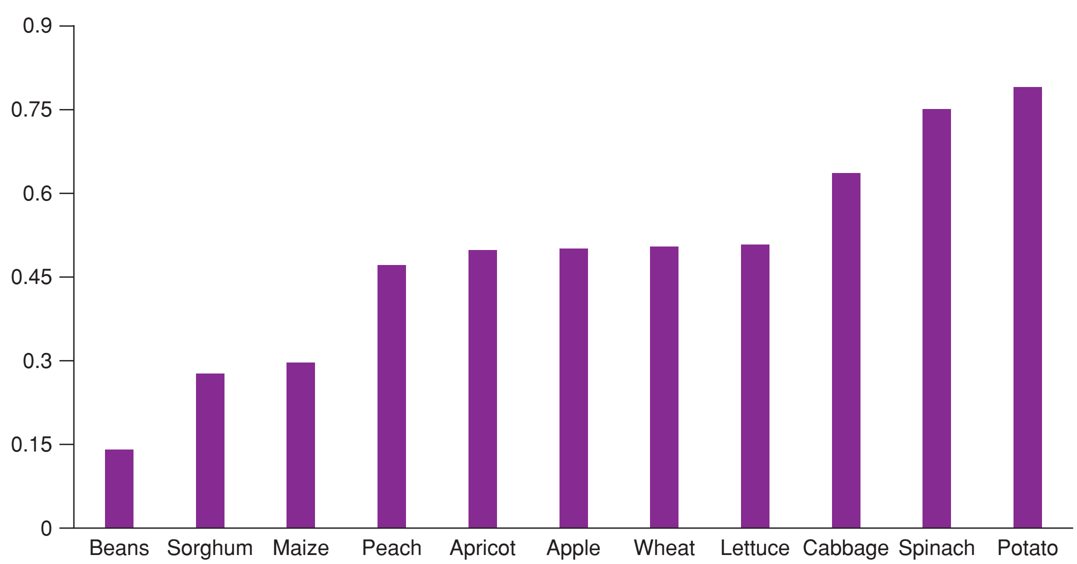
125. **The high point of the analysis on food calorie intake and export is that there is an urgent need to increase production to meet caloric food demand and other needs in Lesotho.** Yield gap measured as the ratio of predicted yields by 2050 divided by attainable yield varies from 0.2 for beans to 0.8 for potato (figure 4.12). Except wheat, the yield gaps for cereals are below half of the attainable yields. Intensification and extensification (that is, expansion of agriculture) are the two main options available to

meet the growing crop demands. The study indicates that to meet the food calorie demand by 2050, cropland must expand to 682,000 ha under the RL scenario or 696,000 ha under the CZ scenario. Such land expansion is clearly unsustainable given the fragile nature of Lesotho's landscape. Land expansion to natural vegetation will increase soil erosion and GHG emissions and adversely affect biodiversity and ecosystem services. It is therefore crucial to design location-specific input and management strategies for closing the yield gap. Constraints to be addressed to effectively narrow yield gaps are discussed in chapter 5.

4.8 Soil erosion

126. **Land degradation is rampant in Lesotho and needs to be controlled due to the significant social and economic costs to the country.** Cropland occupying about 1 percent of Lesotho's entire land area has been degraded, while another 1 percent of the country's land area has been converted to gullies. Some 2.7 percent of the country has been rendered entirely bare land, while more than 11 percent occupied by pasture has been degraded. The annual cost of land degradation in Lesotho is estimated at US$57 million, equivalent to 3.6 percent of the country's GDP.[19] The returns on taking actions against land degradation in Lesotho, estimated at US$6 for every US$1 invested in restoring degraded land provides a clear justification for bold actions to reduce land degradation in the country. Catchment-to-catchment comparison indicates that predicted soil loss is lowest under the RL scenario and highest under the CT scenario, indicating positive effects of CSA adoption in controlling erosion.[20] The range of average predicted erosion rates are 0.06 to 20 ton per ha per year for the CZ scenario, 0.06 to 18.01 ton per ha per year for the RL scenario, and 0.08 to 24.09 ton per ha per year for the CT scenario. Higher average erosion rates are associated with land areas with steep topography, indicating the strong influence of slope length and slope steepness factors on soil loss. Under the CT scenario, some 58 percent of the sub-catchments have predicted

FIGURE 4.12: LESOTHO CROP YIELD GAP



Source: Authors. Based on yield data provided by Department of Agricultural Research, Lesotho.

Note: All values are below 1, indicating that estimated yields by 2050 for the crops are below the attainable yields.

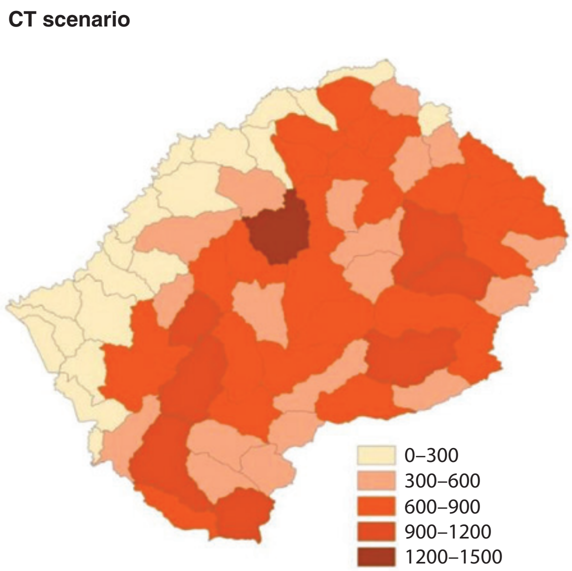
[19] https://www.unccd.int/sites/default/files/inline-files/Lesotho.pdf.

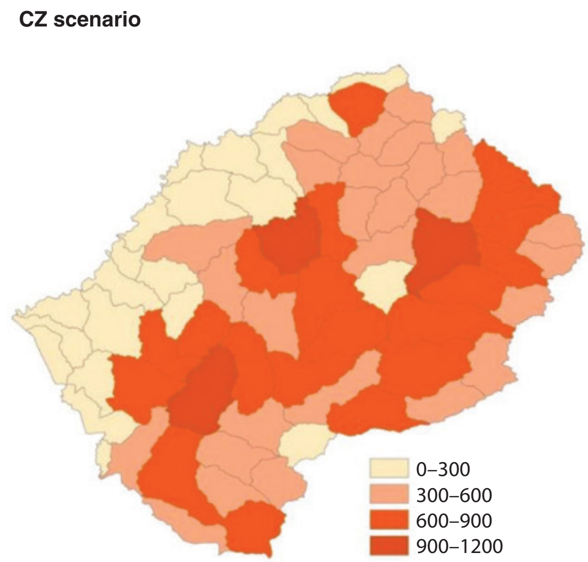
[20] The Revised Universal Soil Loss Equation (RUSLE) (Renard et al. 1997) was used to quantify and understand the distribution of soil erosion in Lesotho's catchment. The RUSLE model represents how climate, soil, topography, and land use (that is, vegetation or soil cover) affect soil erosion caused by raindrop impacts. The model has been extensively used to estimate soil erosion loss; assess soil erosion risk; and guide development and conservation plans to control erosion under croplands, rangelands, and forest lands. The application of RUSLE in this report only covers sheet and rill erosion, as the model does not give an estimate of gully erosion.

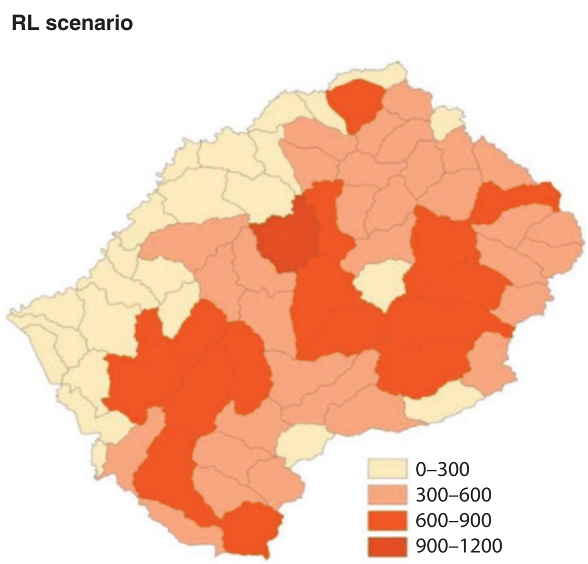
erosion rates higher than 10 ton per ha per year, the commonly accepted maximum average (tolerable) annual soil loss that will permit production levels to be maintained economically (figure 4.14). This proportion declines to 42 percent and 36 percent for the CZ and RL scenarios, respectively, but still reflects the magnitude of the soil erosion menace in Lesotho. In terms of land cover, table 4.9 reveals the highest erosion rates on grassland and shrubland across the scenarios. This confirms that poor rangeland management is the primary cause of soil erosion and land degradation in Lesotho. Integrated catchment management efforts for addressing the problem need to consider among other factors terracing, check dams, grassland reseeding, rotational grazing, protection and demarcation of grazing reserves, fodder production, and capacity building for rangeland fire management.

127. **Low tolerance for soil erosion is indispensable for soil carbon conservation.** Removal of the vegetation cover aggravates losses by soil erosion and increases the rate of decomposition due to changes in soil moisture and temperature regimes.

FIGURE 4.13: PREDICTED SOIL LOSS UNDER CLIMATE CHANGE FOR THE SCENARIOS FOR LESOTHO'S SUB-CATCHMENTS (THOUSAND TONS PER YEAR)

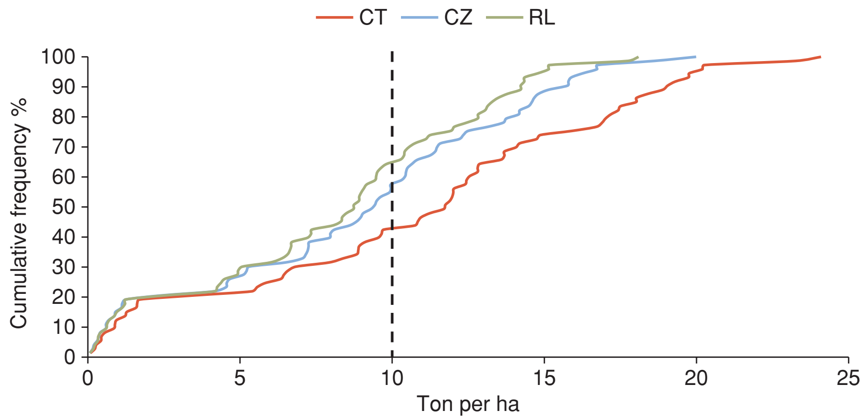






Source: Authors

FIGURE 4.14: CUMULATIVE FREQUENCY DISTRIBUTION OF AVERAGE EROSION RATES ACROSS SUB-CATCHMENTS FOR THE SCENARIOS



Source: Authors

TABLE 4.9: EROSION RATES BY LAND COVER (TON PER HA PER YEAR)

Land cover	Mean erosion rates		
	CT	CZ	RL
Cropland	14.30	11.43	10.73
Grassland	23.83	19.47	17.92
Shrubland	23.99	19.51	18.03
Forest	12.83	10.11	9.59

Source: Authors

Because soil organic matter is concentrated on the soil surface, accelerated soil erosion leads to progressive depletion of soil carbon.

4.9 Pest infestation under climate change

128. **Agricultural pests have large impacts on production in Lesotho.** The African armyworm (*Spodoptera exempta*) is one of the economically important pests affecting crop yields. Although Lesotho recorded African armyworm outbreaks as early as the early 1990s, control measures were easier and effective, as outbreaks were limited to grasslands, and thus exerted minimal impacts on the economy. The African armyworm outbreak that swept across the country in 2013, however, resulted in significant impacts on crops and rangelands. Cereal production and rangelands in 8 of the country's 10 districts were affected with about 90 percent of the damage concentrated in Berea, Leribe, Maseru, and Mafeteng districts. More than 36,000 ha representing over 25 percent of the planted area were affected with the largest losses of up to 100 percent occurring for maize. As grasslands are often breeding grounds for thousands of armyworms, the pest also severely affected rangelands, an essential source of feed for livestock.

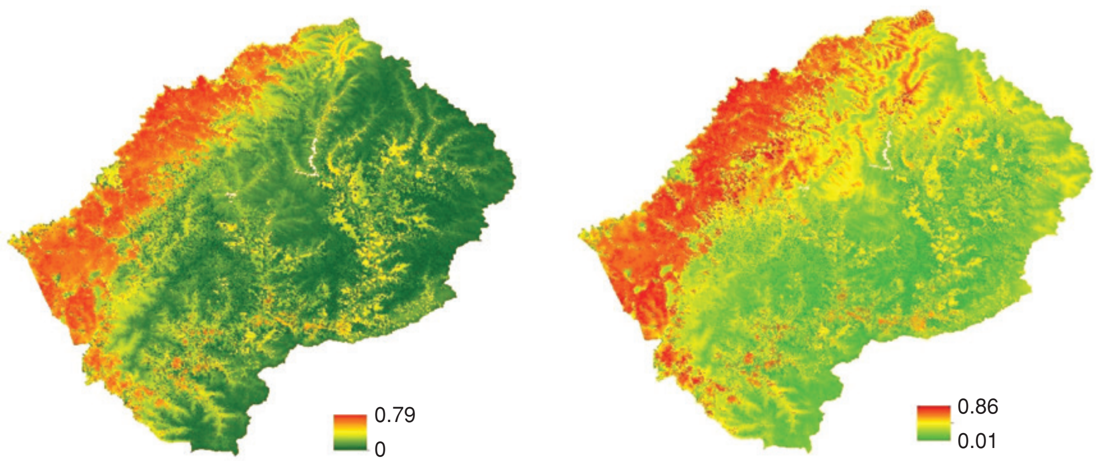
129. **Climate change will likely increase the probability of African armyworm infestation in Lesotho.** The probability of occurrence of African armyworm in Lesotho was estimated using the occurrence data from January–March 2013 as the training data. These training data were combined with location data to derive predictive relationships for the future occurrence of the pest. The predictor variables included elevation, land use, soil type, minimum temperature, maximum temperature, and monthly precipitation. Figure 4.15 (left) shows the probability of occurrence associated with the 2013 infestation and may be regarded as the no climate change scenario. Figure 4.15 (right) is the predicted probability map under projected climate change. The model predicts higher probabilities of agricultural pest infestation and potentially larger affected land area under climate change. The highest predicted probability of pest infestation was 0.8 under no climate change but increased to about 0.9 under climate change. Affected areas with probabilities of infestation greater than 0.4 under no

TABLE 4.10: ESTIMATES OF EROSION-INDUCED CARBON EMISSIONS UNDER CLIMATE CHANGE

Scenario	Gross erosion (thousand tons per year)	Soil carbon displaced by soil erosion (2–3% of sediment; thousand tons of carbon per year)	Emissions (20% of displaced soil carbon; thousand tons of carbon per year)	Emissions in carbon dioxide equivalent (thousand tons)
CT	48,126	962–1,444	192–289	704–1,061
RL	34,968	699–1,049	140–210	514–771
CZ	38,515	770–1,155	154–231	565–848

Source: Authors
Note: Rates of carbon depletion were adapted from Lal (2003).

FIGURE 4.15: PREDICTED PROBABILITIES OF AFRICAN ARMYWORM INFESTATION UNDER NO CLIMATE CHANGE (LEFT) AND CLIMATE CHANGE (RIGHT)



Source: Authors

climate change scenario increased from 709,000 ha to 928,000 ha under climate change (table 4.11). This result indicates that Lesotho must be well prepared for future pest outbreaks. A clear strategy for the control of migratory pests, including development of an effective monitoring and surveillance system, is urgently needed.

TABLE 4.11: LESOTHO LAND AREA UNDER DIFFERENT PREDICTED PROBABILITY OF PEST INFESTATION

Predicted probability	Without climate change		With climate change	
	ha	%	ha	%
< 0.4	2,776,129	80	2,555,531	73
≥ 0.4	709,179	20	927,823	27

4.10 GHG emissions

130. **Reducing emissions within the agricultural sector may contribute significantly to Lesotho's NDC target.** From 2010 to 2016, total GHG emissions in Lesotho have risen from 2.8 million tCO_2eq per year to 3.2 million tCO_2eq per year. During this period, the agricultural sector accounted for 40–50 percent of Lesotho's total emissions (FAOSTAT 2019). Table 4.12 indicates that under the CT scenario, gross GHG emissions will increase by 32 percent to 1.6 million tCO_2eq relative to historical emissions. A similar trend is found under the CZ scenario, while under the RL scenario, gross GHG emissions decrease by 45 percent to 0.7 million tCO_2eq. Livestock dominates the GHG emissions sources for the three scenarios.

Afforestation and rangeland improvement are carbon sinks under the RL and CZ scenarios avoiding emissions of about 0.3 million tCO_2eq and 0.2 million tCO_2eq under CZ, respectively.

131. **There are several options for lowering GHG emissions in the livestock subsector, while also improving productivity and resilience (table 4.13).** The technologies cover three broad aspects of climate-smart livestock production: breeding, feeding, and health management. Some technologies—such as sustainable livestock intensification, carbon sequestration in rangelands, and reducing emissions from manures—could help reduce total emissions, while other technologies, such as stress-tolerant breeds and artificial insemination (AI), are more likely to reduce the intensity of emissions, rather than total emissions (Herrero et al. 2016). Yet, some other technologies, such as inhibitors and selecting for low methane ruminants, are at the proof of concept stage and would require experiential learning and adaptation before being rolled out for large-scale adoption (figure 4.16).

TABLE 4.12: ANNUAL GHG EMISSIONS (tCO_2eq) UNDER THE SCENARIOS

	Current total	From crops	From livestock	From Land Use Change	2050 Total	From crops	From livestock	From Land Use Change
CT	1,224,000	10,089	1,213,911	−183,333	1,618,510	18,795	1,599,716	0
CZ	1,224,000	10,089	1,213,911	−183,333	1,605,181	102,534	1,696,434	−193,787
RL	1,224,000	10,089	1,213,911	−183,333	673,489	3,710	1,054,389	−384,611

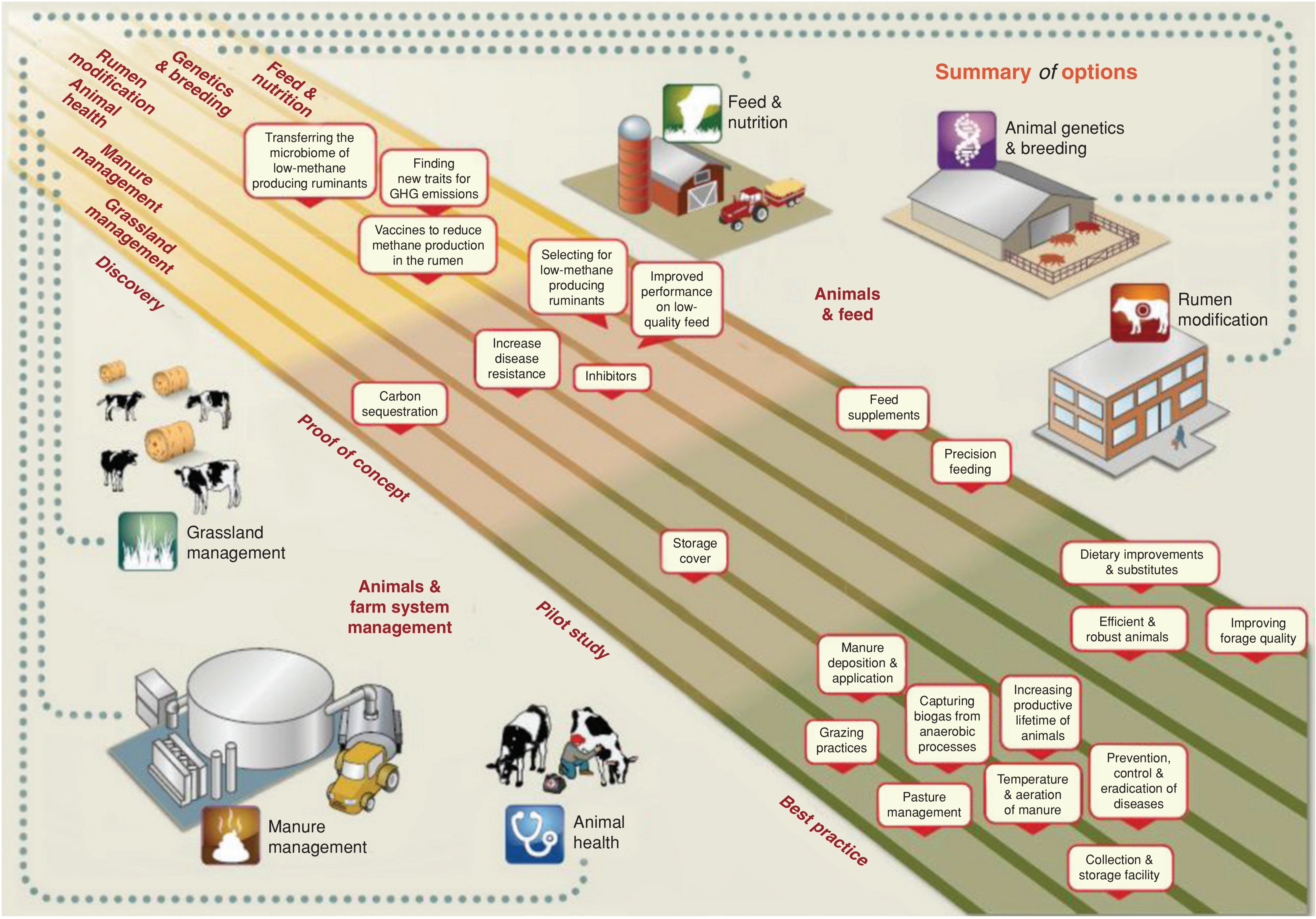
Source: Authors

TABLE 4.13: CLIMATE-SMART OPTIONS FOR LIVESTOCK PRODUCTION AND THEIR CONTRIBUTION TO THE CSA PILLARS

Technologies	P	R	M
Stress-tolerant breeds	✓	✓	✓
Animal breeding: AI technologies for increased productivity (support to bull/semen stations and procurement of semen)	✓	✓	
Selection for low methane producing animals	✓		✓
Animal nutrition rations for livestock value chains	✓	✓	✓
Planting better grasses and legumes and distribution of climate-ready forage seeds	✓	✓	✓
Manure management	✓		✓
Incorporation of dietary supplements in livestock feeds	✓	✓	✓
Internet- and mobile-based disease reporting system to alert users of disease outbreaks and potential actions	✓	✓	
Operationalization of epidemiological surveillance networks	✓	✓	
Active disease surveillance and implementation of biosecurity measures for livestock diseases	✓	✓	✓
Virus characterization and vaccines matching	✓	✓	
Diseases screening in dairy farms	✓	✓	✓
Combating antimicrobial resistance	✓	✓	
Improving milk collection centers	✓	✓	
Quality control of livestock products inspection	✓	✓	

Source: Authors
Note: P = Productivity; R = Resilience; and M = Mitigation.

FIGURE 4.16: GHG MITIGATION OPTIONS IN LIVESTOCK



Source: Global Research Alliance (2013).

Note: Discovery = exploring promising concepts for future proof of concept; Proof of concept = the measure has been demonstrated in an experimental setting, next step is a pilot; Pilot = pilot project has been carried out, next step is commercial development; and Best practice = measure has been successfully implemented in diverse contexts, next step is scaling up.

132. **Emissions intensity, defined as the quantity of GHG emitted per unit of produce declines following the implementation of CSA practices therefore positively contributing to climate change mitigation.** While the overall activity level of RL and CZ scenarios leads to larger total emissions, the CSA strategies implemented within these scenarios generate higher yields such that the emissions intensity decreases in these scenarios relative to CT. For crops, the decline in emission intensity ranges from 1.1 tCO_2eq per ton product for potato and vegetables to 20.4 tCO_2eq per ton product for legumes. Switching to climate-smart livestock practices leads to a decline in livestock emission intensity, ranging from 1 percent for sheep and goats to 37 percent for poultry. The average decrease in livestock emissions intensity, estimated at 21 percent, is lower than the 25 percent CSA target for the country.

4.11 Impact of CSA adoption on job creation

133. **Adoption of CSA practices could create jobs in Lesotho's horticulture subsector.** One of Lesotho's most vital development agenda is to ensure economic growth that translates into stable, wage-paying jobs. In line with NSDP II that recognizes agriculture as one of the potential sectors for job creation and inclusive economic growth, this report also examines how agricultural change under the different scenarios could create stable jobs and thus improve the rural economy. As reflected in table 4.15, labor requirements and therefore job creation potential differ among cropping systems from 10 jobs for every 1,000 ha for maize to 1,300 jobs for every 1,000 ha of orchards and vegetables. Under the CT scenario, potato, orchards, and vegetables farming are the main job creators (2,700–7,150 jobs). Shifting from low-value grain production to more labor-intensive and higher value-added crops (potato, orchards, and vegetables) generates more jobs especially under the CZ scenario. Staple crops such as maize, beans, sorghum, and wheat are inherently the lowest job creators under the scenarios while orchards and vegetables in the CZ scenario generate the highest numbers (14,300–15,600 jobs).

TABLE 4.14: GHG EMISSION INTENSITIES FOR CROPS AND LIVESTOCK (tCO_2eq PER TON PRODUCT)

	Conventional	CSA	Difference
Crops			
Maize	2.2	−11.7	−13.8
Maize - CA		−8.2	−8.2
Other cereals	1.3	−6.1	−7.4
Legumes: beans and peas	8.4	−11.9	−20.4
Potato and vegetables	0.4	−0.7	−1.1
Livestock			
Dairy cattle	115.38	78.54	−32
Other cattle	316.61	245.57	−22
Sheep	3.38	3.34	−1
Pigs	0.18	0.12	−32
Goats	2.32	2.29	−1
Poultry	0.07	0.04	−37

Source: Authors

134. **The key to job creation in Lesotho's agriculture sector is taking a value chain approach.** An agricultural value chain is a set of linked activities that add value to an agricultural product. It comprises a set of actors and actions that improve the product while linking commodity producers to processors and markets (figure 4.17). Depending on

TABLE 4.15: ESTIMATED NUMBER OF FARMING JOBS CREATED UNDER CLIMATE CHANGE

	Coefficient (jobs/ha)	CT	RL	CZ
Beans	0.02	609	475	472
Maize	0.01	1859	438	235
Orchards	1.30	6658	10643	16599
Potato	0.30	3194	3060	4614
Sorghum	0.05	2013	1956	1486
Wheat	0.05	992	1077	779
Vegetables	1.30	10484	10033	15193
Total		**25,809**	**27,682**	**39,378**

Source: Data on number of jobs per ha for different cropping systems are modified from World Bank (2011, 2018a).

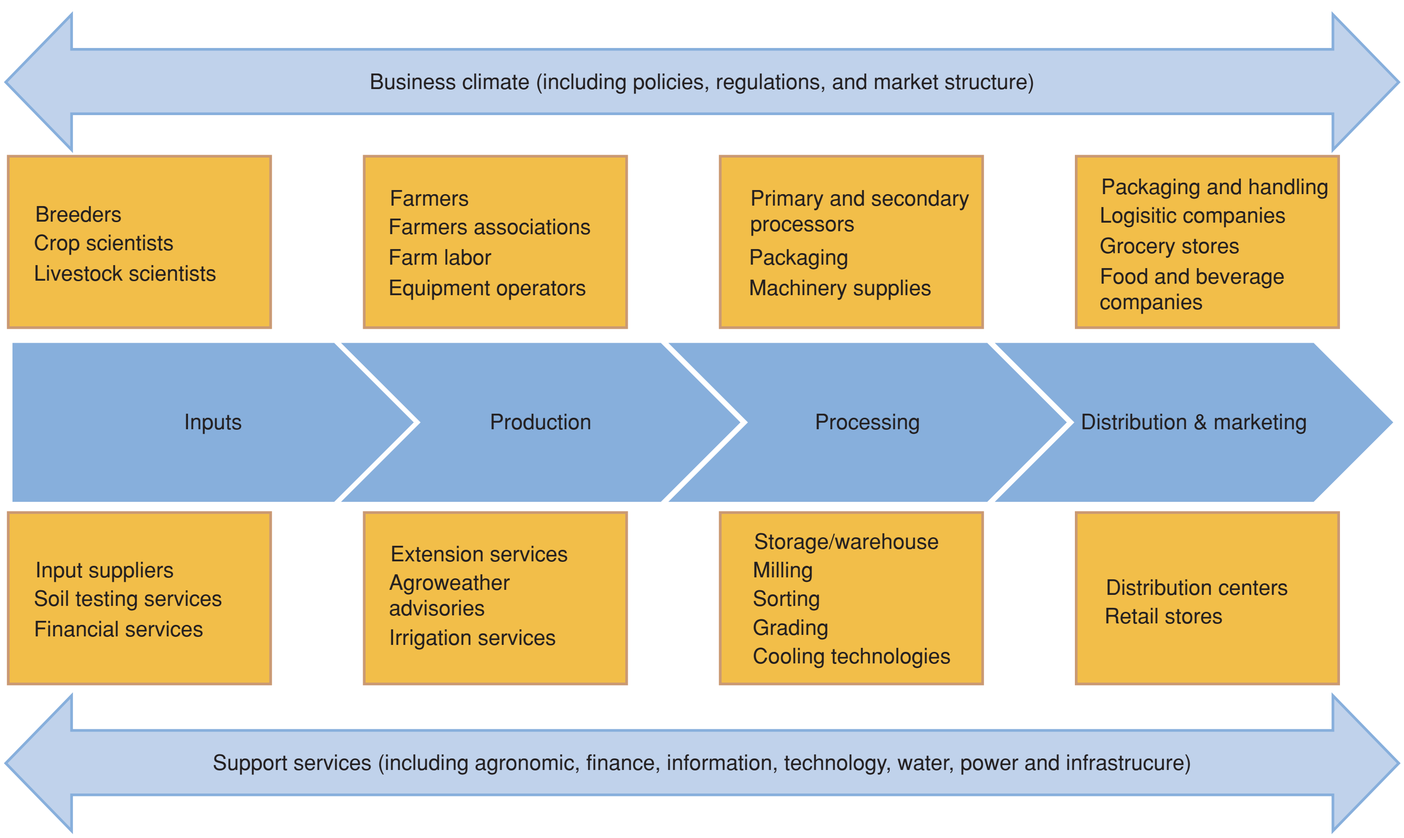
the nature of the product, several actors are directly or indirectly involved in different aspects of the value chain. The key to a job-focused agricultural value chains are identifying opportunities for job creation (more jobs); empowering small farms to capture more value (better jobs); and integrating small farms with established sources of demand (inclusive jobs). The pathways to more, better, and inclusive jobs in Lesotho's agricultural sector are indicated in table 4.16. Lesotho currently has the highest readiness to operationalize the skills, incubation and agripreneurs pathway focusing on youth development, and the jobs through aggregation pathway focusing on helping existing producer organizations to become SMEs.

135. **Unlocking the job creation potential in the commercial horticulture subsector will require Lesotho to exploit its comparative advantage in the production of fruits and vegetables.** Lesotho's climate is favorable to production of many vegetables and deciduous fruits. Due to the country's high altitude, Lesotho's fruits can be harvested 2 to 3 weeks earlier than those of RSA's Western Cape Province (the main center for fruit production), resulting in price premiums for Lesotho producers. To strategically capitalize on this comparative advantage, Lesotho can also build on its proximity to RSA, a leading global exporter of fruit that has advanced research institutions, export infrastructure, and market intelligence (World Bank, 2018b). Lesotho's access to water resources can also make it an attractive investment destination for private sector investment from the water-scarce Western Cape Province if the irrigation infrastructure is developed.

4.12 Linkages between SDGs and NDC in Lesotho

136. **Scaling up CSA will help Lesotho in simultaneously meeting its SDG and NDC commitments.** There are a lot of synergies between Sustainable Development

FIGURE 4.17: AGRICULTURAL VALUE CHAIN ECOSYSTEM



Source: World Bank Group—Future of Food

TABLE 4.16: PATHWAYS TO AGRICULTURAL JOBS IN LESOTHO

Pathways	Examples	Readiness to operationalize pathways
Informal and Formal SMEs	Transform micro enterprises to SMEs Support transition from informal to formal organizations Services, inputs, and other direct and indirect activities across the value chains	Low–Medium
Skills, incubation, and agripreneurs (focus on youth)	Incubation Technical and Vocational Education and Training Agripreneur programs Agriculture programs in Universities	High
Social enterprises	Scouting and scaling up innovative business models Digital agriculture using ICT Venture capital	Low
Productive alliances with large and mid-size agribusiness companies	Linking smallholders with agribusiness companies in value chains	Medium
Jobs through Aggregation	Supporting farmer organizations to become SMEs	High

Source: Modified from World Bank (2018d). Readiness rankings in the last column were based on Authors' assessment.
Note: ICT = information and communication technology; SMEs = small and medium enterprises.

Goals (SDGs) and Nationally Determined Contribution (NDCs). SDGs are a plan of action by countries to address the most pressing development challenges, whereas NDCs are an outline of country-level adaptation and mitigation strategies to address climate change. Lesotho's NDCs specifically highlight the adoption of climate-smart agriculture for improving food security and farmers income. The NDCs also state the importance of afforestation, reforestation and protecting forests for their economic and ecosystem services, among other measures.

Lesotho's NDCs stress the co-benefits of climate actions for six SDGs: poverty reduction, food security and zero hunger, employment generation, waste reduction, and sustainable management of land. The potential contribution of CSAIP to the NDCs and SDGs are indicated in table 4.17.

TABLE 4.17: SDGS–NDCS LINKAGES IN LESOTHO

SDGs	Alignment of SDG and NDC	Potential CSAIP contribution
1: No poverty	Build resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.	Poverty is a rural phenomenon in Lesotho where majority depends on agriculture. Adoption of CSA will lead to 3 to 5 times increase in rural household income.
2: Zero hunger	Ensure sustainable food production systems and implement resilient agricultural practices that: • increase productivity, • maintain ecosystems, • strengthen climate change adaptation capacity, and • improve land and soil quality. Sustainable food production systems also help to reduce greenhouse gas emissions from the food system, thereby contributing to NDC targets	CSA is the core of Lesotho's ambition to end hunger. This report shows that food production will increase fourfold to sixfold following the adoption of climate smart practices. CSA will also reduce soil erosion to levels that will sustain production.

(*continued*)

TABLE 4.17: (Continued)

SDGs	Alignment of SDG and NDC	Potential CSAIP contribution
8: Decent work and economic growth	Achieve higher levels of economic productivity through diversification, technological innovation, including through a focus on climate-smart, high-value added and labor-intensive sectors.	CSA adoption could create jobs that will stimulate Lesotho's rural economy. Shifting from low-value grain production to more labor-intensive and higher value-added crops like potato, orchards, and vegetables could generate stable jobs for men and women.
12: Responsible consumption and production	Substantially reduce waste generation through prevention, reduction, recycling and reuse. Reduce carbon emissions through these processes	Lesotho CSAIP promotes IPM and postharvest management that will help reduce food loss and waste.
13: Climate action	Integrate climate change measures into national policies, strategies and planning. Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.	The CSAIP recommends wide ranging policy measures that will improve CSA knowledge systems and mainstream CSA into GoL strategies and policies.
15: Life on land	Promote the implementation of sustainable management of forests, halt deforestation, restore degraded lands, and substantially increase afforestation and restoration. These practices would help reduce climate vulnerability, enhance resilience and also help sequester carbon	Lesotho CSAIP promotes sustainable landscape management including afforestation, reforestation and rangeland management. The CSA practices promoted in this report will lead to increase in land-use efficiency through higher productivity, thereby reducing the need for clearing more land for agricultural production.

Source: Authors. Alignment of SDGs and NDCs modified from Climatewatch.[21]

4.13 Potential for meeting Lesotho CSAIP targets

137. **The analyses presented in chapters 3 and 4 enable us to assess the prospect of meeting Lesotho's CSA targets.** Table 4.18 shows that the probability of meeting the targets vary from low for increasing productivity and agricultural exports to high for reducing agricultural emissions and livestock emissions intensity. There are interdependencies in the prospect of meeting the targets; for instance, increasing agricultural productivity (target 1) is a prerequisite to doubling farmers' income (target 2), increasing exports (target 3), and to a lesser extent reducing agricultural emissions and livestock emissions intensity (targets 4 and 5). Thus, it is crucial that the CSAIP identifies an integrated solution that will address the potential constraints to meeting the targets, while synergistically delivering productivity and climate benefits to farmers.

[21] https://www.climatewatchdata.org/countries/LSO#ndc-sdg-linkages

TABLE 4.18: POTENTIAL OF MEETING LESOTHO'S CSA TARGETS

No.	Targets	Probability of meeting the target	Remarks
1	Increase yields of major staples by a factor of 2.5.	Low	Yield gap needs to be narrowed by introducing climate-ready, stress-tolerant species and cultivars adapted to Lesotho's context. Other constraints that must be addressed to effectively close the yield gap include weather-induced yield variability, soil fertility constraints, pest infestation, and market accessibility.
2	Double income of smallholder farmers.	Medium	Farmers' income more than doubles for most CSA practices, but cost of adoption may be a barrier to meeting this target.
3	Increase agricultural exports by a factor of 2.5.	Low	The target can be met if Lesotho is able to narrow yield gap, prioritize horticulture and potato for exports, and create the enabling environment for higher levels of CSA adoption.
4	Reduce agricultural GHG emissions by 25%.	High	Can be met following the adoption of climate-smart livestock practices under the RL scenario. Integrated catchment management will help reduce soil erosion and the associated loss of soil carbon. Better rangeland management will also help sequester carbon. Sustainable crop intensification will help reduce cropland expansion, while better livestock and manure management will also help put Lesotho on track of meeting this target.
5	Reduce livestock emissions intensity by 25 percent.	High	This target has the highest probability of being met by stepping up the adoption of climate-smart livestock practices. More efforts are particularly required in lowering emission intensities from goat and sheep.

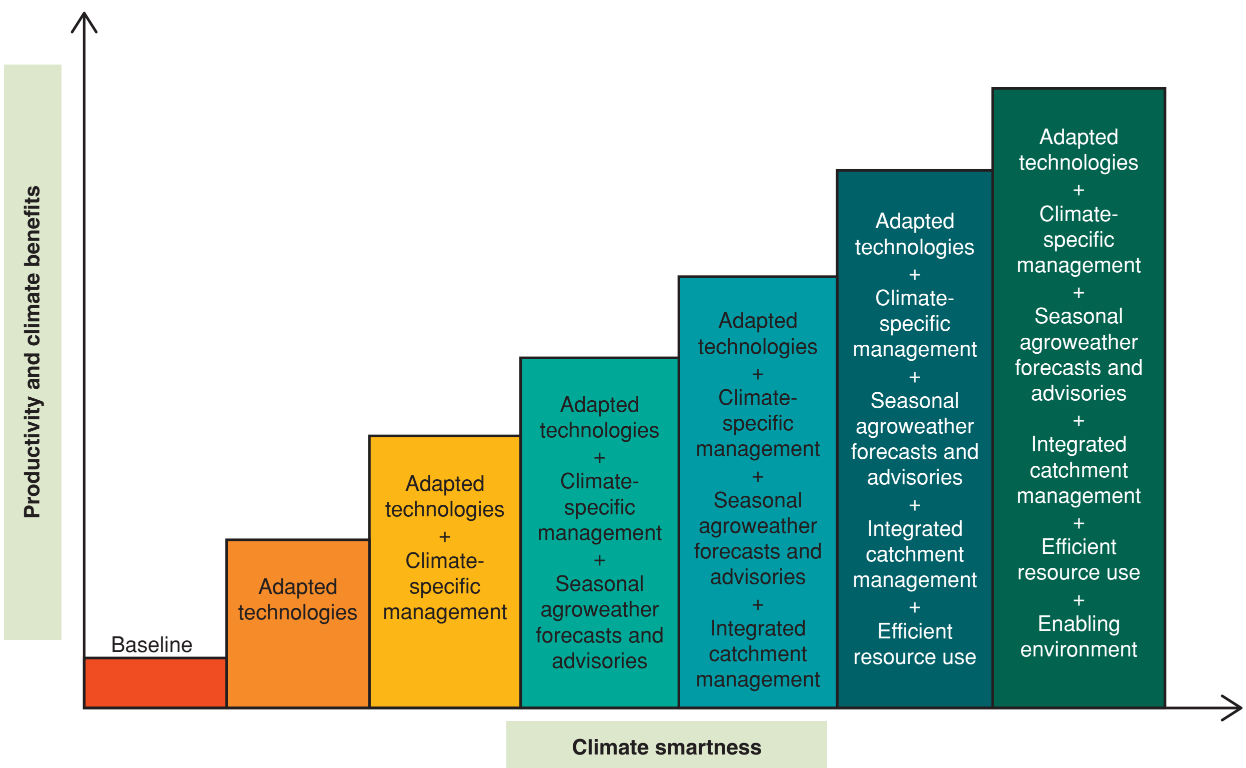
V.


Why Pay more?
Our CHRISTMAS PROMISE to you
TOM. ROMA
17.99 1KG
R15.99 500G
WELCOME TO OUR STORE WHERE WE SELL FRESHNES
R11.99KG
R14.99
Save more
prochef
HUNGRY LION

CSA Investment Needs

138. **To determine Lesotho's CSA investment needs, emphasis was placed on integrating proven CSA technologies that will minimize trade-offs and capitalize on synergies between CSA pillars as exemplified in figure 5.1 where successive addition of CSA technologies leads to an overall increase in productivity and climate benefits derived from the agricultural system.** Climate modeling indicates that yield variability is primarily due to rainfall deficits, implying that there is need for stress-resistant, higher yielding crop varieties, and greater cropping intensity to meet food demand. Increasing cropping intensity implies that expanding efficient irrigation and agricultural water management technologies is a key part of the CSAIP in Lesotho. In addition to improved water use efficiency, strengthening the adaptive capacity of smallholder farmers to adjust and modify their production systems to minimize the potential future impacts from climate variability will require solutions that improve soil health, and increase farm productivity. Regional demand for fruit and vegetables is likely to increase as urban populations grow, incomes rise, and the popularity of healthy diets increases. Higher production and sales of high value crops would also deepen domestic agricultural markets, generate rural employment and improve nutrition. Lastly, implementation of

FIGURE 5.1: RELATIONSHIP BETWEEN CSA BENEFITS AND CLIMATE SMARTNESS OF TECHNOLOGIES



Source: Modified from CCAFS (2014)

sustainable landscape management encompassing interventions from the micro-catchment scale managed largely by communities, to wider development among multiple sectors concerned with productive and non-productive land uses will help optimize ecosystem functions and services.

139. **As noted in chapter 4, very dry conditions can suppress yields, and the observed yield variability from crop simulations is primarily due to rainfall deficits.** This implies that there is need for higher crop yields and greater crop intensity to meet food demand. Thus, expanding the use of efficient irrigation and agricultural water management technologies is a key part of the CSAIP investment in Lesotho. This will entail promoting a more efficient use of surface water accompanied by a more sustainable use of groundwater, leading to improved availability and quality of water at the farm level. In addition to improved water use efficiency, strengthening the adaptive capacity of smallholder farmers to adjust and modify their production systems to minimize the potential future impacts from climate variability will require solutions that improve soil health, and increase farm productivity. Regional demand for fruit and vegetables is likely to increase as urban populations grow, incomes rise, and the popularity of healthy diets increases. Higher production and sales of high value crops would also deepen domestic agricultural markets, generate rural employment and improve nutrition. Lastly, implementation of sustainable landscape management encompassing interventions from the microcatchment scale managed largely by communities and other local stakeholders, to wider development among multiple sectors and stakeholders concerned with productive and non-productive land uses will help optimize ecosystem functions and services including food and agricultural production; ecological regulation of nutrients, carbon stocks, greenhouse emissions, and water flow and supply.

140. **Given the above considerations, four thematic areas have been identified and validated with stakeholders as priority areas for the CSAIP investments.** They are:

- Improve water management in rainfed and irrigated agriculture;
- Scale up CSA technologies for crops, livestock, and aquaculture;
- Promote market access for farmers; and
- Support sustainable landscape and integrated catchment management.

The components of these thematic areas are fully described in box 5.1 and annex 6.

141. **Under the RL scenario, total CSAIP financial costs amount to about US$268 million over a 5-year investment period, corresponding to investment costs of about US$54 million per year.** Under the CZ scenario, total CSAIP economic costs amount to about US$208 million over the 5-year investment period, or about US$42 million per year (table 5.1). Under both scenarios, it is assumed that there are no further investment costs after the fifth year, except for the costs of equipment, maintenance, and inputs which are included from year 6 to 30, as these costs will have to be incurred if the future benefits of the investment plans are to be sustained. Such costs are estimated at 10 percent of the yearly cost.

142. **The CSAIP indicates that total benefits accruing to society (excluding any external environmental benefit) amount to about US$31 million under the RL scenario and about US$63 million under the CZ scenario (tables 5.2 and 5.3).** The overall flow of CSAIP benefits is based on the number of household adopters. However, additional CSAIP benefits related to improved climate information services, modernization of land titling system, and reduced land degradation are also considered (annex 3), even though they are not directly related to the number of households that adopt CSA.

143. **Under the RL scenario, most of the benefits derive from rain-fed crop production (30 percent) and aquaculture (26 percent).** There is a switch from conventional to conservative practices for maize production: a loss of US$10.6 million from reduction in conventional maize production and a corresponding gain of US$6.9 million and US$2.1 million from increasing maize under CA and agroforestry, respectively.

144. **Under the CZ scenario, most benefits derive from irrigated crop production (40 percent) and aquaculture (40 percent).** A significant reduction in maize area under conventional management and the consequent reduction in the incremental benefits

BOX 5.1: BRIEF DESCRIPTION OF THE LESOTHO CSAIP COMPONENTS

Component 1: Improve water management in rainfed and irrigated agriculture

Enhanced and efficient water management is a key factor for adaptation and increasing the efficiency of other CSA measures. The CSAIP will promote off- and on-farm investments in hydraulic infrastructure to restore and improve water distribution and reduce losses, improve water use efficiency, and increase and regulate water access management and governance for household consumption and agriculture production, particularly in areas of high agricultural potential. The CSAIP investment activities will include: sustainable water management practices such as micro-irrigation, water harvesting; modernization of hydraulic infrastructures, and strengthening institutions for effective agricultural water management.

Component 2: Scale up CSA technologies for crops, livestock and aquaculture

This CSAIP component will promote integrated soil fertility management; agroforestry; and conservation agriculture. For livestock, the CSAIP will finance three key interventions: improving access to better livestock breeds, improving animal nutrition; and improving access to animal health services. For aquaculture, the CSAIP will focus on improved stocks, production intensification, better feeding practices, and improved water use efficiency in the ponds.

Component 3: Promote market access for farmers

Activities to be supported under this component include: development of Agriculture Clusters Service Enterprises; development of Market Hub Enterprises; aggregation of smallholder farmers into upgraded commodity value chains; piloting weather index insurance to manage risks; and promoting food quality standards. The component will also support the development of integrated climate information services through public-private partnership.

Component 4: Support sustainable landscape and integrated catchment management

This component will finance structural and vegetative measures of sustainable landscape management. The structural measures include terracing; gully control; flood control; and check dams. The vegetative measures include afforestation/reforestation and grassland rehabilitation. In addition, the component will finance the modernization of land administration through digital land registry and titling, spatial data infrastructure development, and capacity building for land administration.

TABLE 5.1: CSAIP INVESTMENT COSTS (US$, THOUSANDS PER YEAR)

Components	RL	CZ
1. Improve water management in rainfed and irrigated agriculture	14,944	18,382
2. Scale up CSA technologies for crops, livestock, and aquaculture	15,473	9,793
3. Promote market access for farmers	5,882	4,272
4. Support sustainable landscape and integrated catchment management	17,207	9,210
Total amount per year	**53,505**	**41,658**
Total over the complete investment period (5 years)	**267,525**	**208,288**

Source: Authors

are accompanied by an increase in the area under vegetables, potato, and fruits. A reduction in the benefits from sheep and poultry is also recorded due to the reduction in animal numbers under the scenario.

145. **Due to conservative assumptions on adoption rates, the CSA benefits are most likely underestimated.** The two scenarios differ for the number of hectares for each crop and the number of livestock heads. Results are based on the assumptions made about the adoption rate, that is, the proportion of farmers implementing the CSA options promoted within the CSAIP. The assumptions that only 40 percent of farmers

TABLE 5.2: FLOW OF ECONOMIC BENEFITS (US$, THOUSANDS PER YEAR) OF THE CSAIP UNDER THE RL SCENARIO

Phasing of the investment plan	Y1	Y2	Y3	Y4	Y5	TOTAL
Crop production						
Rain-fed	588	882	1,176	1,470	1,763	**5,878**
Irrigated	164	247	329	411	493	**1,644**
Maize	−1,061	−1,591	−2,121	−2,651	−3,182	−10,605
Maize (CA)	691	1,036	1,381	1,727	2,072	6,907
Maize (Agroforestry)	215	322	430	537	644	2,148
Sorghum	186	278	371	464	557	1,855
Wheat	175	262	350	437	525	1,750
Legumes	307	461	615	768	922	3,073
Potato	290	435	580	725	869	2,898
Fresh vegetables	123	184	246	307	369	1,230
Orchards	41	62	83	104	124	415
All crops	967	1,451	1,934	2,418	2,901	9,671
Livestock rearing						
Cattle	256	384	512	640	767	2,558
Dairy cows	67	100	134	167	201	670
Goats	42	62	83	104	125	415
Sheep	89	133	177	222	266	886
Pig	136	205	273	341	409	1,364
Poultry	24	35	47	59	71	236
Animal draft power						
Horse and cart	404	607	809	1,011	1,213	4,044
Donkey and plough	64	96	128	160	192	639
Non-timber forest products (NTFPs) and medicinal plants	434	434	434	434	434	2,172
Aquaculture						
Trout production	1,648	1,648	1,648	1,648	1,648	8,240
Total	4,131	5,155	6,179	7,203	8,227	**30,894**

will switch from conventional to CSA production are conservative, and thus, the estimation of economic benefits is most likely underestimated. In the CZ scenario, a bigger number of aquaculture households is assumed; 400 households under resilient landscape scenario compared with 2,000 households under commercialization scenario. Thus, over a 5-year investment period, scaling up aquaculture is projected to yield economic benefits of $8.2 million for the Resilient Landscape Scenario and $24.7 million for the Commercialization Scenario (tables 5.2 and 5.3). The CZ scenario also assumes expanded area for medicinal plants and other high-value products (mushroom production). In addition, in the same scenario, it is implicitly assumed that a bigger role will be played by improved water management, since it will make possible the expansion of fresh vegetables and irrigated, high-value fruit production systems.

TABLE 5.3: FLOW OF ECONOMIC BENEFITS (US$, THOUSANDS PER YEAR) OF THE CSAIP UNDER THE CZ SCENARIO

Phasing of the investment plan	Y1	Y2	Y3	Y4	Y5	TOTAL
Crop production						
Rain-fed	1,109	1,558	2,007	2,456	2,905	**10,033**
Irrigated	1,324	1,986	2,648	3,310	3,972	**13,241**
Maize	−380	−570	−761	−951	−1,141	−3,803
Maize (CA)	121	181	242	302	362	1,208
Maize (Agroforestry)	0	0	0	0	0	0
Sorghum	62	93	123	154	185	617
Wheat	−15	−23	−31	−38	−46	−153
Legumes	447	670	894	1,117	1,341	4,470
Potato	898	1,347	1,796	2,245	2,694	8,980
Fresh vegetables	1,076	1,614	2,152	2,690	3,228	10,761
Orchards	248	372	496	620	744	2,481
All crops	2,456	3,684	4,912	6,140	7,368	24,560
Livestock rearing						
Cattle	102	152	203	254	305	1,016
Dairy cows	30	46	61	76	91	305
Goats	111	167	222	278	333	1,110
Sheep	−49	−73	−97	−122	−146	−487
Pig	917	1,375	1,834	2,292	2,751	9,170
Poultry	−44	−67	−89	−111	−133	−444
Animal draft power						
Horse and cart	194	292	389	486	583	1,944
Donkey and plough	33	50	67	83	100	333
NTFPs and medicinal plants	94	94	94	94	94	470
Aquaculture						
Trout production	4,120	4,944	5,768	5,768	4,120	24,720
Total	7,965	10,664	13,363	15,239	15,466	**62,697**

TABLE 5.4: CSAIP PROFITABILITY INDICATORS WITHOUT CARBON BENEFITS

Summary results	EIRR (%)	NPV @ 10%, US$, millions
RL	**13**	**40**
CZ	**32**	**228**

Source: Authors

146. **The proposed CSAIP will generate positive returns, above the opportunity cost of capital under both scenarios.** The overall EIRR of the investments plan is estimated at about 13 percent (base case, RL scenario) and about 32 percent (base case, CZ scenario) which is above the opportunity cost of capital in Lesotho estimated at 10 percent. The NPV is about US$40 million and US$228 million

over the 30-year period of analysis, under the RL and CZ scenarios, respectively. The profitability is higher under the CZ scenario, characterized by more commercially oriented assumptions.

147. **The profitability indicators provide the evidence base on the suitability of the CSAIP investment.** The indicators are comprehensive of all costs and benefits. However, while it is assumed that investment costs are mainly public, the estimated benefits are estimated on-farm. A transfer of resources from the public sector to the smallholder farmers is therefore implicitly assumed in the CSAIP. Nevertheless, eventual contributions from the private sector to the funding of the CSAIP could be in the interest of the private sector itself which would directly and indirectly benefit from the economic development of the agriculture sector in Lesotho.

148. **The EIRR and NPV were subject to sensitivity analysis to measure variations due to unforeseen factors and account for risk.** Criteria adopted in the sensitivity analysis are 10 percent and 20 percent cost overrun, 10 percent and 20 percent increase in benefits, and 10 percent and 20 percent benefits decrease (table 5.5).

149. **As expected, when costs increase, and benefits decrease (or are delayed), the profitability of the investment plan worsens (as indicated by decreases in EIRR and NPV).** Many land management technologies, such as agroforestry, terracing, flood control, gully reshaping, and erosion control, entail significant up-front expenditures before benefits are realized. When benefits increase, the EIRR and NPV increase, as well.

150. **The CSAIP is also robust to the number of CSA adopters.** The break-even point to have a profitable investment (expressed in terms of minimum number of beneficiaries needed to obtain a positive NPV) equals 4,972 households, corresponding to a decrease in the adoption rate from 40 percent to about 1 percent under the RL scenario; it equals 7,555 households, corresponding to a decrease in the adoption rate from 25 percent to about 2 percent under the CZ scenario. This indicates that the CSAIP is very robust in relation to a possible decrease in the number of CSA adopters.

151. **Carbon valuation markedly increases the benefits from CSA investments.** The mitigation impact of the CSAIP activities (annex 7) has been included in the economic analysis by valuing the GHG balance at two shadow prices of carbon: low (LSP) and high (HSP) (World Bank Group 2017). Table 5.6 indicates that the mitigation impact of the CSAIP are up to US$4.6–30 million per year for the RL scenario, under the LSP and HSP hypotheses, respectively. For the CZ scenario, the mitigation impacts of CSAIP-related activities are up to US$0.3–1.8 million per year, under the LSP and HSP hypotheses,

TABLE 5.5: SENSITIVITY ANALYSIS

RL Scenario									
	Base case	Cost increments		Benefits increments		Benefits decrease		Benefits delay	
		+10%	+20%	+10%	+20%	−10%	−20%	1 year	2 year
EIRR (%)	13.0	9.0	7.5	12.7	14.6	8.8	6.4	9.0	7.6
NPV @ 10% (US$, thousands)	39,700	−14,690	−38,808	34,488	59,549	−15,633	−46,055	−15,102	−37,401
CZ Scenario									
	Base case	Cost increments		Benefits increments		Benefits decrease		Benefits delay	
		+10%	+20%	+10%	+20%	−10%	−20%	1 year	2 year
EIRR (%)	31.6	26.5	23.5	34.2	38.5	26.1	21.7	22.7	18.6
NPV @ 10% (US$, thousands)	227,850	185,503	166,726	243,486	282,692	165,075	118,448	165,848	130,909

TABLE 5.6: ECONOMIC EVALUATION OF THE CSAIP MITIGATION IMPACT USING THE SHADOW PRICES OF CARBON

1 RL scenario						
Environmental benefits		**874,283 tCO_2eq per year**				
Phasing of the investment plan		**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Effective targeted households, % of the total	%	4	6	8	10	12
Adoption rate of CSA practices	%	40	40	40	40	40
Targeted households, % of the total	%	10	15	20	25	30
Social price of carbon—low	US$ per ton	40	41	42	43	44
Social price of carbon—high	US$ per ton	80	82	84	86	87
Environmental benefits—low carbon price	US$, thousands, per year	1,399	2,151	2,938	3,759	**4,616**
Environmental benefits—high carbon price	US$, thousands, per year	27,977	28,676	29,376	30,075	**30,425**
2 CZ scenario						
Environmental benefits		**84,066 tCO_2eq per year**				
Phasing of the investment plan		**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Effective targeted households, % of the total	%	3	4	5	6	8
Adoption rate of the CSA options	%	25	25	25	25	25
Target households, % of the total	%	10	15	20	25	30
Social price of carbon—low	US$ per ton	40	41	42	43	44
Social price of carbon—high	US$ per ton	80	82	84	86	87
Environmental benefit—low carbon price	US$, thousands, per year	84	129	177	226	**277**
Environmental benefits—high carbon price	US$, thousands, per year	1,681	1,723	1,765	1,807	**1,828**

Source: Authors. Detailed GHG assessment is found in Annex 7.

respectively. The benefits have been included in the economic analysis reported in table 5.7. When the mitigation impact of the CSAIP is included, the EIRR increases from 13 percent (base case) to about 16 percent (LSP) and 73 percent (HSP) and the NPV from US$40 million (base case) to US$76 million (LSP) and US$322 million (HSP) in the RL scenario. For the CZ scenario, the EIRR will increase from 31.6 percent (base case) to 31.8 percent (LSP) and 34.2 percent (HSP), and the NPV will increase from US$228 million (base case) to US$230 million (LSP) and US$245 million (HSP).

5.1 CSA adoption constraints

152. **This report demonstrates the productivity and climate benefits of CSA.** Improved crop varieties, Integrated Soil Fertility Management (ISFM), CA, and crop diversification increase yields and are therefore important for improving food security. Vegetable and high-value crop production, including medicinal plants and mushrooms, and aquaculture production can also be effective in diversifying and smoothening households' incomes, thereby increasing their resilience. Improved water use efficiency will also help minimize yields variability, while adoption of climate-smart livestock practices will help reduce methane. The expansion of orchards in addition to increasing incomes will help sequester carbon, while land rehabilitation and integrated catchment management will help address land degradation.

153. **Despite the productivity and climate benefits, the adoption of CSA can face significant socioeconomic and institutional barriers.** These include the need for significant up-front expenditures

TABLE 5.7: CSAIP PROFITABILITY INDICATORS INCORPORATING CARBON BENEFITS

LSP		
	CZ	**RL**
Economic NPV, US$, millions	228	40
Value of carbon at LSP, US$, millions	2	36
Economic NPV with carbon benefits, US$, millions	**230**	**76**
EIRR (%)	32	13
EIRR with carbon benefits (%)	32	16
HSP		
	CZ	**RL**
Economic NPV, US$, millions	228	40
Value of Carbon at HSP, US$, millions	17	282
Economic NPV with carbon benefits, US$, millions	**245**	**322**
EIRR (%)	32	13
EIRR with carbon benefits (%)	34	73

Source: authors. NPV is estimated at 10 percent discount rate.

on the part of poorer farmers, the non-availability of some inputs in the local markets, lack of information about the potential of improved techniques, and often limited capacity to implement the techniques. Certain techniques associated with CSA can be incompatible with traditional practices that farmers are accustomed with. The implementation of some practices requires collective action that may be lacking (World Bank 2018b).

154. **Ranking of adoption constraints against CSA practices by stakeholders reveals that inadequate implementation capacity (75 percent) and access to inputs or finance (71 percent) are the most critical adoption barriers for all groups of CSA practices (table 5.8 and figure 5.2).** Within crop management, the adoption of improved crop varieties (68 percent), postharvest management (68 percent), and IPM (65 percent) are influenced by the factors the most. For climate-smart livestock management, animal health control (75 percent), grassland reseeding (73 percent), and improved animal breeds (73 percent) suffer from the adoption constraints the most. For integrated catchment management, afforestation/deforestation (69 percent), small-scale irrigation (69 percent), and gully control (63 percent) are mostly influenced by the adoption factors. Livestock and grassland management are influenced the most, scoring highest across most of the adoption factors.

Land tenure influences agroforestry, rotational grazing, grassland reseeding, terracing, and land rehabilitation the most. Secure land tenure is critical to the sustainability of land use and CSA implementation. If land tenure cannot be protected effectively, farmers and commercial investors will be unwilling to invest, or will even give up long-term investments on farmland entirely. Inadequate research impacts the adoption of climate-smart livestock practices the most, with stakeholders scoring improved animal breeds and feeding practices as the most critically impacted (85 and 80 percent, respectively).

5.2 Improving the enabling environment for CSA implementation

155. **Critical to achieving CSA outcomes is an enabling environment that provides efficiency-enhancing public goods in addition to reforming policies that distort market prices and associated input use and production decisions (World Bank 2017, 2018c).** One area in which Lesotho could improve the enabling environment for CSA adoption is to realign agricultural support to break adoption barriers and promote CSA. Currently, fertilizer subsidies contribute 15 percent to maize production, 8 percent to wheat, 7 percent to sorghum, and a modest 3 percent to leafy vegetables. Although increased fertilizer use is vital to reduce deforestation, reverse nutrient depletion, and deliver food security and income benefits to rural poor, Lesotho's fertilizer subsidy program has not effectively targeted the farmers who need the inputs the most. The subsidy program has crowded out the private distributors that are needed for sustainable input markets due to uncertainties regarding government sales and pricing.

156. **An alternative to the fertilizer subsidy delivery method could be a time-bound market-smart subsidy (MKS) to promote market development**

TABLE 5.8: RELATIVE IMPACT OF FACTORS FOR ADOPTION OF CSA PRACTICES IN LESOTHO

	Inadequate access to finance including inputs and credits	Inadequate access to markets	Limited implementation capacity (awareness, skill, training, and education)	Land tenure issues	Research	Inadequate access to infrastructure (roads, storage facilities, and ICT)	Public policy	Average
Crop management								
Minimum soil disturbance, residue retention	48	40	80	50	65	35	60	54
Crop rotation	58	50	60	53	58	38	55	53
Agroforestry	73	48	73	70	63	43	68	62
Judicious fertilizer application	73	48	60	35	55	35	55	51
Organic fertilization	58	45	60	28	58	43	53	49
Inorganic fertilizer	73	58	58	35	55	43	48	53
Improved crop varieties	80	80	70	48	73	63	60	68
Integrated Pest Management	75	55	73	53	73	50	75	65
Postharvest management	75	75	88	35	83	60	58	68
	68	**55**	**69**	**45**	**64**	**45**	**59**	**58**
Livestock and grassland management								
Rotational grazing	60	45	70	78	63	43	80	63
Fire management	50	25	68	53	55	28	78	51
Grassland reseeding	85	63	80	80	78	43	80	73
Fodder production	88	70	78	70	75	43	55	68
Livestock diversification	75	70	85	50	73	55	55	66
Improved animal breeds	88	75	85	45	85	68	68	73
Animal and herd management	68	50	68	68	63	53	68	62
Animal diseases and health control	88	80	80	55	75	70	78	75
Improved feeding practices	70	63	78	50	80	60	63	66
Manure management	58	40	70	38	60	58	60	55
	73	**58**	**76**	**59**	**71**	**52**	**68**	**65**

(continued)

TABLE 5.8: (Continued)

	Inadequate access to finance including inputs and credits	Inadequate access to markets	Limited implementation capacity (awareness, skill, training, and education)	Land tenure issues	Research	Inadequate access to infrastructure (roads, storage facilities, and ICT)	Public policy	Average
Integrated catchment management								
Small-scale irrigation	83	63	73	68	70	65	60	69
Rainwater harvesting	65	38	65	40	38	50	53	50
Terracing	40	20	83	73	58	48	53	53
Gully control	78	35	88	65	53	60	60	63
Flood control	68	25	73	60	50	63	60	57
Check dams	65	28	73	63	53	65	65	59
Afforestation/reforestation	73	40	88	88	60	68	70	69
Grassland rehabilitation	80	35	73	78	50	55	65	62
	69	**35**	**77**	**67**	**54**	**59**	**61**	**60**
Aquaculture								
Improved stocks	80	78	78	40	75	63	63	68
Production intensification	78	70	83	53	73	60	60	68
Better feeding practices	78	75	85	38	65	60	63	66
Improved water use efficiency and pond management	75	65	85	45	70	78	68	69
Diseases control	85	78	83	38	78	55	68	69
	79	**73**	**83**	**43**	**72**	**63**	**64**	**68**
Average	**71**	**54**	**75**	**54**	**65**	**54**	**63**	

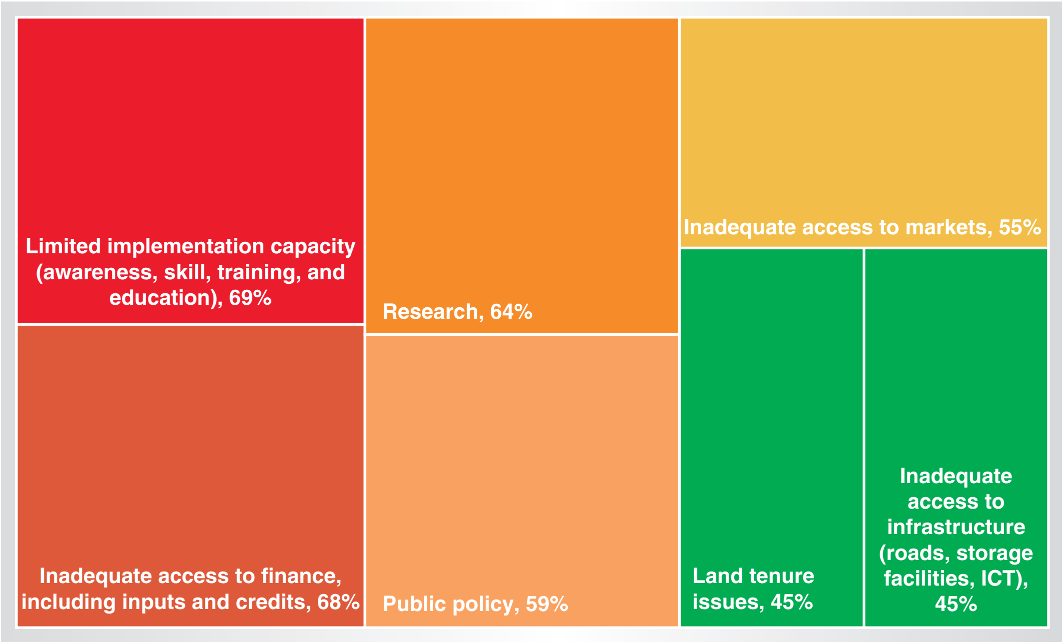
Low High

Source: Based on stakeholders' ranking.

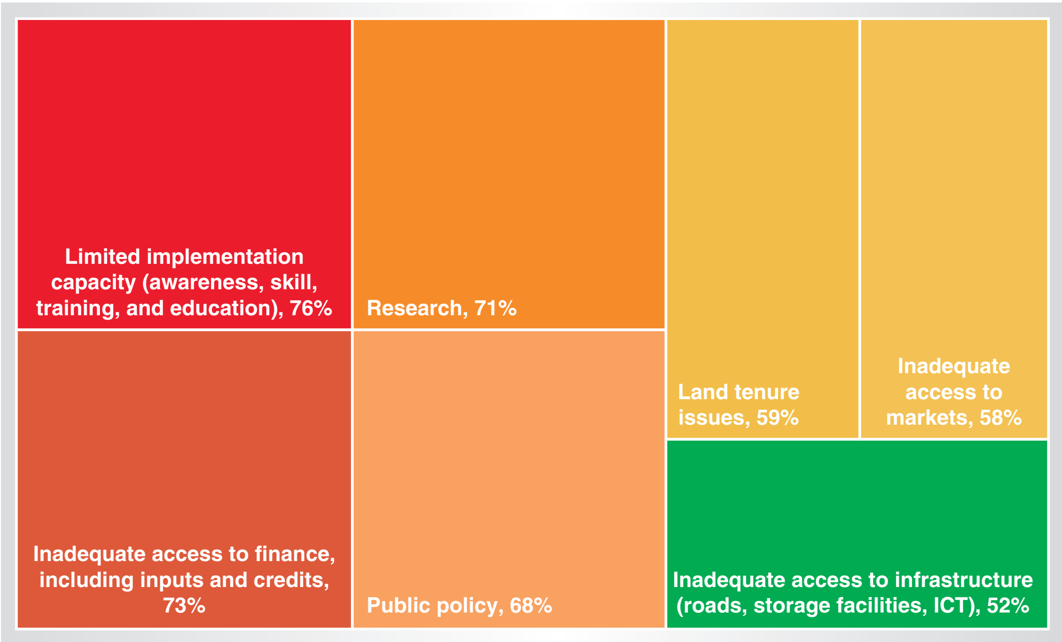
Note: Importance of factors for adoption was first rated as 1 = Very low; 2 = Low; 3 = Moderate; 4 = High; and 5 = Very high. Thereafter, scores for each factor were averaged over the number of respondents and expressed as a percentage. Higher scores indicate that it is more critical and urgent to address a factor (or enabling condition) for effective CSA implementation in Lesotho.

FIGURE 5.2: IMPACT OF FACTORS ON THE ADOPTION OF CSA PRACTICES

Crop management



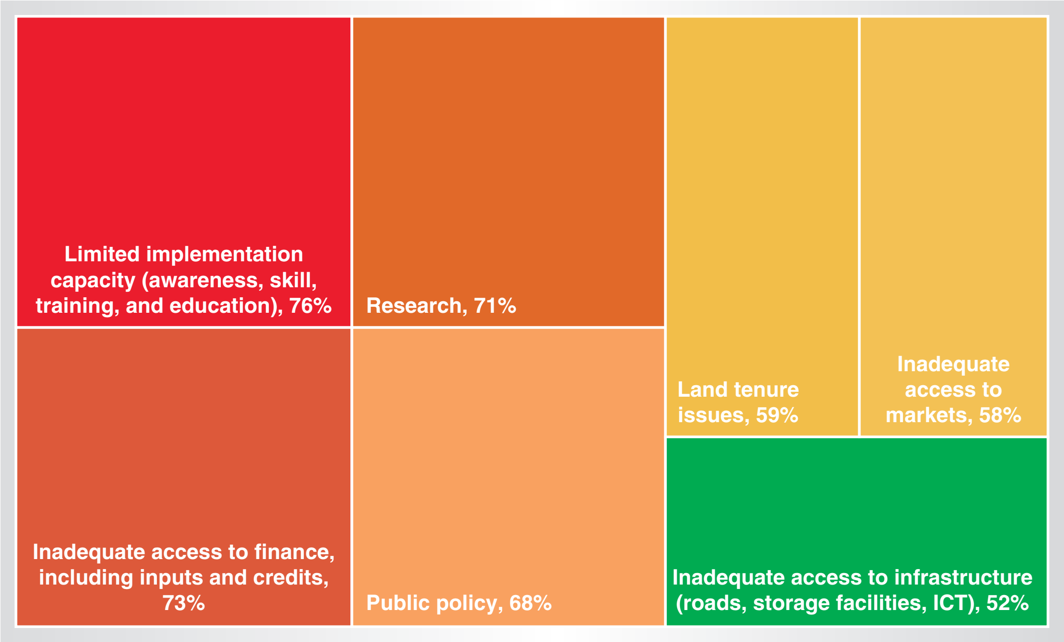
Livestock and grassland management



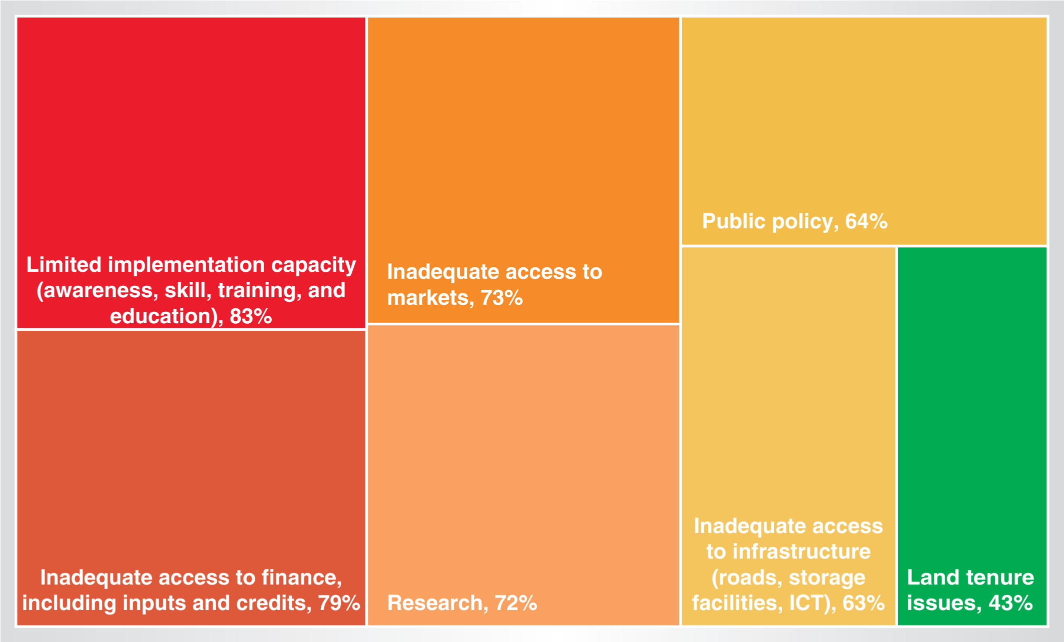
(*continued*)

FIGURE 5.2: (Continued)

Integrated catchment management



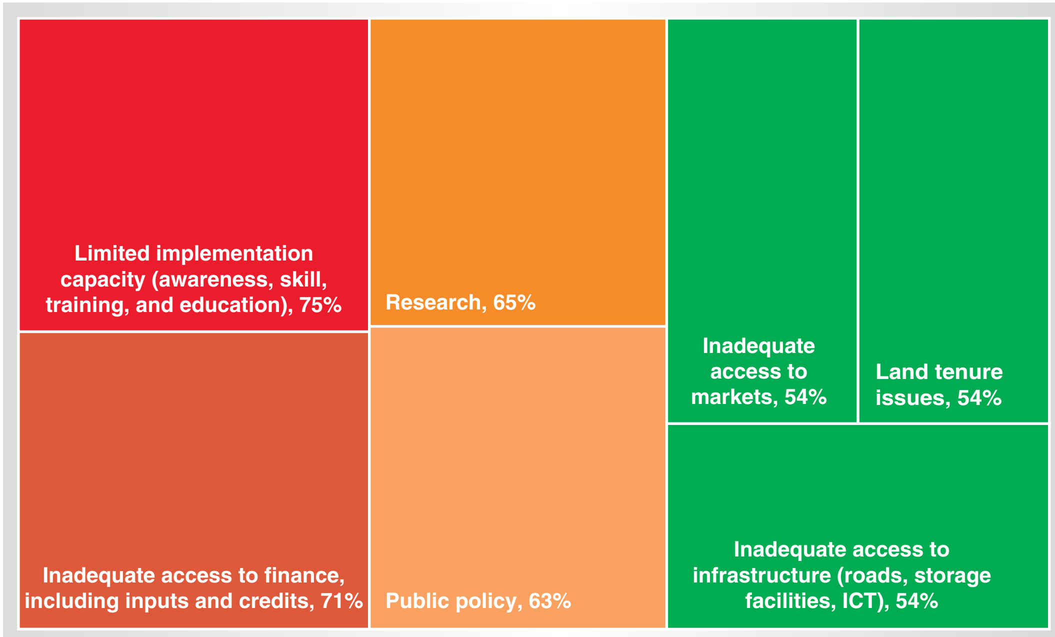
Aquaculture



(continued)

FIGURE 5.2: (Continued)

All CSA practices



Source: Authors

TABLE 5.9: ROLE OF DELIVERY MECHANISMS IN ADDRESSING CONSTRAINTS TO CSA ADOPTION

Delivery mechanisms	Implementation capacity	Access to finance and markets	Inadequate research	Infrastructure	Land tenure
Efficient irrigation technologies and institutions	Establishment of irrigation institutions and strengthening their capacity through technical assistance and training.	Higher and better agricultural produce from irrigation help to deepen agricultural markets.		Investment in irrigation infrastructure will increase productivity and enhance access to domestic and export markets. This will attract private investment, enhance job creation, and stimulate growth.	
Pluralistic* extension services and FFS	Increase the knowledge and skills of farmers, farmer aggregators, agro-processors, agro-dealers, and national and district level extension staff in proven CSA technologies.	Farmer aggregators and other service providers can help connect farmers to relevant markets.	Feedback from extension and FFS can stimulate further research and ameliorate yield-limiting constraints.		

(continued)

TABLE 5.9: (Continued)

Delivery mechanisms	Implementation capacity	Access to finance and markets	Inadequate research	Infrastructure	Land tenure
Market linkages	Horizontal alliance helps to shift smallholder thinking from subsistence farming to agribusiness by training farmers to identify crops with potential for commercialization, grow them profitably, and establish relations with market agents.	Improved legal and regulatory framework for commercial agriculture helps improve access to market.	Public investment can be used to leverage private investment in agricultural research, including developing improved seeds and seedlings and IPM measures tailored to local conditions.	Public private partnership can help address underinvestment, poor infrastructure, deficient services, low visibility, and insufficient funding.	
SLM through participatory approaches	Participatory element of SLM and landscape approaches facilitates knowledge exchange between farmers and community members.	Large mitigation benefits from landscape restoration could open up opportunities from carbon finance.			The delivery method includes modernizing land titling and administration that helps to improve tenure security and proper land market functioning. Secure land tenure incentivizes CSA adoption.
Agricultural research and innovation	Combining agricultural research innovation with extension will help enhance farmers' capacity to implement integrated CSA solutions.		Improved crop and livestock breeding, increased yields, disease resistance, abiotic stress tolerance, and nutrition.		
Digital solutions and services	ICT-based agroweather, agronomic, and market advisories can be used to facilitate learning through feedback (bidirectional information flow) between farmers and advisories providers.	ICT tools can facilitate buyer-seller matching and market transactions for agricultural commodities. ICT also promotes financial inclusion. Market information systems will help reduce information costs.		Regulatory mechanisms that improve affordability will increase internet penetration. This will help diffuse CSA technologies and innovations.	Digitizing and documenting land rights in ways that are supported by local stakeholders enhances transparency and provides incentives for CSA adoption, sustainable land use, and intensification.

Source: Authors

*Pluralistic extension system is provision of extension services for farmers through different providers such as NGOs, private companies, farmer organizations, and public extension services at district or national level. The pluralistic extension system does not eliminate the public extension workers , but rather, the system adds other potential extension agencies to compliment the existing public extension agency.

and encourage private investment in fertilizer and other agricultural inputs. An example of MKS is the input voucher system that local microfinance institutions or agricultural credit cooperatives use to qualify farmers for loans and issue cash or credit vouchers that can be used to redeem inputs, such as seeds or fertilizers. Facilitating access to input credit using the voucher system has proven to encourage farmers to adopt productivity-enhancing technologies in many countries in Africa.

157. **Constraints that must be addressed to effectively close yield gaps in Lesotho are weather-induced yield variability, soil fertility constraints, pest problems, and market accessibility.** Managing climate and weather variability is fundamental to a long-term strategy for adapting agriculture to climate change in Lesotho. This will involve stepping up research efforts in breeding to include precision phenotyping involving the introduction of stress tolerance and yield improvement traits into crops and livestock. Complementing improved breeds, it is important to develop ICT-based agroweather forecasting and dissemination tools and marketing information system to help farmers address the challenges of climate variability and change and enhance their resilience. Agroweather and market advisories will help improve long-term capacity for CSA and sustainable agricultural intensification under changing climatic conditions. They enable farmers to better manage production and marketing risks, helping farmers make informed decisions on what, when, where, and how to produce.

158. **To address productivity declines, better soil management practices, including access of farmers to fertilizer blends tailored to soil and crop requirements, are needed.** Lesotho soils are inherently low in nutrients that are needed for producing crops for food and nutrition security. Furthermore, declining soil fertility due to poor soil management practices is a major threat

to agricultural productivity, manifesting in low per capita food production and agroecosystem resilience. Reversing Lesotho's soil productivity declines cannot be adequately addressed without increased use of inorganic fertilizer combined with improved crop varieties and organic materials. Judicious fertilizer application helps counter soil nutrient depletion, reduces deforestation and expansion of cultivation to marginal areas, and increases crop yields. There is a need to establish fertilizer blending facilities to produce major nutrients and micronutrients that are compatible to needs. Soil fertility testing services also need to be promoted to deliver soil health solution packages to farmers in a commercially viable way.

159. **To reduce crop losses, there is also the need to scale up IPM and strengthen early warning systems for effective pest surveillance and control.** IPM entails the coordinated integration of multiple complementary methods to suppress pests in a safe, cost-effective, and environmentally friendly manner. Early warning systems enable more proactive, less reactive responses, which are well tailored for local conditions. Lesotho's early warning system should incorporate contingency plans, which encompasses efforts to rapidly identify pests, assess the geographical extent of the pests, create awareness among farming communities, and initiate emergency responses to control the pests. The development of rural storage facilities could also help reduce postharvest losses.

160. **The pattern of public support is as crucial as the amount of support for full realization of productivity, mitigation, and adaptation benefits in agriculture.** Public support that focuses on research and investments in improved land management and land tenure rather than on input support are generally more effective, benefit more farmers, and are more sustainable in the long run. CSA technologies that involve significant change in land use (afforestation and rangeland rehabilitation) and landscape alteration (terracing and gully reshaping) generate low private benefits. The low profits suggest that farmers may be reluctant to privately invest in these technologies. Strong public involvement in these technologies is justifiable given their relatively high carbon mitigation potentials. CA, crop rotation, rainwater harvesting, and intercropping with lower profits and little mitigation potentials generate relatively higher profits while requiring minimal government support.

161. **The CSAIP activities are expected to be implemented through different delivery methods, depending on the characteristics of the activities.** Since investment activities are homogeneously grouped into components, it is assumed that each CSAIP component is implemented through a different delivery method (table 5.10). Research and innovation, and digital solutions and services delivery methods are considered a cross-cutting approach as they relate to different investment components and benefits are bundled.

162. **Delivery methods.** Figure 5.3 reports the CSAIP profitability indicators by delivery methods. All the delivery mechanisms generate positive NPVs demonstrating their capacity to produce benefits higher than the costs. The investments aimed at increasing market access are expected to generate the highest IRR, followed by SLM interventions and research for technology innovation in agriculture. Relatively lower IRRs are generated by water management and FFS due to the high costs of the

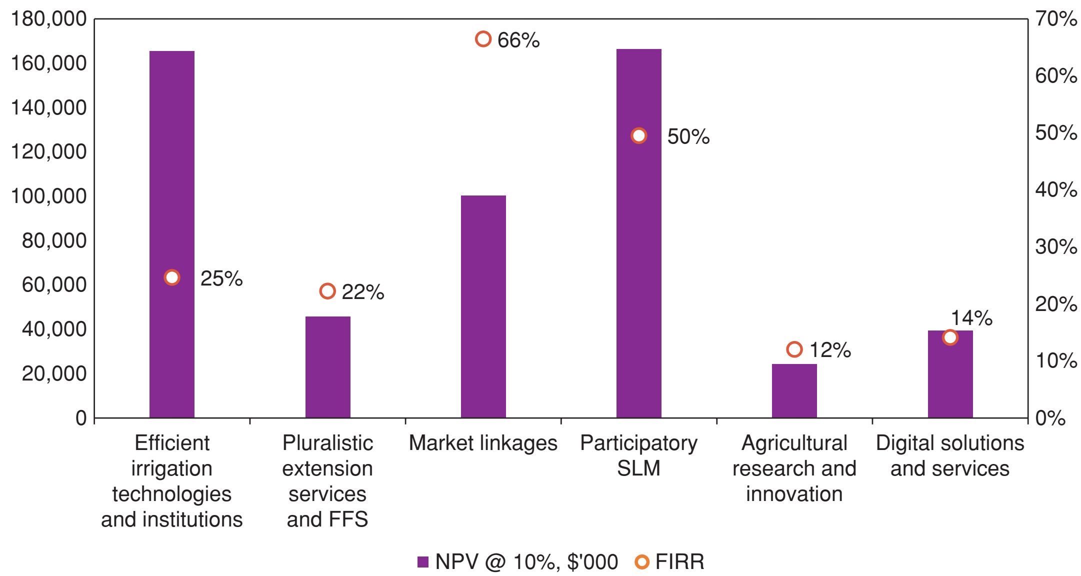
TABLE 5.10: CSAIP DELIVERY MECHANISMS

No.	Delivery mechanism	RL	CZ
		US$, thousands, per year	
1	Efficient irrigation technologies and institutions	14,944	18,382
2	Pluralistic extension services and FFS	15,473	9,793
3	Market linkages	5,882	4,272
4	SLM through participatory approaches	17,207	9,210
5	Agricultural research and innovation[22]	7,630	7,725
6	Digital solutions and services	4,140	5,140

Source: Authors

[22] Specific costs in component 2 for research + extension costs through FFS + advisory services and information costs

FIGURE 5.3: NET PRESENT VALUE AND INTERNAL RATE OF RETURN OF LESOTHO CSAIP DELIVERY MECHANISMS



Source: Authors. NPVs and IRRs were averaged for CZ and RL.

investments compared to the expected benefits and due to the time lag between the investment costs and the benefits.

163. **Prioritizing CSA practices that are adapted to a country's context is a key step toward optimizing the productivity and climate benefits of the practices.** Table 5.11 shows that comparison over 13 indicators shows that the RL scenario performs better on 6 indicators (46 percent), while CZ performs better on 7 indicators (54 percent). Five important lessons emerge for effective scaling up of CSA in the country:

- Though commercialization is more profitable, it requires larger farm size. It is more appropriate for medium-size, emerging farmers and requires strong market-oriented agricultural policies for it to be successful.
- Furthermore, commercialization would require more private initiative and resources, for instance in developing the agricultural value chain and well-functioning land markets. This could constitute a serious barrier given Lesotho's nascent private sector.
- Commercial agriculture generates more stable jobs but will also require a transformational shift in the farming systems and may be challenging

TABLE 5.11: COMPARISON OF INDICATORS UNDER THE TWO SCENARIOS

	CZ	RL
Net household income US$ per year	1,233	698
Increase in crop yields over historical (%)	60	70
Cropland area (ha)	132,247	153,482
Livestock production (ton)	38,849	45,765
Erosion control: Gross erosion (Mt per year)	39	35
Food availability[23] (kcal/capita/day)	675	649
Export potential	moderate	none
GHG mitigation: carbon balance tCO_2-eq	−2,521,976	−26,228,494
Job creation	39,378	27,862
Economic internal rate of return (EIRR) %	32	13
Carbon benefits (US$ million)	2–17	36–282
EIRR % with carbon benefits	32–34	16–73
Financial cost (US$ million)	208	268

Source: Authors. Green color indicates that a scenario performs better on an indicator; orange color indicates otherwise.

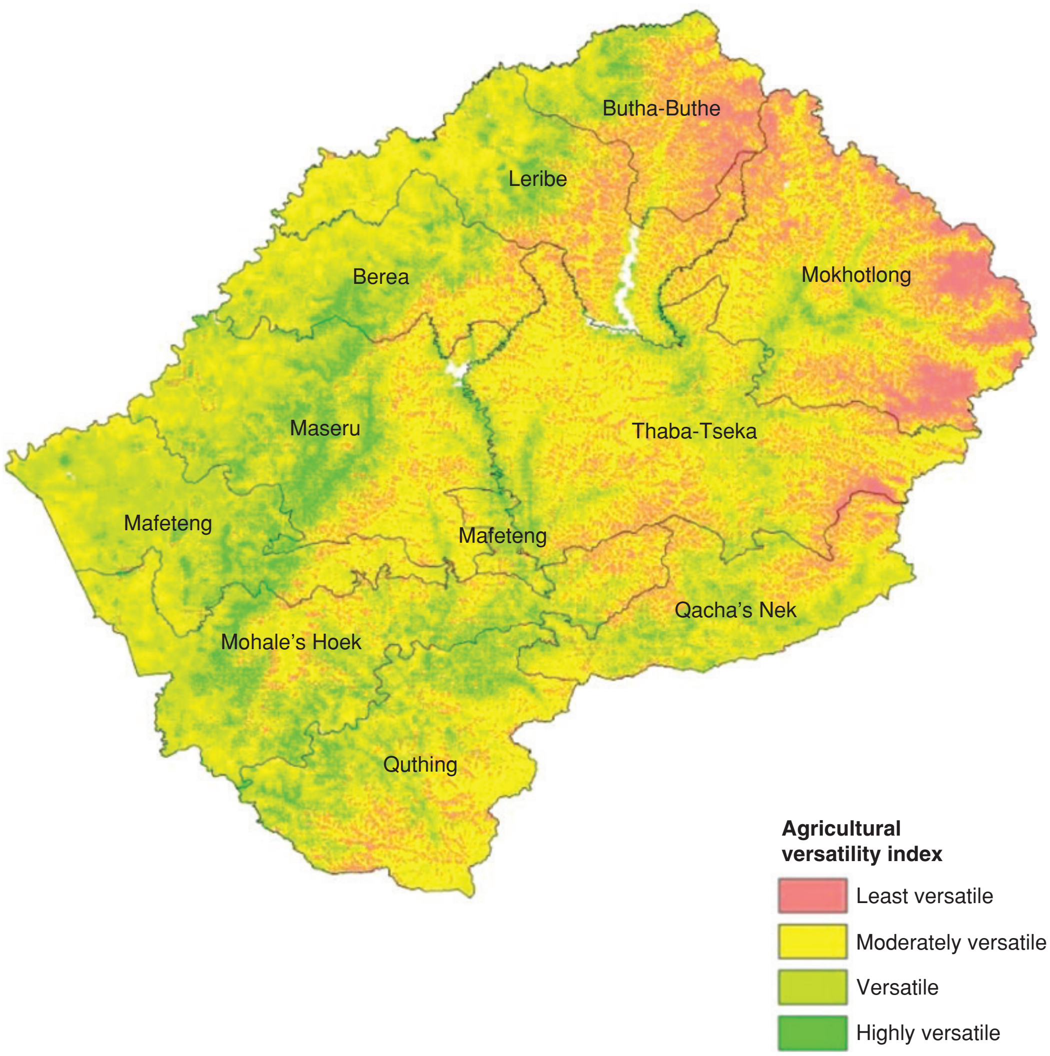
[23] This measures food calories derived from national agricultural production.

given the current level of implementation capacity.

- Though less profitable, climate-resilient agriculture delivers 10 times more carbon benefits as commercial agriculture. Thus, climate-resilient agriculture could potentially benefit from climate finance. Climate-resilient agriculture is also more effective in controlling soil erosion.
- Climate-resilient agriculture is 30 percent costlier for the public sector but is easier to implement. It is more tailored toward adapted technologies, landscape resilience and sustainable agricultural intensification that the average smallholder farmer can practice.

164. Climate-resilient farming seems more feasible given the above considerations. Alternatively, Lesotho may opt for climate-resilient farming and sustainable landscape management in zones more prone to soil erosion, suitable for afforestation and farmer-managed natural regeneration of vegetation, and where less fertile land needs restoration and replenishment. Commercial agriculture can be practiced in more fertile areas that are suitable for potato, orchards, and vegetables. In figure 5.4, the most productive lands in Lesotho are the versatile and the highly versatile land classes that can be preferentially allocated to commercial agriculture. The recommended CSA practices for Lesotho's agroecological zones are shown in table 5.12.

FIGURE 5.4: LESOTHO AGRICULTURAL VERSATILITY MAP



Source: Authors

TABLE 5.12 RECOMMENDED CLIMATE-SMART AGRICULTURE PRACTICES FOR LESOTHO'S AGROECOLOGICAL ZONES

	Lowlands	Foothills	Senqu River Valley	Mountains
Altitude (m)	<1,500	1,501–1,800	1,801–2,000	2,001–3,500
Topography	Flat to gently rolling	Steeply rolling	Steeply rolling	Very steep with bare rock outcrops
Climate	Moist in the north, moderately dry in the south	Moist	Dry	Cold and moist
Soils	Mostly sandy textured, some clayey soils in the south	Rich, alluvial soils along valleys, thin and thick on slopes	Calcareous/lime soil, clayey red soils with low water infiltration	Fragile, thin horizon of rich black loam
Crops	Wheat, beans, sorghum, vegetables, orchards, maize	Wheat, peas, potato, orchards, maize	Beans, sorghum, wheat, vegetables, orchards, maize	Potato, maize, wheat, peas, orchards
Crop management practices	Conservation agriculture, Integrated soil fertility management, intercropping, keyholes, trench gardening, block farming, polytunnels, shade-net, drip irrigation, sprinkler irrigation, rainwater harvesting, crops-tree integration (agroforestry)	Conservation agriculture, Integrated soil fertility management, intercropping, keyholes, trench gardening, polytunnels, shade-net, drip irrigation, sprinkler irrigation, crops-tree integration (agroforestry), rosehip	Conservation agriculture, Integrated soil fertility management, intercropping, keyholes, trench gardening, polytunnels, shade-net, drip irrigation, sprinkler irrigation, rainwater harvesting	Conservation agriculture, Integrated soil fertility management, intercropping, keyholes, trench gardening, polytunnels, shade-net, drip irrigation, sprinkler irrigation, crop-trees integration (agroforestry), rosehip trees
Livestock and aquaculture	Poultry, piggery, dairy cattle, beef cattle, sheep and goats, improved breeds, manure management	Sheep, goats, beef cattle, horses and donkeys, improved breeds, manure management, aquaculture (carp)	Beef cattle, sheep, goats, horses and donkeys, improved breeds, manure management, aquaculture (carp)	Beef cattle, sheep, goats, donkeys, horses, improved breeds, manure management, aquaculture (trout)
Rangeland management practices	Rotational grazing, grassland re-seeding, building of stone walls	Rotational grazing, removal of invasive shrubs, re-seeding grasses	Rotational grazing, removal of invasive shrubs, re-seeding grasses, fodder trees, pasture-trees integration (silvopasture)	Rotational grazing, removal of invasive shrubs, re-seeding grasses, pasture-trees integration (silvopasture)
Sustainable landscape management	Afforestation, reforestation, gully control	Afforestation, reforestation, gully control	Reforestation, gully control, check dams, flood control	Afforestation, reforestation, gully control, terracing, gully control, check dams, flood control

5.3 Financing the investment plan

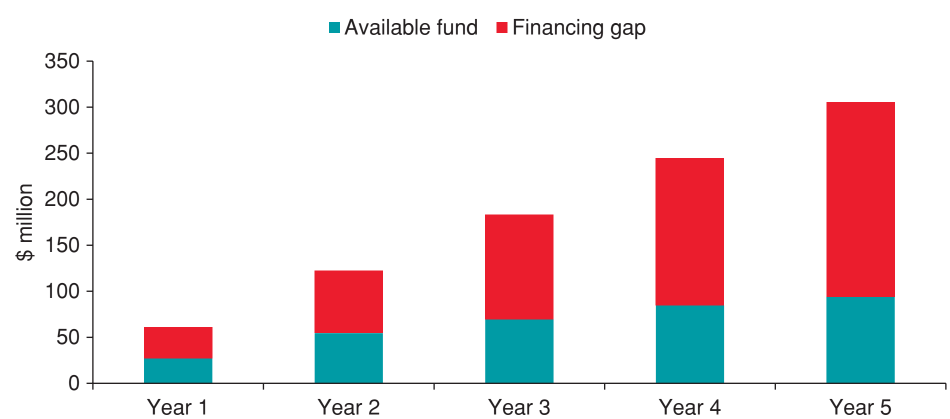
165. **Assuming Lesotho pursues the RL pathway, the cumulative financing gap amounts to US$34 million in year 1, increasing to US$211.5 million by year 5 (figure 5.5).** In estimating the CSAIP financing gap, the report considered existing agricultural projects with CSA-related expenditures and the duration of such projects. The annual financing gap was then estimated as the difference between annual cost of CSAIP and available funds supporting CSA-related expenditures.

166. **Lesotho can benefit from climate finance given its vulnerability to climate risks.** Climate finance refers to all financial flows that help achieve climate change adaptation and mitigation objectives. It can be instrumental in supporting Lesotho's agriculture sector in three main ways. The first way is meeting the gap in financing or increasing the attractiveness of an investment to leverage financing from other sources. The second way is reducing risks associated with an agriculture project either by reducing the overall financing requirement or through providing climate finance in the form of risk mitigation instruments, such as guarantees. The third way in which climate finance could support Lesotho's agriculture sector is using it to finance interventions that systematically reduce the transaction cost associated with CSA at the sector level. The sources of climate finance can be public, multilateral, bilateral, or private (figure 5.6), but for climate finance to be effective in achieving its goals, strengthening the link between financial institutions and farmers is important.

167. **The two major approaches to climate finance are upfront financing typically made available at the early stages of the project cycle, for example through grants, low-cost debt (concessional loans), equity, and guarantees; and results-based financing (RBF) that disburses funds to a recipient upon the achievement and independent verification of pre-agreed results such as emissions reduction.** RBF flows can serve as an additional revenue stream for climate projects. A recent example from Zambia is shown in box 5.2.

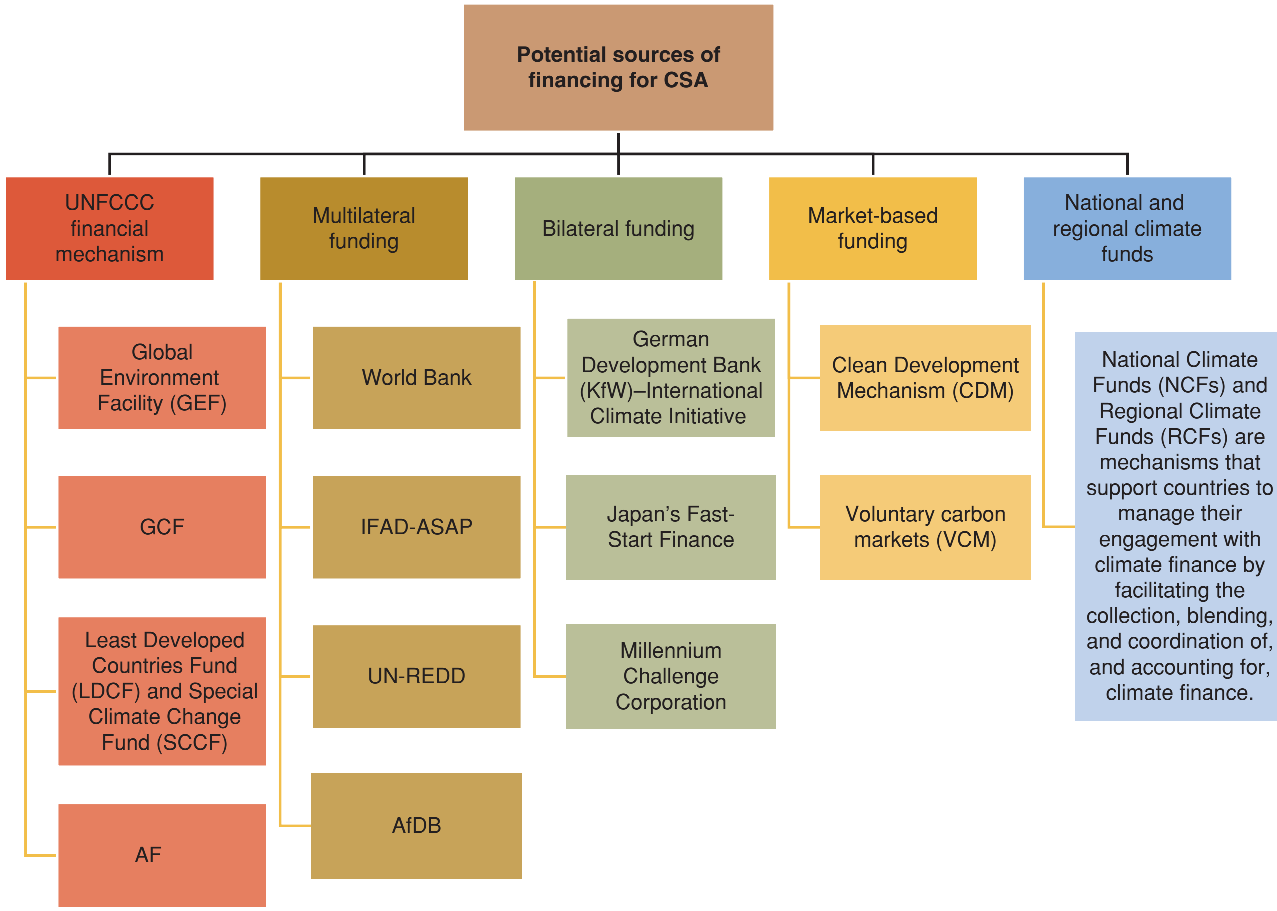
168. **The main funders of CSA-related programs and projects in Lesotho include the World Bank and the African Development Bank (AfDB), as well as bilateral funding institutions, such as IFAD, United States Agency for International Development (USAID), U.K. Department for International Development (DFID), and the European Commission, while United Nations agencies such as FAO, UNDP, and United Nations Environment Programme (UNEP) have also contributed financially and technically.** Lesotho, however, has not yet accessed some of the major international climate finance instruments, such as the GCF and the AF, and more could be done to ensure access to these instruments. Lesotho may adopt a blended finance approach in which public

FIGURE 5.5: CUMULATIVE ANNUAL PROPORTION OF FUNDS UNDER EXISTING AGRICULTURAL PROJECTS AND CSAIP FINANCING GAP



Source: Authors.

FIGURE 5.6: SOURCES OF FINANCE FOR CSA



Source: Adapted from http://csa.guide.

Note: ASAP = Adaptation for Smallholder Agriculture Programme; UNFCCC = United Nations Framework Convention on Climate Change; UN-REDD = United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation.

TABLE 5.13: EXAMPLES OF UPFRONT AND RESULT-BASED CLIMATE FINANCE

	Upfront Climate Finance		Results-based Climate Finance
1	Adaptation Fund	1	Transformative Carbon Asset Facility (TCAF)
2	Global Environment Facility (GEF)	2	Forest Carbon Partnership Facility (FCPF)
3	Green Climate Fund (GCF)	3	BioCarbon Fund (Bio-CF)
4	Special Climate Change Fund (SCCF)	4	Bio-CF Initiative for Sustainable Forest Landscape
5	Least Developed Countries Fund (LDCF)		
6	Pilot Program for Climate Resilience (PPCR)		
7	Climate Investment Funds		

BOX 5.2: CARBON PAYMENT SUPPORTS CSA ADOPTION IN ZAMBIA

Recent years have not been easy for smallholder farmers in Eastern Province of Zambia due to high weather variability. Traditional farming practices, as well as lack of access to improved production technologies and affordable inputs, have resulted in crop production shortfalls. Farmers have pursued unsustainable agricultural practices to help them cope, which have created several landscape challenges including deforestation, soil erosion, nutrient depletion, and biodiversity loss. This led to the launch of the Community Markets for Conservation (COMACO) Landscape Project in the Eastern Province. The COMACO Project illustrates successful partnership in landscape management involving the private sector (COMACO), the Government of the Republic of Zambia, and the World Bank. The project covering 270,000 hectares is a model for rural development that uses inputs, technologies, and markets to help smallholders achieve food security and boost incomes, while conserving the natural resources they rely on. COMACO model's premise is that with the right incentives and training, smallholders will favor CSA practices over unsustainable traditional methods, especially if basic food and income needs are met. Through contract farming, COMACO offers above market prices for crops that are produced in compliance with sustainable soil, farming, and conservation agriculture practices.

Farmers are recruited and organized into cooperatives by COMACO. They then receive training and inputs to implement CSA practices using the lead farmers extension approach. CSA practices disseminated through the project include Agroforestry: planting crops in alleys of *Gliricidia*, a fertilizer tree that fixes nitrogen in soils; mulching and crop residue retention (no burning of biomass); crop rotation and diversification with legumes; and composting. Through contract farming arrangement, COMACO provides markets for crops produced by farmers. In addition, REDD+ activities are being implemented on more than 116,000 hectares of community forests. The project beneficiaries stretch across nine chiefdoms in the province. Land use plans are developed for communities and rules for forest conservation enforced. COMACO finances farmers' recruitment, training, activities monitoring, supervision and other implementation costs. The World Bank offers technical support in project preparation that include emissions reduction feasibility assessment, baseline preparation, and verification and purchase of emissions reduction was generated by the project through a BioCarbon Trust Fund (Payment for Results). There are no upfront investment costs.

In 2017, 18,000 smallholder farmers and participating communities received over $800,000 in carbon payments from the BioCarbon Fund (https://www.biocarbonfund.org/) for 228,000 tons of carbon dioxide equivalent emission reductions verified by international standards. The project provides evidence that climate mitigation and socioeconomic development can be simultaneously achieved through active participation of local communities and policy measures that generate tangible benefit to the communities. The Zambia Integrated Forest Landscape Program is scaling up the COMACO approach and expanding the beneficiary group to more than 250,000 smallholder households over the 14 districts in the Eastern Province with an expected carbon payment of up to US$30 million if net results on reducing deforestation and emissions are achieved.

sector finance is used to crowd in private investment for its CSA Program. Blended finance can be effective in catalyzing investments in situations where perceived risk is higher than actual risk, which is especially true for new sectors and projects with which investors do not have prior experience.

169. **In estimating the CSAIP financing gap, the report considered existing agricultural projects with CSA-related expenditures and the duration of such projects.** The total cost of existing projects is $137 million with about 42 percent funded by the World Bank (table 5.14). Assuming Lesotho pursues the RL pathway, the cumulative financing gap amounts to US$34 million in year 1, increasing to US$211.5 million by year 5 (figure 5.5).

170. **Lesotho CSAIP may benefit from the use of blended finance, that is, the use of public sector finance to crowd in or scale up private investment for the CSAIP (table 5.15).** Blended finance can be particularly effective in catalyzing investments in sectors where perceived risk is higher than actual risk, which is especially true for new sectors and projects with which investors are unfamiliar. Blended finance can also help deliver enhanced development

TABLE 5.14: AGRICULTURE PROJECTS WITH CSA-RELATED EXPENDITURE

Project name	Funding source	Financing period	Total budget US$ million
SADP-AF	WB	2018–2020	10
SADP-II	WB, PHRD	2019–2026	52
WAMPP	IFAD	2015–2022	39
Reducing Vulnerability from Climate Change in the Foothills, Lowlands, and the Lower Senqu River Basin	LDCF	2015–2020	36
Total			**137**

TABLE 5.15: POTENTIAL SOURCES OF FUNDING FOR CSAIP DELIVERY MECHANISMS

Delivery mechanisms	Possible sources of finance
Efficient irrigation technologies and institutions	IFAD, IFC, IDA, set up PPPs with assistance of development partners
Pluralistic extension services and FFS	IFAD, AfDB
Market linkages	IFC, MCC, set up PPPs with assistance of development partners, GCF, other climate funds
Participatory SLM	NDC Partnership, GEF, UNCCD, European Commission, GCF, UNDP
Agricultural research and innovation	BMG, AfDB, IDA
Digital solutions and services	GFDRR, IDA, set up PPPs with assistance of development partners

Source: Authors
Note: UNCCD = United Nations Convention to Combat Desertification.

impacts. In the case of the six delivery mechanisms, the following financing strategies are proposed.

Policy recommendations

171. **Scaling up CSA in Lesotho will require changes in policy and environment.** Policy actions to support effective delivery of CSA in Lesotho are outlined below.

1) **Establish nationally owned CSA Program**

172. **CSA requires judicious policy management: proper coordination between agencies across different sectors at central and local levels.** CSA needs to shift beyond development practitioners to involve government agencies more often. Nationally owned climate-smart agricultural policies and action frameworks tend to increase the adoption of CSA technologies. Lesotho's national CSA program should also incorporate sustainable landscape management approaches for better management of agricultural production and ecosystem services. This will involve multidisciplinary teams from agriculture, forestry, soil conservation, water, and rangeland management.

2) **Improve knowledge management systems**

173. **Several climate-smart technologies are knowledge-intensive, and promoting their adoption will require well designed, inclusive, and innovative knowledge management systems.** The priorities are to strengthen farmers' knowledge of CSA practices, facilitate sharing the techniques, and provide the greatest support to local and indigenous knowledge systems, such as the MFS. This will result in more robust knowledge systems and farmer-led approaches. The use of co-learning and co-management strategies involving scientists and farmers is a way to do this. Scientific experts and farmers working closely together will, in turn, lead to mutual accountability.

3) **Foster equitable access to land**

174. **Secure land rights are necessary for climate-smart agriculture, providing incentives for local**

communities to manage land more sustainably. Customary land rights and gender equality need to be recognized. Fast, effective, and low-cost approaches involving the use of satellite images, global positioning systems, and computerized data management technologies to access, register, and administer land rights are needed. Improving land governance—the way land rights are defined and administered—can be the missing link between land availability and sustainable agricultural development.

4) Establish Strategic Food Reserve Agency

175. **Lesotho needs to establish a Food Reserve Agency to support food security policies and social safety net mechanisms.** The Food Reserve Agency will help ensure a reliable supply and meet local shortfalls in the supply of agricultural commodities critical to food security. The Agency can also help the country meet food emergencies caused by drought, floods, hail, or any other natural disasters, manage food storage facilities, stabilize food prices, and provide relevant market information and agricultural credit facilities to small-scale farmers.

5) Realign agricultural support to promote CSA

176. **There is a need to realign agricultural support to break adoption barriers and promote CSA.** It is vital that government policies and investments address the demand and supply sides of agricultural input use. Reversing land degradation and improving soil health in Lesotho will require increased but targeted use of fertilizers and other inputs. This, in turn, will require building sustainable private sector-led input markets. However, progress in improving input distribution systems is likely to be unsustainable without strong, effective demand for the inputs. Effective demand can only be assured if farmers have access to reliable markets to sell their products at a profit. Thus, both demand- and supply-side interventions are needed to strategically break the adoption barriers associated with climate-smart practices. Examples of demand-side interventions are improving farmers' ability to purchase inputs and providing them with risk management tools. Examples of supply-side interventions include improving road and rural infrastructure to lower transport costs and developing market information systems to reduce information cost.

6) Strengthen agricultural research and extension

177. **The goals of climate-smart agriculture cannot be met without policies and initiatives that encourage agricultural innovations and research, and establish stronger linkages between farmers, climate-smart supply chains, and markets.** There is a need to strengthen research and establish partnership with CGIAR and other international research institutes to develop high-yielding, stress-tolerant, climate-ready varieties that are adapted to Lesotho's environment. Development of heat-tolerant varieties is of importance given the projected increase in warming for Lesotho. Agricultural extension services should be upgraded to catalyze the agricultural innovation process and bring the actors together, coordinate and create networks, facilitate access to information, knowledge and expertise, and provide technical backstopping.

7) Create enabling environment for private sector

178. **Introducing policies and incentives that provide an enabling environment for private sector investment can increase overall investment.** Public investment can be used to leverage private investment in research and development, establish agroforestry, promote afforestation, and develop improved seeds and seedlings. Bundling agricultural credit and insurance together and providing different forms of risk management, such as climate information services, index-based weather insurance, or weather derivatives, are areas of private investment that can be encouraged through public policy and public-private partnerships.

8) Build Capacity to Access Climate Finance

179. **Lesotho faces a financing gap in the agriculture sector with low capacity to access climate finance.** Critical areas that need capacity development include identifying funding gaps and needs; assessing public and private financing options; developing payment for ecosystem services programs; developing bankable investment plans, project pipeline, and financing propositions; and developing financially viable opportunities for effective private sector engagement.

Table 5.16 provides information on specific measures under each policy option, responsible authorities, and time frame for implementing the measures.

TABLE 5.16: LESOTHO CSA POLICY MEASURES AND TIME FRAME FOR IMPLEMENTATION

	Time frame	Responsible authorities
Establish nationally owned CSA Program		
(i) Establish Lesotho CSA Program to guide implementation of CSA and landscape approaches, strategies, practices and technologies	Short	Department of Planning and Policy Analysis of the Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Forestry, Range and Soil Conservation
(ii) Update irrigation policy and support policy planning for mainstreaming CSA	Medium	Department of Planning and Policy Analysis of the Ministry of Agriculture and Food Security
(iii) Introduce evidence-based policies and institutional strengthening for CSA	Short–Medium	Department of Planning and Policy Analysis of the Ministry of Agriculture and Food Security
Develop knowledge management system		
(i) Establish CSA Knowledge Portal	Medium–Long term	Department of Agricultural Research; Department of Crop Services; Department of Livestock all of the Ministry of Agriculture and Food Security; Lesotho Meteorological Services; National University of Lesotho
(ii) Promote inclusive Climate Information Services and Advisories Dissemination Platform	Medium–Long term	Department of Field Services; Lesotho Meteorological Services; Ministry of Science and Communications; ICT Service Providers
(iii) Document MFS practices and integrate with modern science	Short	Department of Field Services; Department of Agricultural Research; Machobane Agricultural Development Foundation; National University of Lesotho
Foster equitable access to land		
(i) Develop cost-effective approaches for managing land rights	Medium	Land Administration Authority
(ii) Document different types of land rights supported by stakeholders	Medium	Land Administration Authority
(iii) Identify opportunities for commercial farming	Short	Land Administration Authority; Department of Soil and Water Conservation; Lesotho National Development Corporation
(iv) Link land rights to land suitability, soil carbon and other key parameters of land use using satellite imageries	Medium	Land Administration Authority; Department of Soil and Water Conservation
Establish Strategic Food Reserve Agency		
(i) Set up Food Reserve Agency and define functions: administer the strategic food reserves, facilitate market development, and manage warehouse/storage facilities	Medium	Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Finance; National Disaster Management Authority
(ii) Awareness building on the role of the Agency	Short	Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Finance; National Disaster Management Authority
(iii) Build and manage warehouses and storage facilities for national seed and grain reserve	Medium–Long	Ministry of Agriculture and Food Security; National Disaster Management Authority
(iv) Subsidize seed and grain storage for qualifying farmers	Long	Ministry of Agriculture and Food Security; Ministry of Development Planning; Ministry of Finance; National Disaster Management Authority

(continued)

TABLE 5.16: (Continued)

	Time frame	Responsible authorities
Realign agricultural support to promote CSA		
(i) Policy reform to align agricultural support to promote CSA	Short	Ministry of Agriculture and Food Security; Ministry of Planning; Ministry of Finance
(ii) Establish inputs e-voucher system	Short–Medium	Ministry of Agriculture and Food Security; Ministry of Planning; Ministry of Finance
(iii) Develop market information systems to reduce information costs	Short–Medium	Department of Field Services of the Ministry of Agriculture and Food Security; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
Strengthen agricultural research and extension		
(i) Establish partnership with international research institutes and develop high-yielding, stress-tolerant, climate-ready varieties	Long term	Department of Agricultural Research, Department of Field Services, all of the Ministry of Agriculture and Food Security; Lesotho Agricultural College , Ministry of Agriculture and Food Security; National University of Lesotho
(ii) Upgrade agricultural extension services to facilitate access to information and improved technical backstopping	Short–Medium	Department of Field Services, Department of Agricultural Research, Ministry of Agriculture and Food Security
Create enabling environment for private sector		
(i) Introduce policies and incentives that provide an enabling environment for private sector investment	Short	Ministry of Agriculture and Food Security; Lesotho National Development Corporation; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
(ii) Encourage private financial service providers to tailor instruments that enable farmers who adopt CSA practices to overcome adoption barriers	Medium	Ministry of Agriculture and Food Security; Lesotho National Development Corporation; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
(iii) Promote PPP and design innovative risk management products (bundling credit and weather index insurance,	Medium–Long term	Ministry of Agriculture and Food Security; Lesotho National Development Corporation; Ministry of Small Business Cooperatives and Marketing; Basotho Enterprise Development Corporation
Build Capacity to Access Climate Finance		
(i) Build capacity to identify funding gaps and needs; assess public and private financing options	Long term	Ministry of Agriculture and Food Security; Ministry of Finance; Ministry of Development Planning
(ii) Develop financially viable opportunities for effective private sector engagement	Long term	Ministry of Agriculture and Food Security; Ministry of Finance; Ministry of Development Planning
(iii) Develop results-based financing/ payment for ecosystem services programs	Long term	Ministry of Agriculture and Food Security; Ministry of Finance; Ministry of Development Planning

Source: Authors

Note: Short term = 1–2 years; Medium term = 2–5 years; Long term = greater than 5 years

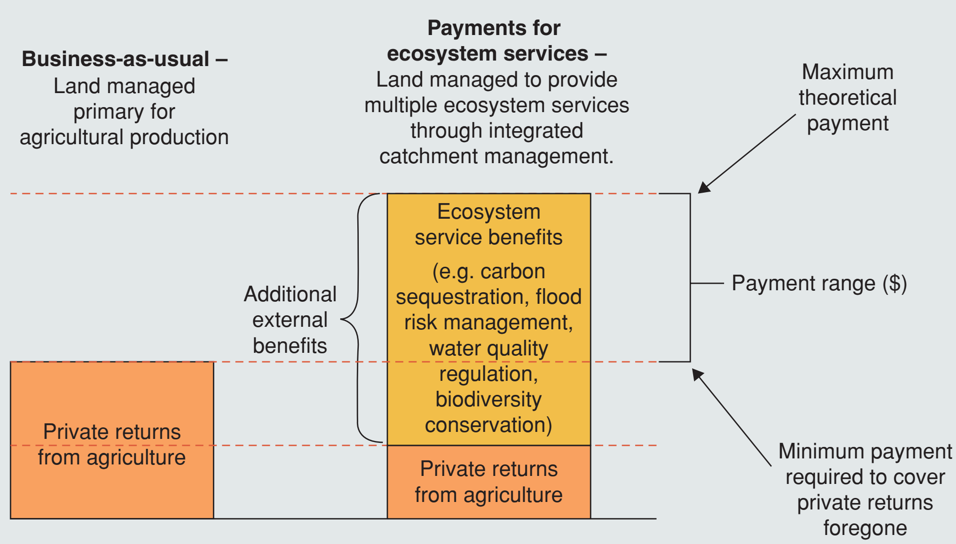
BOX 5.3: BEST PRACTICES IN DESIGNING PAYMENT FOR ECOSYSTEM SERVICES

The diverse benefits that humans derive from the natural ecosystems are referred to as ecosystem services. Examples include the supply of food, water, and timber (provisioning services); the regulation of climate, air quality, and flood risk (regulating services); essential underlying functions such as soil formation and nutrient cycling (supporting services); and opportunities for recreation, tourism and education (cultural services). The type, quality, and quantity of services derived from an ecosystem is a function of decisions of individuals and communities managing the ecosystem. When the benefits of an ecosystem service accrue mainly to resource managers, as in the production of crops or livestock, private markets usually work relatively well in inducing service provision. However, when the benefits of an ecosystem service flow primarily to others, such as climate regulation or water purification, public interests and the interests of the resource manager may be misaligned. This difference in private and social benefits, or the problem of "externalities," results in a market failure: individuals will tend to provide too little of the ecosystem service (Jack et al. 2008).

Potential policy solutions to externalities problems include: provision of services by government; private contracts between the provider and the recipients; voluntary efforts by individuals, communities and businesses; direct government regulation; and incentive or market-based mechanisms in form of charges (for example, taxes and user fees), tradable permits (for example, markets for pollution reduction), certification schemes (for example, eco-labels), and payment for ecosystem services (PES).

PES is a scheme whereby the beneficiaries provide payment to the providers of ecosystem services. PES provides an opportunity to put a price on previously unpriced ecosystem services, and in doing so brings the ecosystem services into the wider economy (Smith et al. 2013). PES typically involves a series of payments to resource managers in return for a guaranteed flow of ecosystem services over and above what would otherwise be provided in the absence of the payment (figure B5.3.1).

FIGURE B5.3.1: LAND MANAGED PRIMARILY FOR AGRICULTURAL PRODUCTION VERSUS LAND MANAGED TO PROVIDE MULTIPLE ECOSYSTEM SERVICES UNDER A PES SCHEME



Source: Modified from Smith et al. (2013)

PES can be developed at a range of spatial scales including local, catchment, national, and international. In terms of financing, PES can be a public payment scheme in which government pays resource managers to enhance ecosystem services on behalf of the wider public; a private payment scheme featuring self-organized private deals in which beneficiaries of ecosystem services contract directly with service providers; or a public-private payment scheme that

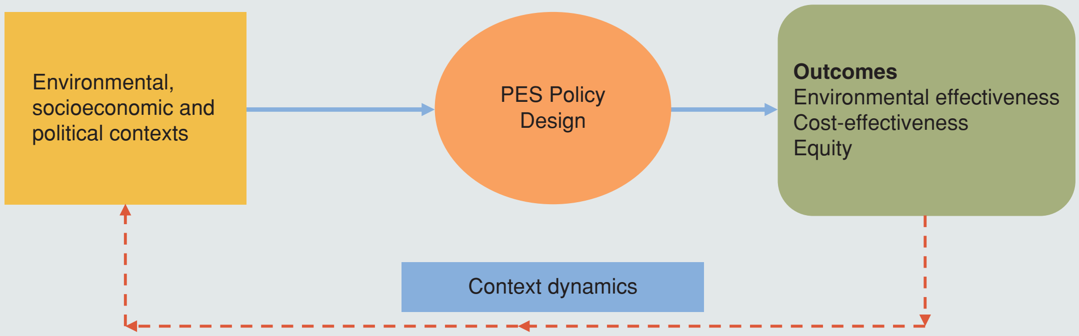
(*continued*)

BOX 5.3: (Continued)

draws on both government and private funds to pay resource managers for the delivery of ecosystem services. The mode of payment can be output-based, or input based. Output-based payments are made based on actual ecosystem services provided. For example, payments might be made for a certain level of carbon sequestration, emissions reduction, or a measured increase in biodiversity. Input-based payments are made based on certain land management activities (practices) being implemented. For example, payments might be made for the creation and maintenance of buffer strips along watercourses, reforestation of degraded land, rangeland conservation or adoption of other CSA practices.

Context interacts with PES Policy design to determine the success of PES schemes (figure B5.3.2). Lessons on PES design that may be relevant for Lesotho are indicated below.

FIGURE B5.3.2: THE ROLE OF ENVIRONMENTAL, SOCIOECONOMIC AND POLITICAL CONTEXTS ON PES DESIGN AND OUTCOMES



Source: Adapted from Jack et al. (2008)

Political and economic feasibility of PES depends on the political power of those who bear the costs and benefits. Ecosystem service providers tend to prefer a PES policy over traditional regulation because a PES approach offers compensation for environmental conservation, and participation is voluntary. However, the overall viability of a PES will be determined by the preferences and power of all relevant stakeholders, including beneficiaries of the ecosystem service, policymakers, financiers, community members, and program administrators. Thus, an important aspect of PES policy design is a process involving negotiating and implementing the PES agreement. To ensure consistency with macroeconomic objectives, it is important to assess the immediate quantitative impact of the PES on the fiscus, including the overall cost, cashflows over the duration of the PES, and how long it could take for costs to be recovered.

Managing tradeoffs between cost-effectiveness and poverty alleviation. When land that produces a high level of services is held by poor members of the society, then a PES approach may contribute to poverty reduction by paying these landholders for the services they provide. However, PES schemes are likely to make a true improvement in poverty outcomes only if they pay landowners an amount substantially higher than they otherwise could have earned with the land.

Minimizing transaction costs. PES schemes are often focused on many individual landowners whose collective activities alter the levels of a given ecosystem service. This may increase policy costs but working with a third-party technical service provider such as an NGO or a community could reduce the costs of working with many farmers. Also, participatory processes may help reduce long-term monitoring and enforcement costs in addition to promoting equity outcomes.

Assessing ecosystem services. PES schemes rely on observable proxies because direct monitoring of ecosystem service outputs can be difficult or costly. Advanced techniques such as satellite remote sensing and bioeconomic modeling can be applied to estimate ecosystem services from easily observable ecosystem properties.

References

Agwe, J., M. Morris, and E. Fernandes. 2007. "Africa's Growing Soil Fertility Crisis: What Role for Fertilizer?" *World Bank Agriculture and Rural Development Note* 21: 4.

Alcamo, J. 2008. "The SAS Approach: Combining Qualitative and Quantitative Knowledge in Environmental Scenarios." *Developments in Integrated Environmental Assessment* 2: 123–150. https://www.sciencedirect.com/science/article/pii/S1574101X08004067

Bossio, D., K. Geheb, and W. Critchley. 2010. "Managing Water by Managing Land: Addressing Land Degradation to Improve Water Productivity and Rural Livelihoods." *Agricultural Water Management* 97 (4): 536–542.

CIAT (International Center for Tropical Agriculture) and World Bank Group. 2018. "Climate-Smart Agriculture in Lesotho." CSA Country Profiles for Africa Series.

Deininger, Klaus, Derek Byerlee, Jonathan Lindsay, Andrew Norton, Harris Selod, and Mercedes Stickler. 2011. *Rising Global Interest in Farmland: Can It Yield Sustainable and Equitable Benefits? (English)*. Agriculture and rural development. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/998581468184149953/Rising-global-interest-in-farmland-can-it-yield-sustainable-and-equitable-benefits

FAOSTAT (Food and Agriculture Organization Corporate Statistical Database). 2019.

Giertz et al. 2019. Lesotho Agriculture Public Expenditure Review.

Global Research Alliance. 2013. *Reducing Greenhouse Gas Emissions from Livestock: Best Practice and Emerging Options.* New Zealand: Global Research Alliance on Agricultural Greenhouse Gases (GRA).

GoL (Government of Lesotho). 2014. *Lesotho Agriculture and Food Security Investment Plan.* NAIP 2015–2020.

Government of Lesotho 2019. Lesotho Poverty Trends and Profile Report 2002/2003 to 2017/2018.

Hallegate, S. 2012. "A Cost-effective Solution to Reduce Disaster Losses in Developing Countries. Hydro-Meteorological Services, Early Warning, and Evacuation." Policy Research Working Paper 6058, World Bank, Washington, DC.

Hatfield, J. L., T. J. Sauer, and J. H. Prueger. 2001. "Managing Soils to Achieve Greater Water Use Efficiency: A Review." *Agronomy Journal* 93 (2): 271–280.

Herrero, Mario, Benjamin Henderson, Petr Havlík, Philip K. Thornton, Richard T. Conant, Pete Smith, Stefan Wirsenius, Alexander N. Hristov, Pierre Gerber, Margaret Gill, Klaus Butterbach-Bahl, Hugo Valin, Tara Garnett, and Elke Stehfest. 2016. "Greenhouse Gas Mitigation Potentials in the Livestock Sector." *Nature Climate Change* 6: 452–461. https://doi.org/10.1038/nclimate2925

IFC. 2019. "Impact of Efficient Irrigation Technology on Small Farmers." International Finance Corporation, World Bank, Washington, DC.

Jack, B. K., C. Kousky, and K. R. E. Sims. 2008. "Designing Payments for Ecosystem Services: Lessons from Previous Experience with Incentive-based Mechanisms." *Proceedings of the National Academy of Sciences* 105 (28): 9465–9470. DOI:10.1073/pnas.0705503104

Lal, R. 2003. "Soil Erosion and the Global Carbon Budget." *Environment International* 29: 437–450.

Lazo, J. K. 2015. "Survey of Mozambique Public on Weather, Water, and Climate Information." NCAR Technical Note NCAR/TN-521+STR. doi:10.5065/D6B56GS4.

Liniger, H., W. Critchley, M. Gurtner, G. Schwilch, and R. Mekdaschi Studer (eds.). 2007. "Where the Land Is Greener: Case Studies and Analysis of Soil and Water Conservation Initiatives Worldwide." World Overview of Conservation Approaches and Technologies (WOCAT), Wagenigen, The Netherlands.

Liniger, H. P., R. Mekdaschi Studer, C. Hauert, and M. Gurtner. 2011. “Sustainable Land Management in Practice—Guidelines and Best Practices for Sub-Saharan Africa.” TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT), and Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Liniger, H. P., and R. Mekdaschi Studer. 2019. “Sustainable rangeland management in Sub-Saharan Africa—Guidelines to good practice.” TerrAfrica; World Bank, Washington DC; World Overview of Conservation Approaches and Technologies (WOCAT); Centre for Development and Environment (CDE), University of Bern, Switzerland.

Mekbib, S. B., A. O. Olaleye, M. N. Mokhothu, M. Johane, S. B. Tlali, and T. W. Godeto. 2011. Assessment of the Adaptive Capacity of the Machobane Farming System to Climate Change in Lesotho. Working Paper Series, No 60. African Technology Policy Studies Network.

Nhemachena, C., G. Matchaya, and S. Nhlengethwa. 2016. “Agricultural Growth Trends and Outlook for Lesotho.” ReSAKSS (Regional Strategic Analysis and Knowledge Support System). https://www.resakss.org/sites/default/files/ReSAKSS-SA%20-%20ATOR%20-%202016%20-%20high%20res%20with%20crop%20marks%20%28002%29.pdf.

O’Neill, B. C., Elmar Kriegler, Kristie L. Ebi, Eric Kemp-Benedict, Keywan Riahi, Dale S. Rothman, Bas J. van Ruijven, Detlef P. van Vuuren, Joern Birkmann, Kasper Kok, Marc Levy, William Solecki. 2017. “The Roads Ahead: Narratives for Shared Socioeconomic Pathways Describing World Futures in the 21st Century.” *Global Environmental Change* 42: 169–180.

Pretty, J., A. Noble, D. Bossio, J. Dixon, R. Hine, F. T. W. Penning de Vries, and J. Morison. 2006. “Resource-conserving Agriculture Increases Yields in Developing Countries.” *Environmental Science and Technology* 40 (4): 1114–1119.

Raskin, P. D. 2005. “Global Scenarios: Background Review for the Millennium Ecosystem Assessment.” *Ecosystems* 8 (2): 133–142. https://link.springer.com/article/10.1007/s10021-004-0074-2

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder. 1997. “Predicting Soil Erosion by Water: A Guide to Conservation Planting with the Revised Universal Soil Loss Equation.” Agriculture Handbook Number 703. USDA Agricultural Research Service.

Reva, A. 2019. *Linking Smallholders to Markets: A Supplier Development Program for Vegetable Farmers in Lesotho*. World Bank, Washington, DC. https://hubs.worldbank.org/docs/ImageBank/Pages/DocProfile.aspx?nodeid=31158303

Sheffield, J., G. Goteti, and E. F. Wood. 2006. “Development of a 50-yr high-resolution global dataset of meteorological forcings for land surface modeling.” *J. Climate* 19 (13): 3088–3111. https://doi.org/10.1175/JCLI3790.1

Smith, S., P. Rowcroft, M. Everard, L. Couldrick, M. Reed, H. Rogers, T. Quick, C. Eves, and C. White. 2013. *Payments for Ecosystem Services: A Best Practice Guide.* Defra, London.

West, P. C., H. K. Gibbs, C. Monfred, J. Wagner, C. C. Barford, S. R. Carpenter, and J. A. Foley. 2010. “Trading Carbon for Food: Global Comparison of Carbon Stocks vs. Crop Yields on Agricultural Land.” *Proceedings of the National Academy of Sciences, USA* 107: 19645–19648.

World Bank. 2015. *Lesotho: Systematic Country Diagnostic*. Report No. 97812. World Bank, Washington, DC.

World Bank Group. 2016. *International Development Association and International Finance Corporation and Multilateral Investment Guarantee Agency Country Partnership Framework for Kingdom of Lesotho for the Period FY16-20*. Report No. 97823-LS. World Bank, Washington, DC.

World Bank Group. 2016. “Lesotho Water Security and Climate Change Assessment.” Report No. 108018. World Bank, Washington, DC.

World Bank Group. 2017. “Guidance Note on Shadow Price of Carbon in Economic Analysis.” Report No. 123940. World Bank, Washington, DC.

World Bank Group. 2018a. “Scaling Up Climate-Smart Agriculture through the Africa Climate Business Plan.” Report No. 130849. World Bank, Washington, DC.

World Bank Group. 2018b. “Unlocking the potential of Lesotho’s Private Sector: A focus on Apparel, Horticulture and ICT.” Report No. 128075. World Bank, Washington, DC.

World Bank. 2018c. *Future of Food: Maximizing Finance for Development in Agricultural Value Chains.* World Bank, Washington, DC.

World Bank. 2018d. Presentation on *Promoting More, Better and Inclusive Jobs in Agriculture in Africa: Some pathways to consider*. World Bank, Washington, DC.

World Bank. 2019. *Lesotho Poverty Assessment: Progress and challenges in reducing poverty*.

World Bank Group. 2019. “Lesotho Smallholder Agriculture Development Project SADP II.” Report No: PAD3310. World Bank, Washington, DC.

Zhou, X., M. J. Helmers, M. Al-Kaisi, and H. M. Hanna. 2009. Cost-effectiveness and cost-benefit analysis of conservation management practices for sediment reduction in an Iowa agricultural watershed. *Journal of Soil and Water Conservation* 64 (5). doi:10.2489/jswc.64.5.314.

Annex 1: Major Stakeholders Consulted During the CSAIP Process

Institutions	No.
Ministry of Agriculture and Food Security	29
Lesotho Agriculture College (LAC)	16
National University of Lesotho (NUL)	14
Lesotho National Farmers Union (LENAFU)	16
Lesotho Meteorological Services (LMS)	8
Department of Agricultural Research (DAR)	9
Food and Agricultural Organization (FAO)	6
Ministry of Development Planning (MDP)	5
World Food Program (WFP)	5
Catholic Relief Services (CRS)	5
Disaster Management Authority (DMA)	4
Alliance Insurance	3
Bureau of Statistics	3
Lesotho National Development Corporation (LNDC)	3
United Nations Development Program (UNDP)	3
Department of Water Affairs (DWA)	2
Department of Science and Technology	3
European Union (EU)	2
Maseru District Agriculture	2
Red Cross	2
Tasty Food Packers Pvt. Ltd	2
Second Private Sector Competitiveness and Economic Diversification Project (2nd PSCEDP)	1
District Agricultural Officer - Mafeteng (DAO Mafeteng)	1
Central Bank of Lesotho (CBL)	1
Energy Department	1
Finance and Administration	1
International Fund for Agricultural Development (IFAD)	1
Khotla Business Forum	1

(*continued*)

Institutions	No.
Lesotho Flour Mills Ltd	1
Ministry of Finance	1
Ministry of Small Business Development, Cooperatives and Marketing	1
Moratuoa Prepakers	1
Ministry of Small Business Development, Cooperatives and Marketing–Department of Marketing	1
Potato Lesotho Association (PLA)	1
Private Sector Development and Economic Diversification Support Project (PSDEDSP)	1
Private Sector Foundation of Lesotho (PSFL)	1
Smallholder Agricultural Development Project (SADP)	1
Wool and Mohair Promotion Project (WAMPP)	1
World Vision Lesotho (WVL)	1
Total	**160**

Annex 2: Land-Use Scenarios Assumptions

The demand for built-up area was based on UN projections of average annual urbanization rate of 2.85 percent for all scenarios. Cropland under the CT scenario was assumed to grow at the same rate as the population, while water and barren land were kept static for all the scenarios.

Land cover extent and cropland proportions under CT are assumed to be the same as current. Under the CT scenario, crop production will be largely by conventional methods as observed in the Household Production Survey analysis of adoption of agricultural practices.

About 40 percent of maize will be under CA under the CT scenario but will increase to 70 percent under the Resilient and Diversified Landscape scenario. The RL scenario also includes agroforestry practices on 30 percent of farmland.

Improved varieties with a reduction in growing period to 90 percent of conventional varieties will be used on all farmlands under the two scenarios excluding CT. The improved varieties will have advantages for weed competition, pest resistance, and drought tolerance. To address nutrition concerns, the proportion of biofortified crops will be 10 percent for the CZ scenario increasing to 40 percent for the RL scenario.

It is assumed that 15,000 ha of cropland will be applied with fertilizer and manure. Fertilizer use will increase from about 25 kg N per ha under CT to 80 kg N per ha under the CZ scenario and 50 kg N per ha under the RL scenario. Manure use under the CZ and Comparative Advantage scenario will be 5 ton per ha, increasing to about 15 ton per ha under the RL scenario. Irrigation of crops under the CT scenario is 20 percent of irrigable area. Strategies under the other two scenarios are as indicated in table A2.3.

Some 60 percent of grassland under the CT scenario is severely degraded. Some 25 percent of this will be improved through better practices under the CZ scenario, increasing to 40 percent under the RL scenario. The remaining pastures will stay moderately degraded. Some 20 percent of forests under the RL scenario will be under farmer-managed natural regeneration. Leguminous shrubs will be planted on 70 percent of shrubland for the RL scenario and only 10 percent for the CZ scenario. Under the RL scenario, about 25 percent of land that would have been cropped under the CT scenario is spared for biodiversity conservation, but none under the CZ scenario. The CZ scenario however includes exploitation of aquaculture and NTFPs (honey, mushroom, aloes, and rosehip) for exports.

TABLE A2.1: LAND COVER EXTENT FOR THE SCENARIOS (HA) BY 2050

Scenario	Built-up area		Cropland		Grassland		Shrubland		Forest		Water		Barren land		Total	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
CT	288,372	9.4	774,341	25.4	1,516,379	49.6	232,686	7.6	45,836	1.5	60,710	2.0	133,562	4.4	3,051,886	100
CZ	288,372	9.4	971,241	31.8	1,288,922	42.2	232,686	7.6	76,393	2.5	60,710	2.0	133,562	4.4	3,051,886	100
RL	288,372	9.4	579,939	19.0	1,592,198	52.2	244,320	8.0	152,785	5.0	60,710	2.0	133,562	4.4	3,051,886	100

TABLE A2.2: CROPLAND PROPORTIONS UNDER EACH SCENARIO (PERCENT)

Crop	CT	CZ	RL
Maize	62	22	35
Sorghum	11	16	20
Bean	10	20	10
Wheat	7	7	20
Potato	6	15	7
Fresh vegetables	2	10	4
Orchards	2	10	4
Total	**100**	**100**	**100**

TABLE A2.3: IRRIGATION LAND UNDER THE SCENARIOS (HA)

Crop	Trend	CZ and comparative advantage	Resilient and diversified landscape
Potato	500	5,000	4,000
Fresh vegetables	1,500	5,000	4,500
Orchards	500	2,500	4,000
Total	2,500	12,500	12,500

Annex 3: Approach for the CBA

The methodology consists of a combination of financial and economic analyses, in both "with" and "without" CSA investment scenarios. On-farm profitability indicators are estimated, considering all inputs used, including labor. Economic values are computed and used in the analytical models. Based on the targeted land area, number of livestock heads, farm typologies, number of households, and the estimated CSA adoption rates, farm models' results are aggregated to estimate the flow of expected net incremental benefits consequent to CSA adoption ("with" CSA investment scenario) with respect to the baseline ("without" CSA investments scenario). Investment costs are estimated from data available in the literature and from previous public investment projects in the country. A comparison between overall economic costs and benefits of the potential investments is made and overall profitability indicators of CSA are computed, namely EIRR and NPV. The robustness of the economic analysis is measured through a sensitivity analysis which considers the performance of the investment options in case of changes in the analytical assumptions and risk. An estimation of the environmental benefits related to carbon sequestration is also provided, including an indication of the environmental impact on the profitability indicators EIRR and NPV. The carbon sink associated with the implementation of the CSA practices is evaluated using the recommended shadow price of carbon as indicated by the World Bank and calculated based on the concept of marginal abatement cost. The shadow price of carbon indicates the carbon price which is consistent with achieving the core objective of the Paris Agreement on climate change of keeping temperature rise below 2°C. The detailed analytical methodological phases are described below.

The CBA was applied to "with" and "without" CSA investments scenarios in which the CT scenario is assumed to be the without CSA investment scenario and the CZ and RL scenarios are the with CSA investment scenarios.

Activity models were constructed with Excel models which simulate different crops, livestock, and aquaculture activities, as well as the different household typologies operating in the agriculture sector of Lesotho. The proposed set of "activity" models considers both "without CSA investments" (that is, "conventional" farm management) and "with CSA investments" (that is, CSA-improved farm management). It was assumed that following CSA investments, farmers will be able to switch from conventional to CSA-improved technology, introduce high-value agriculture activities in their farms, and fully adopt new agricultural activities.

Financial analysis. The financial analysis aimed at assessing the financial viability of hypothetical CSA investments, therefore determining the incentives for the target group to engage in CSA. The financial activity models simulate farm gate budgets of running activities, considering revenues, operating costs, and margins. Crop "activity" models refer to rain-fed and irrigated production, depending on the crop. They refer to 1 ha of cropland. Livestock "activity" models simulate the dynamic of a typical herd (average) over a 20-year period. Aquaculture "activity" model refers to a 6-month production cycle. Production costs include cash inputs and labor costs. All inputs are valued at market price. Both gross and net margins are computed. In addition, returns to family labor are computed. Financial performance indicators computed at the activity level are computed before tax.

Economic analysis and estimation of unit benefits. The economic analysis estimates the main quantifiable economic benefits arising from the potential CSA investments, considering the perspective of the society rather than individuals alone. It uses economic prices instead of the financial ones. Table A3.1 shows details about the computation of shadow exchange rate (SER) and standard conversion factor (SCF).

TABLE A3.1: COMPUTATION OF SER AND SCF

	Average 2016–2017 US$, millions	Source of data
1) Total imports (M)	678	World Bank
2) Total exports (X)	1,594	World Bank
3) Import taxes (Tm)	39	World Bank
4) Export taxes (Tx)	148	
SER	13.01	SER = (M + X)/[(M + Tm) + (X − Tx)] × OER
Official Exchange Rate (OER)	13.66	
SCF	0.95	SCF = SER/OER
Value added tax (VAT)	0.15	
SCF (with VAT)	0.81	SCF with VAT of 15% also applied to all tradable goods

Source: Authors.

For some key traded goods, specific import/export parity prices at farm gate are computed with reference to international border prices, applying conversion factors for each category of costs and eliminating taxes and transfers. Specifically, import parity prices are computed for fertilizers which are among key imported items, starting from the international free on board (FOB) prices at the nearest port and considering tariffs and taxes, marketing charges, and transportation costs. Export parity prices are computed for major exportable crop commodities.

The economic analysis computes the net incremental benefits per hectare of land per unit of livestock production. The economic analysis is conducted over a 30-year period, 2020–2050. Net benefits are computed after (family) labor costs.

Assumptions and computation of the overall direct benefits

The unit economic benefits are aggregated over the total number of beneficiaries to estimate the overall flow of economic benefits. Inputs for the estimation included cropland area, cropland proportions, and irrigated land (number of hectares); CA adoption rates (percentage); and livestock proportions (number of heads). The economic analysis was performed considering 122,400 ha of cropland area in the RL scenario and 111,000 ha in the CZ scenario, corresponding to 15.5 percent and 14 percent of total national cropland area, respectively. On average, households cultivate 0.5 ha (Table A3.2). It is assumed that in the RL scenario, households will have the same amount of land available, while in the CZ scenario, they will become more commercially oriented and will be able to expand their cropland to 2.5 ha for instance through farmer aggregation promoted under the scenario. Therefore, the targets include 122,125 households, or 23 percent of households in Lesotho, in the RL scenario and 28,107 farmer groups in the CZ scenario. Two different adoption rates for CSA were used as aspirational targets for 2050: 40 percent under the RL scenario and 25 percent under the CZ scenario.

Other sources of benefits including climate information services, land titling, and administration needed for proper functioning of the land market, and reduced erosion were also considered in the CSAIP (table A2.4). Benefits from climate information services were estimated through two techniques: benchmarking of disaster risk reduction (Hallegate 2012) and contingent valuation (Lazo 2015). The benchmarking approach was used to estimate the order-of-magnitude benefits of reducing damages

TABLE A3.2: DISTRIBUTION OF FARM SIZES IN LESOTHO

Farm category	Farm sizes ha	Average Ha	Proportion %
Small	Less than 1	0.5	66
Medium	1–4	2.5	28
Large	Greater than 4	6.0	6

Source: Based on Lesotho Household Budget Survey

TABLE A3.3: IMPORT PARITY PRICE FOR KEY IMPORTABLE INPUTS

Commodity		Urea[a]		Phosphate[a]		Compound D[a]	
	Unit	Financial	Economic	Financial	Economic	Financial	Economic
Price FOB, January 2019	US$ per metric ton	260.00	260.00	102.50	102.50	215.50	215.50
Plus:							
- Transport, insurance, and freight to Lesotho	US$ per metric ton	53.0	53.0	53.0	53.0	53.0	53.0
- Marketing Charges (2.5%)	US$ per metric ton	6.50	6.50	2.56	2.56	5.39	5.39
Border cost, insurance, and freight (CIF) price	US$ per metric ton	319.50	319.50	158.06	158.06	273.89	273.89
LSL equivalent	LSL per metric ton	4,364.37	4,156.26	2,159.13	2,056.18	3,741.30	3,562.91
- VAT (15%)	LSL per metric ton	654.66	—	323.87	—	561.20	—
- Marketing Charges (2.5%)	LSL per metric ton	109.11	103.91	53.98	51.40	93.53	89.07
- Import tariff (13%)	LSL per metric ton	567.37	—	280.69	—	486.37	—
Wholesale border price	LSL per metric ton	5,128.13	4,260.17	2,536.98	2,107.58	4,396.03	3,651.98
- Transport to regional market 2	LSL per metric ton	800.00	800.00	800.00	800.00	800.00	800.00
- Transport to farmgate 3	LSL per metric ton	100.00	100.00	100.00	100.00	100.00	100.00
- Marketing charges (2.5%)	LSL per metric ton	128.20	106.50	63.42	52.69	109.90	91.30
Farm Gate Import Price	LSL per metric ton	6,156.34	5,266.67	3,500.41	3,060.27	5,405.93	4,643.28
Farm Gate Import Price	LSL per kg	6.16	5.27	3.50	3.06	5.41	4.64
% of nutrient in product	%	0.46	0.46	0.45	0.45	0.60	0.60
Input subsidy (50%)	LSL per kg	6.69	—	3.89	—	4.50	—
Farm gate market price	LSL per kg	6.69	11.45	3.89	6.80	4.50	7.74
Conversion factor		1.71		1.75		1.72	

Source: World Bank 2017.
Note: a. Urea: Black Sea, bulk; Phosphate: Casablanca, rock; Potassium: Vancouver, standard grade;
b. 200 km @ LSL 4 per km; c. 100 km @ LSL 4 per km.

from weather-related events resulting from the adoption of the integrated weather and market information services. The results of contingent valuation of weather services in Mozambique were transferred, correcting and adjusting for the Lesotho context. Table A3.5 illustrates the conversion of per household willingness to pay (WTP) to Lesotho from Mozambique using simple income ratios and then aggregating to national benefit estimates.

Following World Bank 2011 report on Rising Global Interest in Farmland, benefits from land titling were assumed to be 9 percent of the average gross revenues for the crops modeled in the analysis (Deininger et al. 2011). The benefits were from reduced land degradation and soil loss resulting from the implementation of SLM practices, including terraces and other physical measures, flood control and drainage, gully control, reforestation, and natural regeneration of vegetation cover. It is expected that such practices are implemented on degraded cropland, grasslands, and forested land.

Following Zhou et al. (2009), we estimated such benefits considering the amount of avoided soil loss due to erosion (estimated under both the RL and CZ scenarios) and using the average U.S. dollar value indicated in Zhou et al. (2009), adjusted to the Lesotho context through the benefits transfer approach. Additional indirect benefits from reduced grassland degradation could also include better livestock feeding consequent to improved pastures. However, to be conservative in the overall benefits from reduced erosion and land degradation estimation, such benefits are not included in the estimates.

TABLE A3.4: EXPORT PARITY PRICE FOR EXPORTED OUTPUT

Commodity	Unit	Merino wool	
		Financial	Economic
FOB price at port of arrival	US$ per metric ton	11,000.00	11,000.00
Maritime fret	US$ per metric ton	50.00	50.00
International insurance (2% of FOB price)	US$ per metric ton	220.00	220.00
Exchange rate	LSL per US$	13.66	13.01
CIF price at port of departure	LSL per metric ton	147,254.80	140,233.21
Export duties (10% of CIF)	LSL	14,725.48	0.00
Handling (2.5% of CIF)	LSL	3,681.37	3,681.37
Storage fee (1% of CIF and duties)	LSL	1,619.80	1,402.33
Port fee (50% of the storage fee and handling fee)	LSL	2,650.59	2,541.85
Transportation cost from port to farm	LSL per metric ton	22,088.22	22,088.22
Price at the farm gate (LSL per ton)	LSL per metric ton	102,489.34	110,519.43
Price at the farm gate (LSL per kg)	LSL per kg	102.49	110.52
Conversion factor		1.08	

Source: Authors

TABLE A3.5: BENEFITS FROM CLIMATE INFORMATION SERVICES, LAND ADMINISTRATION, AND EROSION CONTROL

Benefits from climate information services				
Benchmarking calculation of benefits from improved information services		Lesotho		
GDP, 2017	US$, millions	2,600		
Vulnerability factor	%	1%		
Loss reduction factor	%	26%		
Benchmarking benefit estimate (national)	US$, millions	6.63		
Benchmarking benefit estimate for agricultural sector at 5.8%	US$, millions per year	0.38		
Conversion of Mozambique contingent valuation parameters to Lesotho context				
	Lower	**Middle**	**Upper**	
Mozambique annual WTP (US$)	0.53	1.16	2.62	
GDP per capita (current US$)				
Mozambique (2017)	416	606	606	
Lesotho (2017)	1,181	1,181	1,181	
Income ratio: Lesotho versus Mozambique (2013)	2.84	1.95	1.95	
Adjusted Lesotho annual WTP	1.51	2.26	5.11	
Number of CSAIP households				
RL scenario	120,866	120,866	120,866	

(continued)

TABLE A3.5: (Continued)

CZ scenario	28,107	28,107	28,107	
CSAIP WTP (US$ per year)				
RL scenario	181,982	273,246	617,158	
CZ scenario	42,319	63,542	143,517	
		RL scenario	CZ scenario	
Total climate information services	US$, thousands per year	1,001.70	528.06	
Benefits from improved land titling and administration				
Costs	**US$, thousands per year**	**2,000.00**		
		RL scenario	CZ scenario	
	ha	122,400	111,000	
Value of gross revenue	%	9%		
Average gross revenue crops Lesotho	US$ per ha	2,915		
Total benefits	000 $	32,107	29,117	
Benefits by year	US$, thousands per year	6,421	5,823	
Benefits by year	US$ per year	6,421,481	5,823,402	
Benefits from reduced land degradation and soil loss				
		CT	**RL**	**CZ**
Soil loss due to erosion	ton per ha	13	12	13
Save	ton per ha		1.7	0.5
Save	US$ per ha		15.4	4.5
Save overall	US$, thousands		1,881	500
Save by year	US$, thousands		376	100
Save by year	US$		376,111	100,078

Annex 4: LesAgMod Use and Limitations

Computer simulation models are widely used to support a range of policy decisions, planning processes, and environmental review. With the prevalence of models to support such efforts, it becomes important to identify the purpose for which models are developed, appropriate model use, model limitations, and to guide the interpretation of model results.

Model objectives

LesAgMod has been developed by the World Bank to support the Government of Lesotho's effort to plan for investment in climate smart agriculture. The model may be used to inform the following types of analyses:

- Estimate the impact of climate change on agricultural production in Lesotho
- Estimate the socioeconomic implications of changing agricultural land use and management practices in Lesotho
- Estimate greenhouse gas emissions from agriculture under different management regimes.

It is intended that *LesAgMod* be transparent, easy to use, and freely available. The WEAP software and its GUI were designed to facilitate a shared model vision. However, the *LesAgMod* application is complex and requires the model user to be familiar with modeling concepts and the agricultural context within Lesotho. Additionally, *LesAgMod* requires a significant investment of time to become familiar with the schematic, properties of objects, and interpretation of model results.

Interpretation of model results

LesAgMod is a long-term planning model developed for planning analysis at the national and sub-national level. It is not intended to be used to support real-time operations. Model results are best interpreted using various statistical measures such as long-term averages.

LesAgMod divides Lesotho into 74 sub-catchments and uses an annual timestep to estimate changes in land use over the simulation period and a monthly time step for estimating agricultural production. The model necessarily simplifies the depiction of streamflows by aggregating surface water diversions, return flows, surface runoff, and groundwater inflows to the stream network. Only downstream from these points of aggregation will *LesAgMod* accurately simulate streamflows. Operational requirements that affect day-to-day management of water infrastructure are not included in the model, such as timed reservoir releases or daily irrigation scheduling. Average monthly flows may not accurately represent operations that respond to daily variability in water conditions. Therefore, disaggregation of model results at the monthly time scale to finer time scales should be undertaken with caution and may not be an appropriate use of the model.

Computational method

LesAgMod uses a Linear Programming (LP) solver to solve a series of equations that seek to maximize an objective function that will best allocate land and water resources in a manner that maximizes farmer profits. This set of equations also includes physical and operational constraints of the system, such as constraints on the availability of suitable land within each sub-catchment and across Lesotho as a whole.

The LP solver does not optimize across multiple time steps or across multiple objectives (that is, it is not formulated as a multi-period optimization). Rather, the LP solver runs annual to allocate available and water resources within the system that maximizes profit based on estimates of crop prices and cost of production. Objectives achieved for a given time step are enforced as constraints in all successive iterations.

Some model limitations

As with any computer-based, mathematical model that is trying to represent and provide new insights to physical and socio-economic systems, there are limitations of the model in terms of what it represents and the information it can provide. LesAgMod is no different. Some of the model limitations include:

1. The model primarily represents the production side of the agricultural systems of Lesotho, with demand not explicitly accounted for.
2. Only the seven primary crops of Lesotho are considered in the model, and thus other crops that might become more important in the future cannot be considered.
3. In terms of crop and livestock production inputs, input substitution is not explicitly modeled (for example, labor cannot be substituted for fertilizer to achieve the same yield).
4. Livestock profit optimization is currently not modeled, rather livestock value is estimated simply as the net benefit.
5. The estimation of area planted within each sub-catchment is assumed to be based on a profit maximization and does not consider institutional or cultural constraints to agricultural expansion or contraction.
6. Cost of inputs are assumed to apply uniformly across Lesotho and are thus not represented at the sub-catchment level.
7. The model assumes a rate of potential growth or contraction of planted area at the sub-catchment level for each of the commodities. The rate varies among the commodities, but the same rate is applied to each sub-catchment.
8. Cropped area that is designated as "under-production" within a sub-catchment is assumed to be actively cropped. This means that while total crop production can change from year-to-year due to changes in yield, cropped area expands or contracts in a relatively continuous manner from year-to-year. Indiscriminate crop fallowing is not considered.
9. Planting and harvest dates are defined exogenously for each crop and are assumed to apply the same to all sub-catchments.

Annex 5: Land Suitability Evaluation for Lesotho

Land suitability evaluation is a process used to determine the potential of land for different kinds of land use. It entails matching the inherent characteristics of land with the requirement of the envisaged use. Land suitability evaluation is central to land-use planning and development because it informs resource managers about the suitability of parcels of land and their limitations in the quest for ensuring long-term productivity and sustainable use of the land.

Climate, topography, and soil characteristics are the principal factors governing agricultural land suitability in Lesotho. The land suitability technique applied was a parametric method that rated the land characteristics based on the requirements of a given crop on a scale ranging from 0 (not suitable) to 100 (highly suitable) within a geographical information system (GIS). The index of productivity for each pixel of land was calculated using the equation

$$IP = A * \sqrt{\left(\frac{B}{100} * \frac{C}{100} * \frac{D}{100}\right)},$$

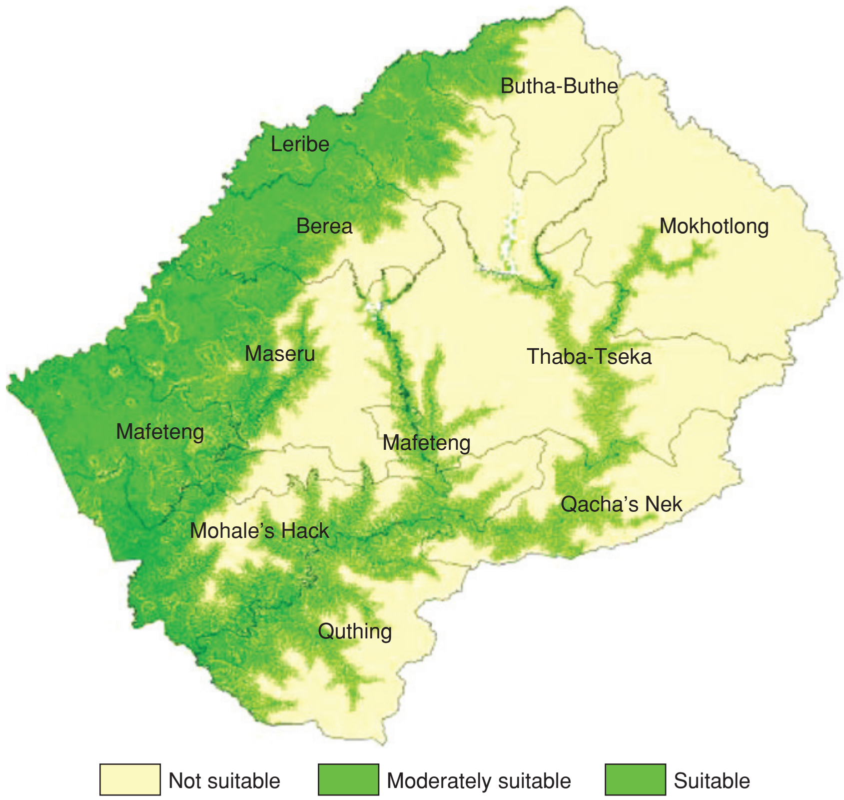
where *A* is the overall lowest characteristic rating, and *B*, *C*, and *D* are the lowest characteristic ratings for each land quality group. The land quality groups considered in this study are climate, topography, soil physical properties, and chemical fertility. Four land suitability classes and their respective IP values for each crop were defined: Highly suitable (75–100); Suitable (50–74); Moderately suitable (25–49); and Not suitable (0–24).

In addition, an agricultural versatility map was produced to identify the areas of Lesotho that are suited for a diversity of crops, where each of the seven digital land suitability maps for orchards, vegetables, beans, wheat, maize, potato, and sorghum were combined within a GIS. Each suitability class was assigned a numerical value where Highly suitable = 3; Suitable = 2; Moderately suitable = 1; and Not suitable = 0. Theoretically, the additive grids for all seven spatial map surfaces therefore should have a range between 0 (implying a pixel is not suitable to all crops) and 21 (implying a pixel is highly suitable to all crops). Considering, however, the fact that some land areas are not highly suitable or even suitable for some crops in Lesotho, the actual maximum for the range is 16. The resultant Agricultural Versatility Map was classified into four classes: Least versatile (versatility index = 0–2); Moderately versatile (versatility index = 3–5); Versatile (versatility index = 6–8); and Highly versatile (versatility index = 9–16). The agricultural versatility map is useful for investors looking at land suited to a wide variety of crops, and to inform protection of agricultural land from non-agricultural development. It can be used to target interventions such as crop intensification, diversification, and natural regeneration of trees and other vegetation.

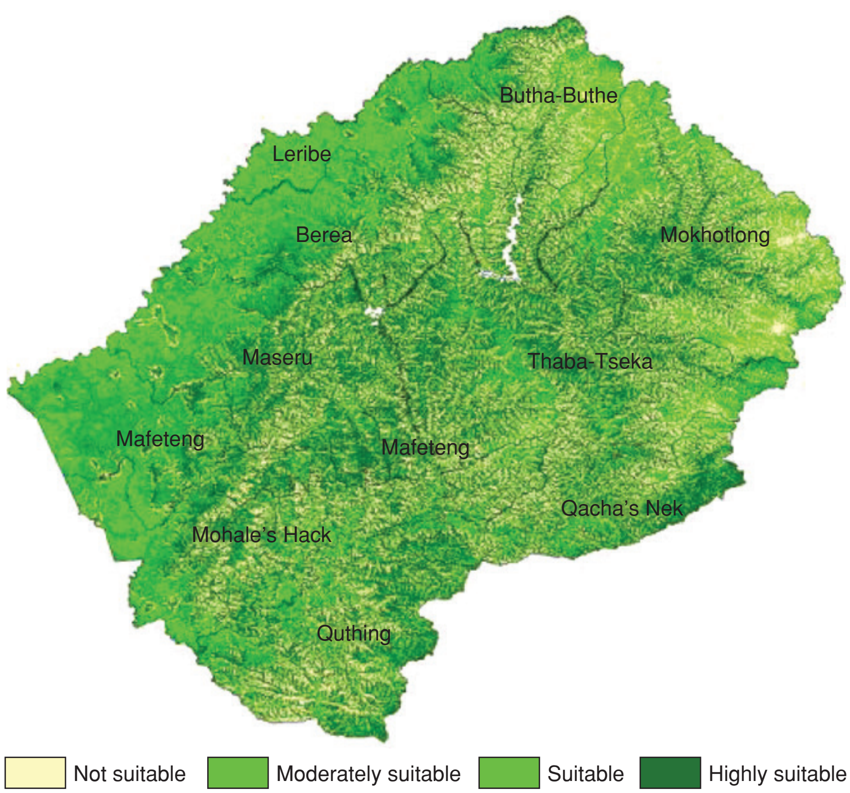
The land suitability and versatility maps are shown in figure A5.1.

FIGURE A5.1: LAND SUITABILITY AND VERSATILITY MAPS

Suitability map for orchards (apples, peaches, apricots)



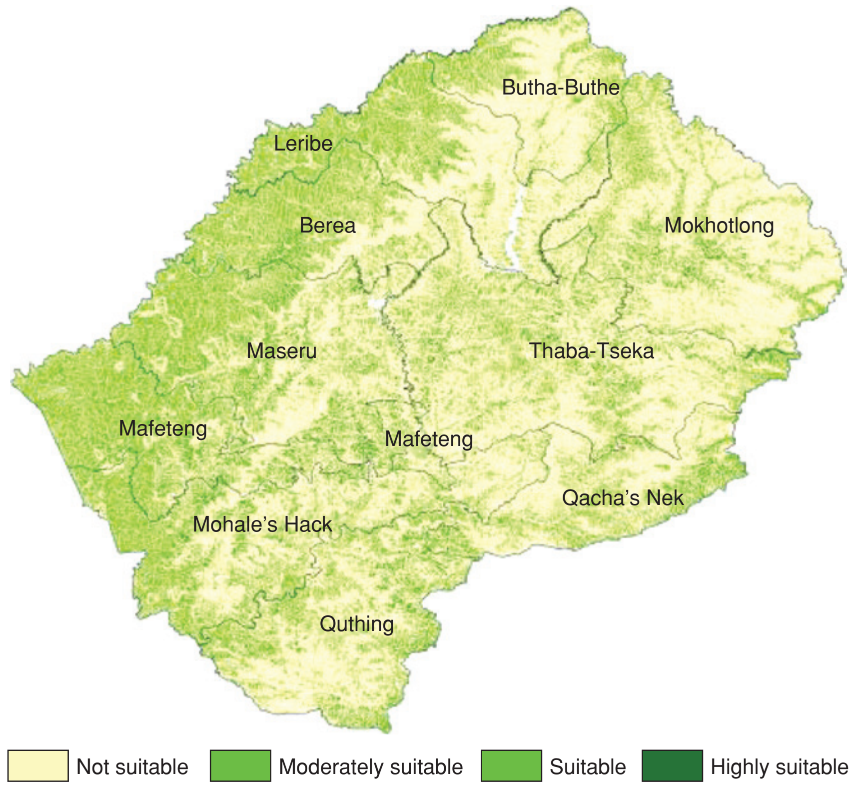
Suitability map for potato



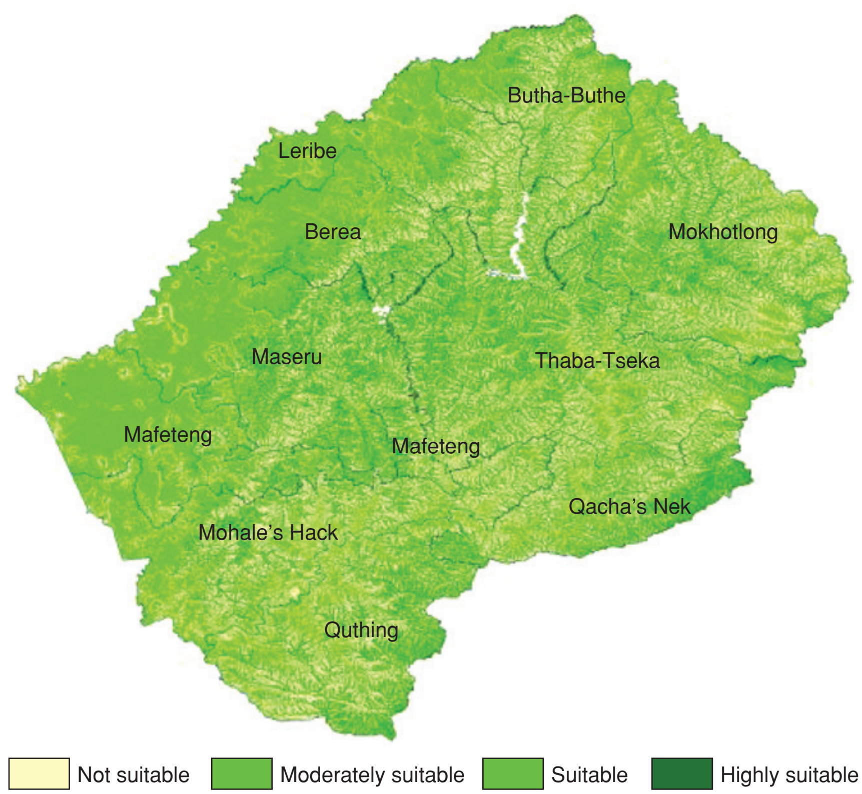
(continued)

FIGURE A5.1: (Continued)

Suitability map for vegetables (cabbage, spinach, lettuce)



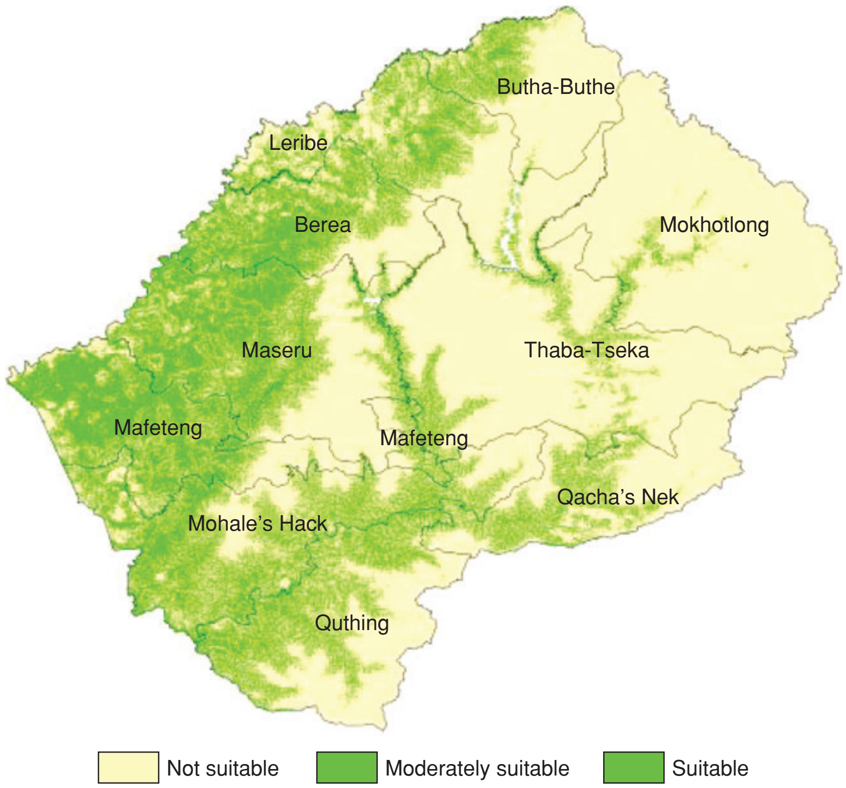
Suitability map for beans and pulses (Kidney beans, Fortified beans, Chickpea)



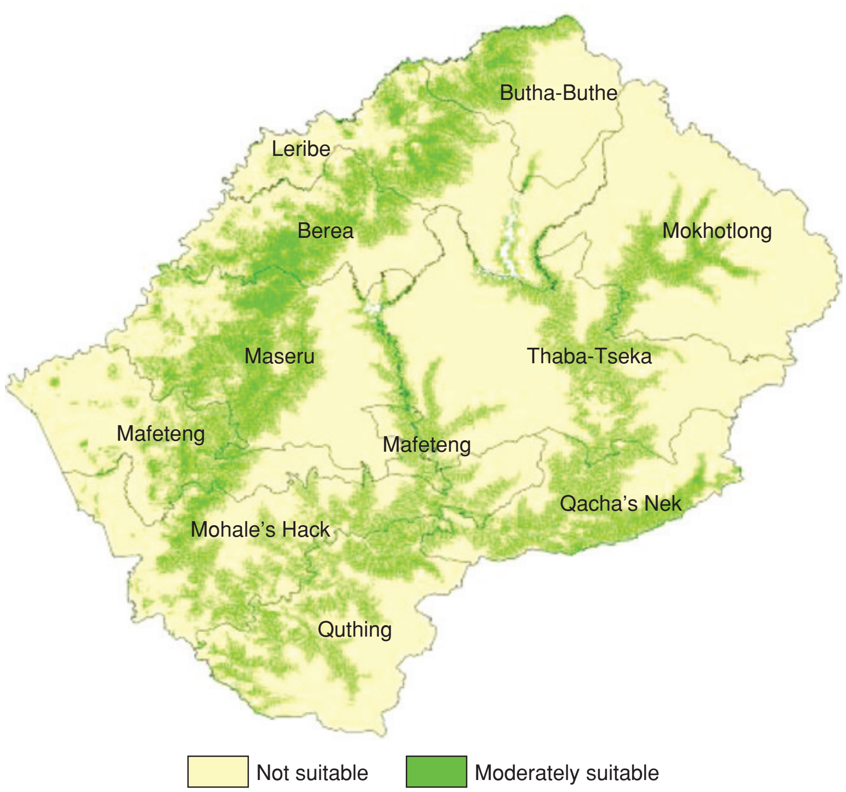
(continued)

FIGURE A5.1: (Continued)

Suitability map for maize



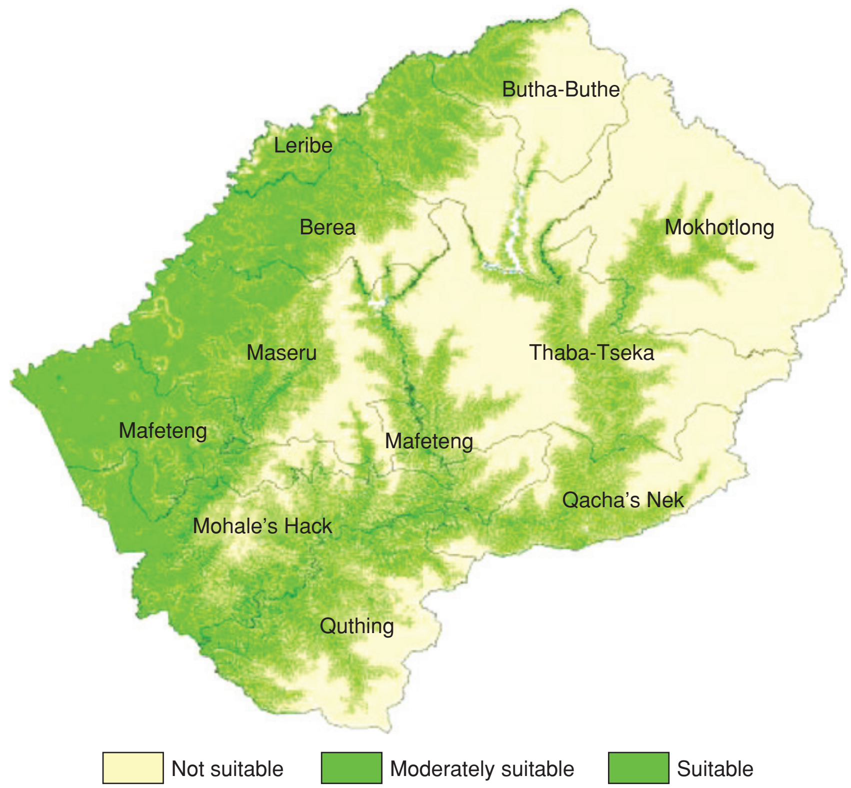
Suitability map for wheat



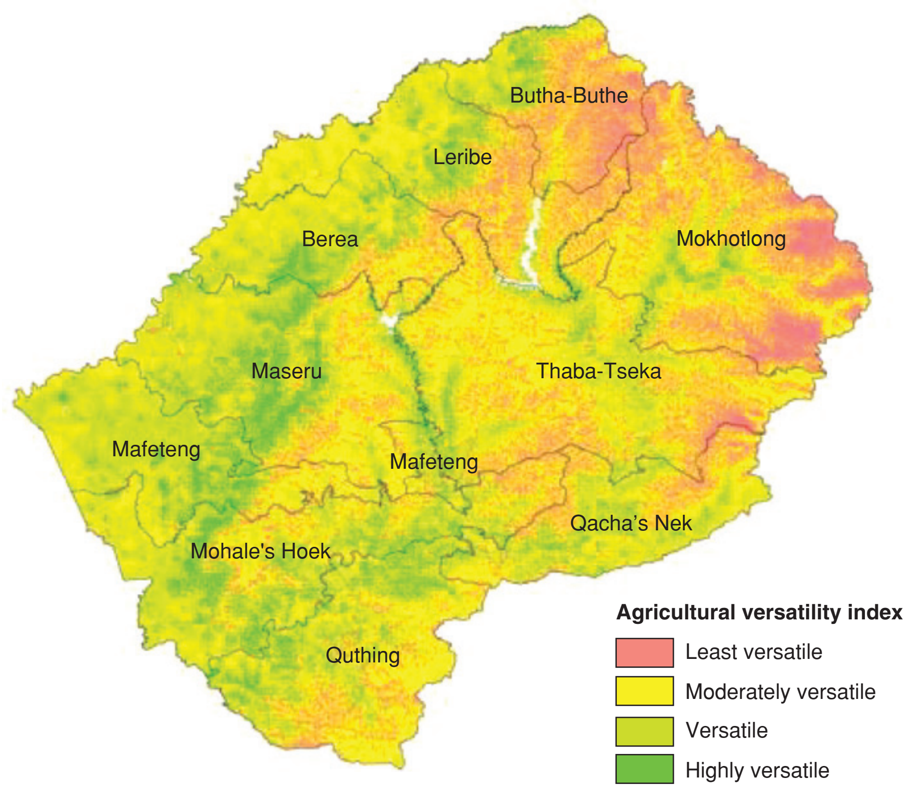
(continued)

FIGURE A5.1: (Continued)

Suitability map for sorghum



Agricultural versatility map



Source: Authors

Annex 6: Critical Investments for Lesotho's Agricultural Transformation

Based on modeling and consistent with Lesotho's NDC plan and agricultural policies, a set of integrated solutions crucial to transforming Lesotho's agricultural sector were identified. The solutions were also validated with Lesotho stakeholders and are consistent with the country's NDC (box A6.1), NSDP II, and other agriculture-related policies.

I. Improve water management in rainfed and irrigated agriculture

Enhanced and efficient water management is a key factor for adaptation and increasing the efficiency of other CSA measures. The recent Climate Risk Assessment

BOX A6.1: CSA OPTIONS ARTICULATED IN LESOTHO'S NDC

The following practices are indicated in the Lesotho NDC with reference to agriculture and related vulnerable sectors (see NDC 2017, table 2, page 10):

Agriculture sector

- Diversify livestock; improve range management; increase access to drought resistant crops and livestock feeds; adopt better soil management practices; provide early warning/meteorological forecasts and related information.
- Increase use of irrigation systems that use low amounts of water; increase rainwater and sustainable ground water harvesting for use in agriculture; increase planting of native vegetation cover and promotion of re-greening efforts; and intensify crop and livestock production.
- Build adaptation capacity in climate resilient agronomic practices for smallholder farmers
- Promotion of climate-smart agriculture (Agro-meteorology)
- Support an expanded program of constructing multipurpose dams for irrigation and aquaculture
- Promote innovations in post-harvest storage and food processing
- Promote the growing of drought-tolerant and heat-tolerant crop varieties and hardy livestock
- Implement CA and agroforestry practices
- Adjustment of planting dates and crop variety; crop relocation; improved land management, for example, erosion control and soil protection through tree planting

Water sector

- Implement integrated catchment conservation and management program
- Expanded rainwater harvesting; water storage and conservation techniques; water re-use; water-use and irrigation efficiency
- Support an expanded program of constructing multipurpose dams to enhance water storage
- Support the revision of water-related policies and strategies
- Establish a national integrated water resource management framework that incorporates district and community-based catchment management

Land use sector

- Integrated approach to Sustainable Land Use Planning and Management
- Promote improved land use practices

(Impact Mapping) identified this as an extremely high potential contribution to improving smallholder farmers' resilience. The CSAIP will promote off- and on-farm investments in hydraulic infrastructure to restore and improve water distribution and reduce losses, improve water use efficiency, and increase and regulate water access management and governance for household consumption and agriculture production, particularly in areas of high agricultural potential. Farmers will increase adoption of irrigation and expand cultivation of high-value crops (for example, irrigated vegetable and fruit production). Increased water availability will also create opportunities for aquaculture investments. The CSAIP investment activities will include

(a) Water harvesting promotion (for example, rainwater runoff collection, through provision of household surface ponds to receive runoff water from adjoining lands and roof water gutters and tanks);
(b) Restoration/modernization/construction of hydraulic infrastructures (for example, reservoirs, weirs, dams, dikes, wells/boreholes, canals, and livestock watering points); rehabilitation and modernization of existing small-scale gravity/manual/motorized irrigation schemes; repair or replacement of headworks, conveyance system canals and pipelines, and irrigation system structures and installations, including water-saving systems such as drip irrigation; supply and installation of distribution and on-farm pressurized and/or pipeline systems; and auxiliary irrigation equipment, including groundwater abstraction systems where technically feasible; and
(c) Implementation of sustainable water management practices through capacity building at farmers' level.

Most of these practices will also contribute to land conservation and soil erosion reduction through retarding runoff flows.

II CSA approaches for crops, livestock, and aquaculture

Given the declining soil fertility levels in Lesotho and its adverse impacts on agricultural productivity and the critical need to build climate resiliency, this CSAIP component will also provide investment support for soil fertility management interventions as follows:

(a) Develop the Lesotho Soil Information System to disseminate information on nutrient status and agricultural potentials of soils (for example, support for updating soil capability and suitability assessment, soil survey mapping, dissemination of soil and crop suitability products, data generation, and database management).
(b) Promote soil testing services to deliver soil health solution packages to farmers in a commercially viable way.
(c) Establish fertilizer blending facilities to produce fertilizers that are compatible to needs.
(d) Build institutional capacity for integrated soil fertility management.

The fertilizer blending facilities will be promoted as joint ventures between farmer organizations, private firms, and the government (central and district) and may over time transfer their shares to the public through equities or debts.

Livestock is Lesotho's main agricultural subsector with wool and mohair contributing more than 50 percent of agricultural exports. The short-cycle stock (chicken and pigs), especially kept by women, contribute significantly to household food security. Cattle rearing is a source of draft power, milk, fuel (dung), and meat. To improve the resilience and productivity of the local production of meat, milk, wool, and mohair, while reducing GHG emissions per unit of produce, the CSAIP will finance three key interventions: improving access to better livestock breeds (for example, introduction of heat-tolerant breeds, promoting AI technologies for increased productivity, selection of low methane-producing animals, and supporting the development and implementation of the regulatory framework for animal genetic resources improvement), improving animal nutrition (for example, developing and disseminating animal nutrition rations for livestock value chains; supporting the enforcement of quality standards for industrial animal feeds; and supporting the production of better grasses and legumes and distribution of climate-ready forage seeds, that is drought-tolerant feed crops, such as cowpeas, sorghum, maize, and soybeans to targeted livestock small-scale producers. The project will also support the incorporation of dietary supplements in livestock feeds) and improving access to animal health services (for example, improved veterinary services and animal disease surveillance and enhanced prevention and control of animal diseases).

III. Promote market access for farmers

The CSAIP will strengthen the role of the private sector in CSA implementation and will contribute to the development of agribusiness models with smallholders. Activities to be promoted include the following:

(a) Development of Agriculture Clusters Service Enterprises (ACSEs) as drivers of commodity value chains. These enterprises will own food processing and storage plants and will be set up as joint ventures between farmer organizations, private operators, and the government (central and local);
(b) Development of Market Hub Enterprises (MHEs) as drivers of food distribution system transformation. MHEs will own and operate food market hubs equipped with adequate infrastructure close to major cities. They will be specialized in aggregating priority food commodities and distribution to wholesalers. MHEs may be promoted as joint ventures between ACSEs, banks, private firms, and the government (central and local) and may over time transfer their shares to the public through equities or debts;
(c) Promotion of the aggregation of smallholder farmers into upgraded commodity value chains. This builds on the fact that smallholder inclusion in value chains is critical for poverty reduction, food and nutrition security, and resilience;
(d) Pilot weather index insurance to manage risks associated with adverse weather events. Agricultural meso-level operators, such as farmers' associations, input providers, financial service providers, and processors represent an optimal channel to reach many smallholder farmers and could result in better management of agricultural risks through developing innovative links (for instance, access to farm inputs and credits) along the supply chain and improving quality of weather index insurance products and promoting commercial scalability;
(e) Promotion of food quality standards, enhancement of import and export policies, improvement of regulatory and legal framework for the private sector, and building of technical and institutional capacity of service providers; and
(f) Postharvest management, which is key to reduce postharvest losses, which could be problematic especially due to climate change (increase in pests and diseases and increase in losses due to extreme climatic events).

This component also includes support for an integrated agroweather and market information system and advisory services. Managing climate variability is fundamental to a long-term strategy for adapting agriculture to climate change in Lesotho. There is a need to expand risk management tools to enable farmers to better manage production and marketing and mitigate environmental risks.

Achieving growth among smallholder farmers has always required access to timely, cost-effective, and personally relevant information on improved agricultural practices, markets, prices, inputs, and weather—and news of impending disasters. Integrating information on weather and markets into planning for adaptation and sustainable agriculture entails the following:

- The use of modern tools for climate data sourcing and analysis, including automatic meteorological measurements and satellite data products on a near real-time basis;
- Analysis of weather risks and assessment of impacts using advanced crop-weather interactions modelling;
- The formulation of highly practical advice that famers can apply directly to their operations; and
- Dissemination of weather and market advisories to farmers using modern information and communication technologies.

It is important to develop agroweather forecasting and dissemination tools and a marketing information system to help farmers address the challenges of climate variability and change and enhance their resilience. Agroweather tools will improve long-term capacity for CSA and sustainable agricultural intensification under changing climatic conditions. An integrated agroweather and market information systems development under the CSAIP will involve three activities:

- Improve agrometeorological forecasting and monitoring.
- Develop climate-smart, agroweather, and market information system and advisories using 'big data' analytics.
- Build institutional and technical capacity for agrometeorological observation, forecasting, agricultural statistics, and market advisory dissemination.

IV. Sustainable landscape and integrated catchment management

Investing in improved land management, such as with resource-conserving technologies, will also considerably improve on-farm water productivity in both rain-fed and irrigated agricultural systems (Bossio et al. 2010). Soil management practices to improve infiltration and soil water storage (such as zero till) can boost water use efficiency by an estimated 25–40 percent, while nutrient management can boost water use efficiency by 15–25 percent (Hatfield, Sauer, and Prueger 2001). Pretty et al. (2006) suggest that improved land management is one of the most promising ways of increasing on-farm water productivity in low-yielding rain-fed systems. Therefore, the CSAIP will adopt a landscape approach to improve crop, livestock, and aquaculture production in the context of rural development and enhancement of household livelihoods, restoration of degraded land, and integrated catchment management.

Activities under this theme would include afforestation, development of a multi-stakeholder institutional framework for integrated catchment area management (for example, through community awareness campaign, establishment of natural resource management [NRM] committees at the community level, development of village action plans, and development of catchment area management plans and functional catchment committees); land-use planning to identify and map the combination of land uses that can best meet the needs of stakeholders while safeguarding resources for the future; promotion of the conservation and sustainable management of aquaculture resources; and promotion of CSA options at the farm level for crops (for example, crop diversification and climate-ready cultivars and improved water use efficiency through appropriate irrigation). Activities will also target the development of NTFPs, as well as aquaculture production.

Land degradation in Lesotho is undermining the finite resources on which people depend for food security.[24] Widespread degradation is detected on the arable parts of the lowlands, where cultivation is intensive (cropland occupying about 1 percent of Lesotho's entire land area has been degraded while another 1 percent of the country's land area has been converted to gullies); on grasslands, mainly due to overgrazing; and on gentle slopes, due to the expansion of cultivated land. The CSAIP will finance interventions aimed at reducing soil erosion and land degradation, through a combination of structural and vegetative measures. The structural measures will include (a) terraces and other physical measures, for example, bench terraces, vegetated soil bunds, and stone bunds; (b) flood control and drainage measures, for example, rock catchment water harvesting and runoff/floodwater farming; and (c) gully control measures, such as gully erosion management, reshaping of gully erosion through integration of silt fences, erosion blankets and brush packing, and stone wall check dams. Such structures will require from one to five years to be established and mostly annual maintenance interventions. The CSAIP will consider both the establishment and the maintenance costs. The CSAIP will also address land degradation through vegetative measures including reforestation and natural regeneration of vegetation cover, through training of village NRM committees in tree nurseries and sustainable forest management, establishment of community nurseries, input packages for community nurseries, and tree planting and grasslands management on communal areas. Such activities will complement soil degradation control measures listed above. Additional vegetative measures (for example, intercropping, CA, mulching and crop residue management, and crop rotation) have already been considered in previous investment areas (see CSA adoption). A summary of the investment activities is provided in table A5.1.

The computation of the investment costs related to the above described activities is made using the following approaches:

(a) Estimating the unit cost per household head and using the total number of targeted households, as indicated in the section on investment targets;
(b) Computing the unit cost per hectare or livestock head and using the total number of hectares per head targeted;
(c) Identifying the needed number of infrastructure and using the corresponding unit cost (establishment and maintenance); and
(d) For communal investments, computing the unit cost per community interventions and considering the number of communities (for example, villages) targeted by the CSAIP.

Costs are computed using available figures from other investment programs in the agriculture sector of Lesotho, or from the literature (for example, see Liniger et al. 2007; Liniger and Studer 2019).[25] Costs already included in the

[24] The annual cost of land degradation in Lesotho is estimated at US$57 million, equivalent to 3.6 percent of the country's GDP. See https://www.unccd.int/sites/default/files/inline-files/Lesotho.pdf.
[25] In these cases, a 'transfer function' to determine the equivalent cost in Lesotho is used. For instance, assume a practice costs 100 dollars in country x with GDP per capita of 1,000 dollars in year 2000. If Lesotho's GDP per capita is assumed to be 1,020 dollars in year 2000, then that CSA practice will cost 102 dollars in year 2000 in Lesotho. Then, 102 dollars in year 2000 can be converted to the corresponding current amount.

TABLE A6.1: LESOTHO CSA INVESTMENT ACTIVITIES

I. Improve water management in rainfed and irrigated agriculture
Water harvesting
Roof water gutters and tanks
Garden surface ponds
Small-scale irrigation
Weirs
Small earth dams
Rehabilitation and modernization of irrigation schemes
Spring- and stream-fed gravity systems
Manual lifting systems
Motorized pumping systems
Drip irrigation (drip kit and treadle pump)
Implementation of sustainable water management practices
Capacity building
Strengthening water institutions and building water management capacity at farm level
II. Scale up CSA technologies for crops, livestock, and aquaculture
Agricultural research toward climate-resilient technologies and management practices
Multi-stakeholder institutional framework for integrated catchment area management
Community awareness campaign
Establish village natural resource management (NRM) committees and develop village action plans
Development of catchment area management plans (CAMPs) and functional catchment committees
Land-use planning
Promote better soil fertility management
Soil information system development and information dissemination
Promote soil testing services to deliver the packages to farmers in a commercially viable way
Establish fertilizer blending facilities to produce fertilizers that are compatible to needs
Build institutional capacity for integrated soil fertility management
Crops
Promote CSA options at the farm level: minimum soil disturbance residue retention, crop rotation, agroforestry, judicious fertilizer application, organic fertilization, inorganic fertilizer, improved crop varieties, postharvest management
IPM
NTFPs development
Training of village NRM committees in technical issues related to NTFPs (honey and so on), business planning, and links to market
Training of youth in making inputs for NTFP production such as beehives
Inputs and small equipment for producer groups

(continued)

TABLE A5.1: (Continued)

Livestock
Development and monitoring of improved rangeland management plans at community level
Promote CSA options at farm level: rotational grazing, fire management, grassland reseeding, fodder production, livestock diversification, animal and herd management, improved feeding practices, manure management
Improved animal nutrition
Improved access to better livestock breeds
Improved access to animal health services
Support to animal health sector
Support to wool and mohair processing and marketing
Aquaculture
Improved stocks
Production intensification
Better feeding practices
Improved water use efficiency and pond management
Diseases control
III. Promote market access for farmers
Develop ACSEs
Develop MHEs
Market link development and upgraded commodity value chains
Pilot meso-level weather index insurance
Promote food quality standards
Postharvest management
Support integrated agroweather and market information system and dissemination of advisory services
Develop information on climate vulnerability and impacts at smallholders'/community level
Develop agricultural statistics
Strengthen in-country agrometeorology capacity
IV. Support sustainable landscape and integrated catchment management
Terraces and other physical measures
Bench terraces
Establishment costs, 5 years
Maintenance costs, twice per year
Vegetated soil bunds
Establishment costs, 15 months
Maintenance costs, once per year
Stone bunds
Establishment costs, 36 months
Maintenance costs, once per year

(*continued*)

TABLE A5.1: (Continued)

Flood control and drainage measures
Rock catchment water harvesting
Establishment costs, 5 years
Maintenance costs, once per year
Runoff/floodwater farming
Establishment costs, 30 month(s)
Maintenance costs, once per year
Gully control measures
Gully erosion management
Establishment costs, 15 months
Maintenance costs, once per year
Reshaping of gully erosion through integration of silt fences, erosion blankets, and brush packing
Establishment costs, 15 months
Maintenance costs, once per year
Stone wall check dams
Establishment costs, 15 months
Maintenance costs, once per year
Reforestation and natural regeneration of vegetation cover
Training of village NRM committees in grasslands rehabilitation and plant nurseries
Establishment of community nurseries
Input packages for community nurseries
Tree planting and grasslands management on communal areas
Improve and modernize land administration system (digital land registry and titling, national spatial data infrastructure, and capacity building for land administration)

Source: Authors

estimation of the net incremental benefits through the economic analysis described above (for example, costs at the farm level borne by farmers engaging in the proposed activities and accounted for in the economic models) are excluded here to avoid double counting.

Investment costs are estimated assuming that the Lesotho CSAIP will mainly rely on public sector-driven delivery mechanisms. The "support to integrated agroweather information system and advisory services" will be led by the agriculture extension department with inputs from the Lesotho Meteorological Service. The "promotion of better soil fertility management" will be anchored in the Department of Soil Conservation, while "improvement of water management" will be led by the irrigation section in the Department of Crops. The Department of Agricultural Research will provide support to all the components as required. The adoption of CSA-related crop, livestock, and aquaculture production techniques would be promoted through the FFS approach which has been proven effective in the on-farm technology dissemination. The landscape approach and planning would be promoted through a pluralistic participatory approach (public extension service in partnership with local NGOs and the active participation of local communities). Last, the private sector participation for sustainable agri-food system would be strengthened through a public-private partnership (development of business models and adoption of a Matching Grant Facility [MGF] for wider inclusion of micro, small, and medium enterprises [MSMEs] and farmers' organizations).

Annex 7: Estimation of GHG Balance

EX-ACT developed by the FAO was used to estimate the GHG emissions and carbon sequestration of the agricultural development resulting from the land-use scenarios. EX-ACT is an appraisal system aimed at providing ex ante estimations of the impact of development programs, projects, and policies in the agriculture, forestry, and other land-use sectors on GHG emissions and carbon stock changes, constituting the carbon balance. It is a land-based accounting system, measuring GHG impacts per unit of land, expressed in tCO_2-eq per hectare and year. It allows to make projections about the impacts that a prospective project or intervention is most likely to have and to compare this "with-project" scenario to the alternative business as usual 'without-project' scenario in which the project never took place. Negative values indicate avoided emissions or increased sequestration while positive values indicate an increase in emissions. In this analysis, the CT scenario was assumed to be the "without-project" scenario while the CZ and RL scenarios are the "with-project" scenarios.

Table A7.1 indicates that the RL scenario will generate a net carbon sink of 26 million tCO_2-eq, equivalent to 0.87 million tCO_2-eq per year, or 1.5 tCO_2-eq per ha per year. Livestock activity is the major carbon emitter with 6 million tCO_2-eq, followed by inorganic fertilizers

TABLE A7.1: ESTIMATED CARBON BALANCE FOR THE RL SCENARIO

	Over the economic project lifetime (tCO_2-eq)			Annual average (tCO_2-eq per year)		
Project activities	**GHG emissions of without-project scenario (1)**	**Gross emissions of with-project scenario (2)**	**Net GHG emissions (2−1)**	**GHG emissions of without-project scenario (3)**	**Gross emissions of with-project scenario (4)**	**Net GHG emissions (4−3)**
Afforestation	—	−6,517,278	−6,517,278	—	−217,243	−217,243
Annual crops to orchards	—	−18,223	−18,223	—	−607	−607
Rangeland improvement	—	−2,498,661	−2,498,661	—	−83,289	−83,289
Improved annual crop production	223,940	−1,730,829	−1,954,768	7,465	−57,694	−65,159
Improved orchards practices	−15.000	−164,243	−149,243	−500	−5,475	−4,975
Grassland management	—	−20,741,663	−20,741,663	—	−691,389	−691,389
Livestock management	46,117,926	52,354,542	6,236,615	1,537,264	1,745,151	207,887
Forest rehabilitation	—	−2,504,146	−2,504,146	—	−83,472	−83,472
Fertilizers application	106,307	2,006,377	1,900,070	3,544	66,879	63,336
Aquaculture	—	18,804	18,804	—	627	627
Total	46,433,173	20,204,680	**−26,228,494**	1,547,772	673,489	**−874,283**
Per hectare	81	35	**−46**	2.7	1.2	**−1.5**

with 1.9 million tCO_2-eq. However, improved grassland management helps reduce most of these emissions with carbon sequestration of 21 million tCO_2-eq. Afforestation, switching from annuals to orchards, rangeland improvement, forest rehabilitation, and improved crop production all sequesters about 13.5 million tCO_2-eq. GHG dynamics for the CZ scenario are similar but generate considerably lower carbon sink of 2.5 million tCO_2-eq, equivalent to 84 thousand tCO_2-eq per year, or 0.2 tCO_2-eq per ha per year. Livestock activity is also the major carbon emitter (7 million tCO_2-eq), while application of fertilizers and pesticides emits about 4.9 million tCO_2-eq. Grassland management, conversion of annuals to orchards, afforestation, rangeland improvement, and improved practices in orchards are estimated to sequester about 8.4 million tCO_2-eq.

TABLE A7.2: ESTIMATED CARBON BALANCE FOR THE CZ SCENARIO

	Over the economic project lifetime (tCO_2-eq)			Annual average (tCO_2-eq per year)		
Project activities	**GHG emissions of without-project scenario (1)**	**Gross emissions of with-project scenario (2)**	**Net GHG emissions (2−1)**	**GHG emissions of without-project scenario (3)**	**Gross emissions of with-project scenario (4)**	**Net GHG emissions (4−3)**
Afforestation	—	−2,281,062	−2,281,062	—	−76,035	−76,035
Annual crops to orchards	—	−174,423	−174,423	—	−5,814	−5,814
Rangeland improvement	—	−3,358,130	−3,358,130	—	−111,938	−111,938
Improved annual crop production	718,680	−494,730	−1,213,410	23,956	−16,491	−40,447
Improved orchards practices	−12,600	−1,425,630	−1,413,030	−420	−47,521	−47,101
Grassland management	—	−6,102,907	−6,102,907	—	−203,430	−203,430
Livestock management	49,865,026	56,920,719	7,055,693	1,662,168	1,897,357	235,190
Fertilizers and pesticides application	106,307	4,996,386	4,890,078	3,544	166,546	163,003
Aquaculture	—	75,215	75,215	—	2,507	2,507
Total	50,677,413	48,155,437	**−2,521,976**	1,689,247	1,605,181	**−84,066**
Per hectare	103	98	**−5**	3.4	3.3	**−0.2**

KHOTSO PULA NALA

WORLD BANK GROUP