PRODUCTIVITY RESILIENCE LOWER EMISSIONS

CLIMATE SMART AGRICULTURE INVESTMENT PLAN

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Abbreviations

A1	Smaller villagized holdings, (5-6ha cropping, 25 ha livestock)
A2	Larger commercial holdings (20 to >120ha)
AER	Agro-ecological Region
AKIS	Agricultural Knowledge and Innovation System
CAADP	Comprehensive Africa Agriculture Development Programme
CIAT	International Center for Tropical Agriculture
CO_2e	Carbon dioxide equivalents
CSA	Climate Smart Agriculture
CSAIP	Climate Smart Agriculture Investment Plan
CTCN	Climate Technology Centre and Network
ECRAI	Enhancing the Climate Resilience of Africa's Infrastructure
EM-DAT	Emergency Events Database
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical Databases
GDP	Gross Domestic Product
GLEAM	Global Livestock Environmental Assessment Model
GoZ	Government of Zimbabwe
ha	hectares
ICT	Information Communication Technology
IDA	International Development Association
IEc	Industrial Economics, Inc.
IPCC	Intergovernmental Panel on Climate Change
LSCF	Large Scale Commercial Farms
NAPF	National Agricultural Policy Framework
NDCs	Nationally Determined Contributions
SSC	Small Scale Commercial operations
TSP	Transitional Stabilization Program
UNFCCC	United Nations Framework Convention on Climate Change
ZAIP	Zimbabwe Agriculture Investment Plan
ZIMSTAT	Zimbabwe National Statistics Agency
ZimVAC	Zimbabwe Vulnerability Assessment Committee

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ES

Executive Summary

Introduction and motivation

This report presents a Climate Smart Investment Plan (CSAIP) for Zimbabwe's agricultural sector. The agricultural sector plays a critical role in the Zimbabwean economy, serving as a source of livelihood for approximately 70% of the population and contributing 15-20% to Gross Domestic Product (GDP). However, agricultural production in Zimbabwe remains highly dependent on climate, with a primarily rainfed, low technology production base, low adaptive capacity, and large seasonal climatic variability. Furthermore, climate change is expected to negatively impact agricultural production, both through increased occurrence of extreme weather events such as floods and droughts, as well as from rising temperatures and changes in precipitation. Without more effective adaptation, the impacts of a drier climate on the agricultural sector could cause a decline in Zimbabwe's GDP of over 2%. Against this backdrop, the adoption of Climate Smart Agriculture (CSA) practices as both an adaptation and mitigation strategy is becoming increasingly important.

In response, the Government of Zimbabwe, with the assistance of the World Bank, is supporting the development of this CSAIP. Through stakeholder consultation, supported by quantitative modeling and expert elicitation, this CSAIP identifies and prioritizes packages of CSA investments and policy actions that will support improvement across three key CSA pillars, namely the achievement of a more **productive, resilient,** and **low-emissions** agricultural sector. It provides guidance on implementation mechanisms for these CSA interventions, discussing details such as investment costs and supporting institutional arrangements. It seeks to align goals and objectives across Zimbabwe's existing agricultural policies and climate change strategies, which will contribute to the achievement of the country's Vision 2030, and the Nationally Determined Contributions (NDCs), among others. Additionally, this CSAIP is intended to serve as an input to developing a new, climate resilient Zimbabwe Agricultural Investment Plan for the future.

Background

Before 2000, Zimbabwe was one of the strongest economies in southern Africa, with diversified industrial and agricultural sectors, and an extensive agro-processing industry. However, a series of political and economic crises over the past 20 years have caused major economic setbacks. Currently, the most pressing economic concern is stimulating economic growth. This depends on improving the productivity and resilience of the agricultural sector, the mainstay of the Zimbabwean economy. At the time of writing, the agricultural sector is struggling to maintain productivity in light of high inflation causing rapidly rising prices for key agricultural inputs. CSA practices can help improve agricultural productivity in a way that is both resilient to future uncertainties as well as helping to address the country's emissions reduction target of 33% per capita by 2030. Zimbabwe is already pursuing a selection of CSA adaptations, including Conservation Agriculture, which includes zero tillage, crop rotation, and mulching practices. There is much room for scaling up of these efforts.

Improving the productivity of the agricultural sector goes hand in hand with addressing the enabling environment in relation to:

Smallholders and water access	Land tenure security, poverty and gender issues	Low national budget allocations
Most farmers in Zimbabwe (89%) are smallholder farmers who rely on rain-fed agriculture and less than 1% of smallholders have access to irrigation. Farmers' limited access to water affects food production, particularly during frequent droughts, which leads to food security issues, and increasing reliance on food imports and aid. Irrigation and water storage infrastructure are currently in a state of disrepair.	Unresolved land tenure security issues reduce farmers' incentives to make investments that increase productivity. Additionally, climate and weather-related shocks disproportionately impact vulnerable groups such as women and youth, whose situation is worsened by the reduction in alternative income opportunities since the 1990s due to drought and other factors. Women and youth face institutional, legal, economic, and social barriers.	From 2007 to 2011, government support for the agricultural sector declined from 7.3 to 4.4% of the national budget. While government spending on agriculture has been increasing since 2016, this increase has been largely directed to the provision of agricultural inputs rather than investments in enablers of productivity and resilience. Aside from these direct subsidy programs, Government funds are spent largely on salaries.

Addressing these foundational issues will create the enabling environment necessary to move to a more productive, resilient and low emissions agricultural sector that benefits millions of farmers.

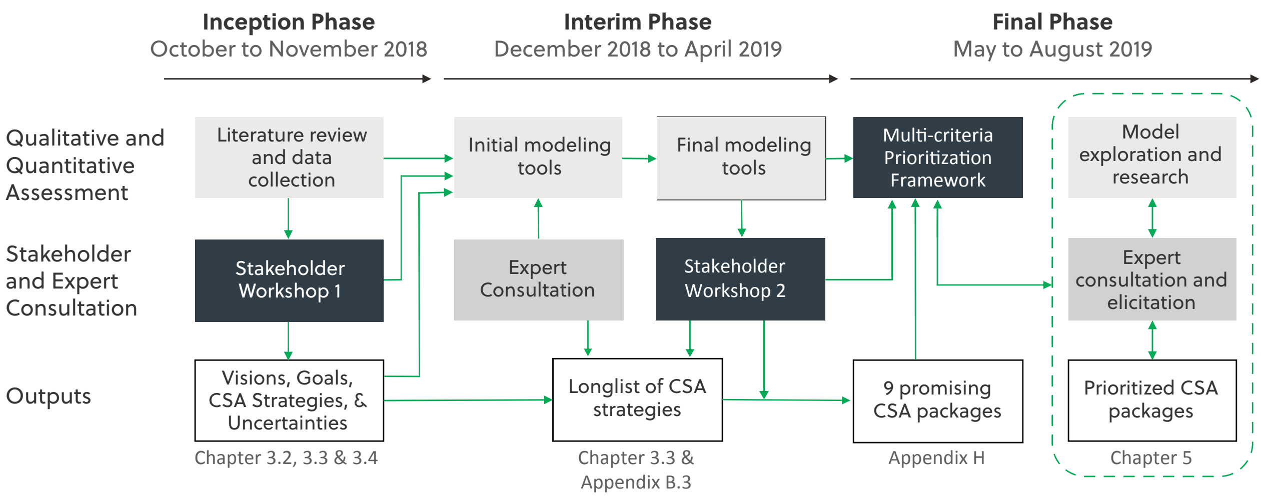
Methodology

This CSAIP was developed in accordance with the principles of the Programmatic Approach for CSAIPs, which focused on the three CSA pillars of productivity, resilience, and mitigation and utilized a general four-step approach:

- Identification of visions, goals, CSA options, and key uncertainties;
- Scenario development to assess the robustness of CSA to uncertainties;
- Analysis of the performance of identified packages of CSA options; and
- Final prioritization and recommendations.

This general approach was applied specifically to the context of Zimbabwe's agricultural sector through a combination of literature and policy reviews, qualitative assessment, quantitative modeling, expert consultation and stakeholder workshops, as shown on Figure ES-1. An initial set of CSA options was compiled from a desk review. A collaborative, stakeholder-driven process was subsequently conducted to identify visions, goals and key uncertainties. Qualitative and quantitative assessment tools were used to assess the vulnerability of Zimbabwe's agricultural sector to various uncertainties, and build the case for investment in CSA generally. The output of this modeling process, coupled with expert and stakeholder consultation, informed the development of a shortlist of nine promising packages of CSA strategies. By developing and applying a prioritization framework, a final set of five recommended packages was developed from the shortlist, on the basis of a number of different selection criteria. The application of this four-stage approach ultimately resulted in the development of targeted and robust packages of CSA options that are considered feasible in relation to the existing physical, social, and political constraints, and are well-aligned with the primary goals of government and policy already in place. Each of the various outputs shown on Figure ES-1 is discussed in turn below.

Figure ES.1 Workflow Schematic



Development of Visions and Goals

Based on feedback from consultations with stakeholders, a set of normative visions of the future for Zimbabwe's agricultural sector was identified, based on the pillars of CSA:

Productivity
To achieve food and nutrition security through a diversified, sustainable, and commercially driven agricultural sector

Resilience
To ensure the agricultural sector is resilient to climate shocks by 2030

Mitigation
To achieve a sustainable agricultural sector that reduces greenhouse gas emissions through carbon conservation and carbon sequestration

Development of a Longlist of possible CSA Strategies

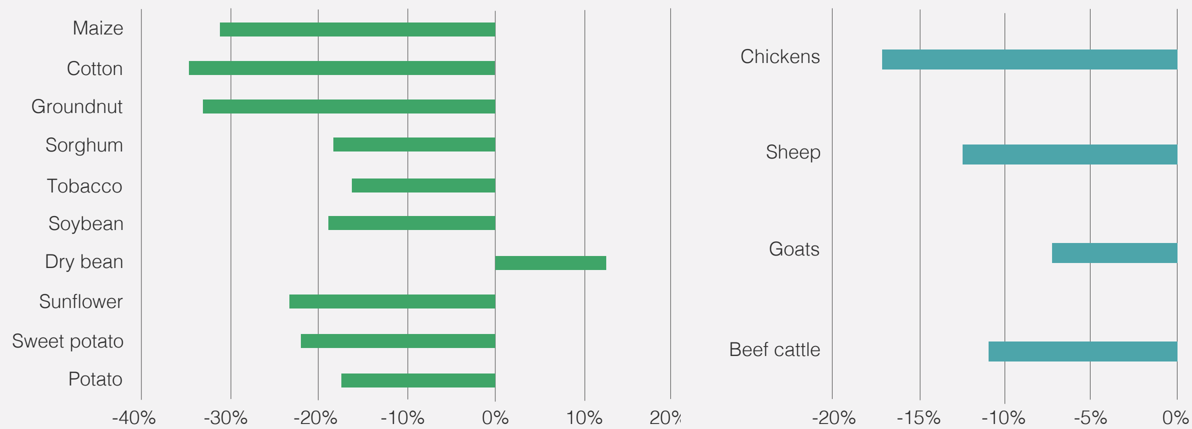
Based on research, expert elicitation, and stakeholder input during workshops, a set of close to 30 individual CSA strategies were identified. They span different investment categories, from options focusing on cropping and livestock, to infrastructure, disaster risk management, markets and education. This set forms the basis for the investment packages recommended by the CSAIP.

Identifying Key Uncertainties and Motivating the Role of CSA given these Uncertainties

When developing plans for the future, it is critical to consider the impacts of uncertainty. During the stakeholder consultations, groups defined key drivers of uncertainty, including future population growth, regional and international markets and climate change. These uncertainties informed an assessment of the vulnerability of Zimbabwe's agricultural sector to a range of possible future conditions, using scenario analysis to explore what various uncertain futures would look like without investment in CSA, (i.e., a "no action" future).

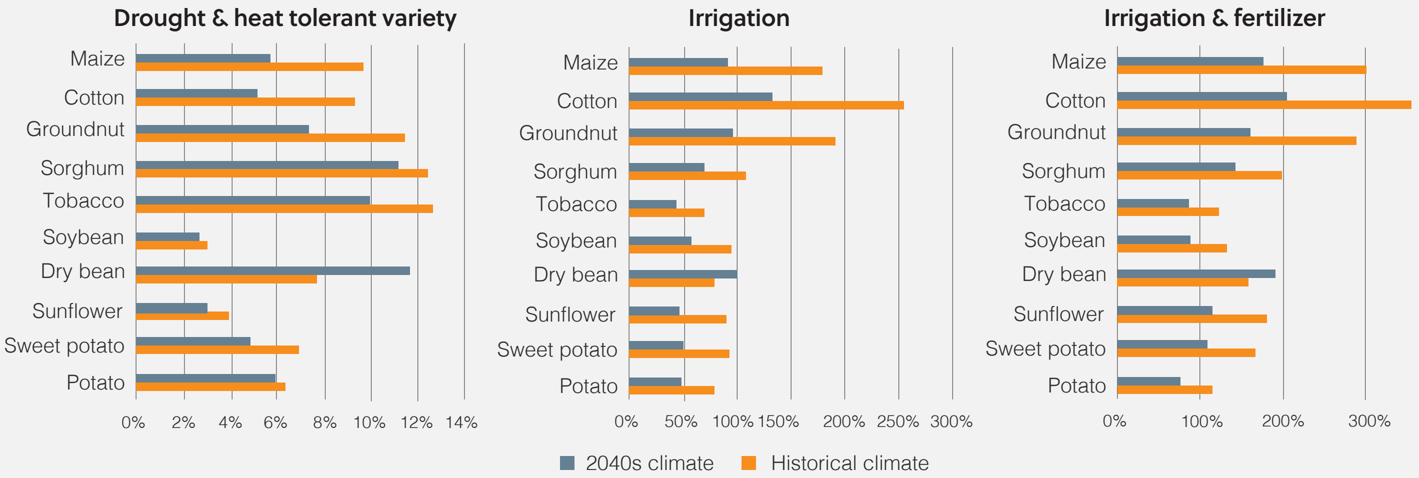
Under a changing climate, maize, a staple food crop in Zimbabwe, is expected to see a 33% yield reduction by the 2030s, with a range of expected yields from +35% to -50% across three different climate scenarios considered (a dry/hot, a medium and a wet scenario). This assessment was repeated for 10 different crops, and all but one of the 10 show an expected decline in yield, ranging from 15% to 36% (see left graph of Figure ES.2). Additionally, increases in temperature were estimated to result in decreases in the income generated from beef cattle by 11-13% by 2040. Sheep and chickens were impacted to an even greater degree, with income reductions from 13-15% and 17-21%, respectively (see right graph of Figure ES.2). An increase in temperature is also linked with increased incidence and prevalence of livestock diseases. Thus, without action to increase resilience, climate change will likely leave Zimbabwe's agricultural sector in fast decline. These impacts are expected to be further exacerbated by population growth.

Figure ES.2 Change in Crop Yields 2040s (medium climate projection) / Change in Livestock Income (%) 2040s (medium climate projection)



Having documented the vulnerability of Zimbabwe's agricultural sector to uncertainty, the next part of the analysis explored the ability of an indicative set of CSA investments to achieve a more resilient agricultural sector under various uncertain futures. Crop-switching to drought and heat tolerant crop varieties was estimated to increases yields by 3-12% across all crops (see left graph of Figure ES.3). While investment in irrigation has high initial capital costs, it provides estimated yield increases of between 50 and 140% (see middle graph of Figure ES.3). The combination of investment in irrigation and fertilizer increases yields by 100-210% (see right graph of Figure ES.3). It is even more effective in a hot and dry future climate with yields that are five times higher than they would be without action.

Figure ES.3 Yield projections for all crops at the present and in 2040, showing the benefits of three different CSA investments



Changes are relative to current conditions for the same climate e.g. changes for irrigation in the 2040s are relative to current practices with 2040 climate

The results show that CSA can result in substantial yield increases across various uncertain futures. The remainder of the CSAIP describes the process of developing and evaluating specific packages of CSA investments that will contribute to improved productivity, resilience and mitigation in Zimbabwe's agricultural sector in spite of the pressures posed by an uncertain future.

Prioritizing CSA Packages

Having established that CSA is a robust short- and long-term strategy in Zimbabwe, the study aimed to identify *no regret* investment packages that maximize positive outcomes and minimize negative outcomes for the agricultural sector given an uncertain future. A set of nine high-impact investment packages made up of combinations of individual CSA options were developed. These shortlisted packages were subsequently evaluated by local and international experts across nine different criteria, with criteria divided into two categories: those that move Zimbabwe toward achieving the **CSA pillars**, and those that have the necessary elements of the **enabling environment** in place to be successful. The results of the evaluation were used to create a set of five high priority investments packages.

Recommended CSA Investment Packages and Next Steps

The CSAIP recommends five high priority investment packages, detailed on the following page. The packages collectively encompass the key Zimbabwean agricultural sub-sectors and are capable of advancing Zimbabwe's CSA goals identified by stakeholders. Costs for each package were estimated by investigating prior World Bank projects that conducted similar activities to those proposed in each investment package.

The next steps for this CSAIP will focus on further development of these investment packages, and integration with Government policies, with the aim of ultimately identifying investors. As part of this process, a broader dissemination and outreach strategy will be initiated. Additionally, the Government of Zimbabwe is in the process of developing a revised Zimbabwe Agricultural Investment Plan, for which the CSAIP will provide important inputs.

INVESTMENT OPPORTUNITIES	IMPACT POTENTIAL[1]	INVESTMENT VOLUME

PACKAGE A: ENHANCED AGRICULTURAL KNOWLEDGE AND INNOVATION SYSTEM

Investment Opportunities	Impact Potential	Investment Volume
Build capacity of public extension workers	Improves smallholder farmer productivity and resilience in crop production (maize, small grains and horticulture)	US$ 50 – 75 MILLION OR $83-$125 PER BENEFICIARY
Invest in innovation platforms based on strong public, private and civil society service partnerships	Switching to improved crop varieties increases yields by 6-21%	
Invest in Information Communication Technology (ICT)-enhanced information dissemination systems	Increase incomes, nutrition security and resilience, particularly in Agro-ecological Regions IV and V	
	Moving away from monocultures increases soil carbon sequestration	

PACKAGE B: SUSTAINABLE LIVELIHOODS THROUGH DIVERSIFIED LIVESTOCK SYSTEMS

Investment Opportunities	Impact Potential	Investment Volume
Invest in improved/alternative feeding systems	Improved feeding practices reduce livestock feed intake by 63%	US$ 30 – 60 MILLION OR $100-200 PER BENEFICIARY
Climate resilient breeding program and extension services	Improved feeding practices reduce livestock methane emissions by 56%	
Commercialization of livestock in the smallholder farmer sector	Using velvet beans could increase profits for non-dairy cattle farmers with a benefit-cost ratio of 1.5-1.9	
	Switching to smaller livestock increases protein production, provides a more climate resilient food source, and significantly reduces greenhouse gas emissions	

PACKAGE C: WATER HARVESTING FOR RESILIENT CROP AND LIVESTOCK PRODUCTION

Investment Opportunities	Impact Potential	Investment Volume
Invest in soil and water conservation techniques as part of integrated catchment management	Improved water availability results in increased livestock and crop productivity, which increases farmer income	US$ 75 – 100 MILLION OR $95-$125 PER BENEFICIARY
Invest in in situ water harvesting and small scale water infrastructure to enhance crop and livestock production	If conservation tillage were adopted in Agro-ecological Region V, soil carbon sequestration would decrease emissions by 6,400 tCO_2e / year	
Build the capacity of extension workers and farmers in sustainable water harvesting practices, including water conservation and Conservation Agriculture	Mulching reduces soil evaporation after rainfall by 15-24%	
	Irrigation for maize results in 4.5 greater yield in Agro-ecological Region V	

PACKAGE D: WOMEN- AND YOUTH-FOCUSED VALUE CHAIN DEVELOPMENT

Investment Opportunities	Impact Potential	Investment Volume
Organic vegetable, poultry, and goat production in peri-urban areas around Harare	Enhances income and food security among women- and youth-owned farms	US$ 20 – 40 MILLION OR $330-670 PER BENEFICIARY
Promote sustainable financial inclusion for women and youth	Increased productivity of high value vegetables and poultry	
Invest in women- and youth-oriented production and marketing networks	Comparable projects suggest up to 30% lower likelihood of malnourished children to mothers involved in urban farming	

PACKAGE E: RESILIENT COMMERCIAL DAIRY FARMING

Investment Opportunities	Impact Potential	Investment Volume
Improved feed and fodder production	Boost productivity of commercial A2 dairy farmers, reducing milk imports and increasing farmer income and food security	US$ 30 – 60 MILLION
Breeding programs for climate resilient dairy cow breeds	Improving on-farm conditions can result in increases in milk output of 7.8 times	
Provision of robust extension services	Reduced malnourishment in children	
Climate smart production for milk and cold chain management	Job creation based on	

[1] See Figure 2-1 in Section 2.1 of the main report for a map of Zimbabwe's Agro-ecological Regions.

Chapter 1

Introduction

This chapter introduces the motivation for this work and defines the objectives to be achieved (Section 1.1). These objectives will be realized by applying the general CSAIP approach presented in Section 1.2. Section 1.3 provides a roadmap for how to read this document.

1.1 Objectives and Motivation

The agricultural sector plays a critical role in the Zimbabwean economy, contributing 15-20% to Gross Domestic Product (GDP) and 25% to formal employment. Additionally, it is the largest single source of export earnings at over 40%, accounts for 63% of raw materials for agro-based industries, and is a direct and indirect source of livelihoods for 67% of the country's population.

However, agricultural production in Zimbabwe is under threat from a variety of challenges. Large inter-annual and seasonal climatic variability challenge the primarily rainfed production base, a situation made worse by low levels of farming technology, low adaptive capacity, and weak support services. Historically, climate variability has had major implications on socio-economic development. For example, the 2015/2016 El Nino event lowered rainfall and reduced agricultural production to the point where four million people needed temporary food aid.

Furthermore, future climate change is expected to impact both average and extreme climate conditions in Zimbabwe, resulting in dramatic impacts on agricultural production. Hotter and drier conditions, coupled with more frequent and more severe extreme weather, are likely to reduce crop and animal production. A recent World Bank study found that by 2030, without adaptation, the impacts of a drier climate on the agricultural sector could cause a decline in Zimbabwe's GDP of over 2% (Benitez et al. 2018). The same study showed that investing in irrigation and enhanced crop varieties would greatly reduce these impacts, and recommended a broader evaluation of possible investment options. Against this backdrop, adoption of Climate Smart Agriculture (CSA) as an adaptation and mitigation strategy, is becoming increasingly important. The World Bank is assisting the Government of Zimbabwe to develop this CSAIP.

This CSAIP sets out to document the vulnerability of Zimbabwe's agricultural sector to climate risks. Through stakeholder consultation, supported by quantitative modeling and expert elicitation, the CSAIP identifies, prioritizes, and provides an estimate of the cost of packages of CSA investments, and policy actions that will support the achievement of a more productive, climate resilient, and low-emissions agricultural sector. It provides guidance on implementation mechanisms for the interventions, discussing policy context, enabling environment and investment costs, as well as supporting institutional arrangements. CSA is a key part of Zimbabwe's Nationally Determined Contributions (NDCs) and the CSAIP seeks to build the country's capacity to meet their climate commitments.

This CSAIP is aligned to the goals and objectives of the National Agricultural Policy Framework (NAPF) (GoZ 2018b), Vision 2030 (GoZ 2018c) and the Transitional Stabilization Programme (TSP) (GoZ 2018d). It also takes account of the ongoing agriculture visioning exercise, climate change strategies, policies and guidelines; as well as taking on board recommendations from the Comprehensive Africa Agriculture Development Program (CAADP) Post Compact Review of Zimbabwe's 2013-2017 Agriculture Investment Plan (ZAIP) (2018). Crucially, the CSAIP is intended to serve as input to the process of developing a new, climate resilient ZAIP. This CSAIP builds on the existing CSA country profile for Zimbabwe (CIAT World Bank 2017) and CSA agriculture manual (CTCN 2017), and other related efforts, which offer the entry point for how CSA can help the agricultural sector both adapt to and mitigate climate change while achieving agricultural sector growth. The development of this CSAIP fosters dialogue between different stakeholder groups, including the Government of Zimbabwe and local famers, as well as potential donors and private sector investors.

1.2 Overview of the General CSAIP Approach

The development of this CSAIP builds on general goals laid out in the Programmatic Approach for CSAIPs, which revolve around achieving improvement across three key pillars, namely

Productivity **Resilience** **Mitigation**

The generalized CSAIP process can be summarized in a four-step approach:

- Identification of visions, goals, CSA options, and key uncertainties;
- Scenario development to assess the robustness of CSA to uncertainties;
- Analysis of the performance of the identified packages of CSA options; and
- Final prioritization and recommendations.

This same general four-step approach has previously been applied in Bangladesh and Zambia and is being applied in Lesotho. These projects are part of commitments made in the Eighteenth Replenishment of the International Development Association (IDA) to "develop at least five climate-smart agriculture profiles and investment plans in IDA countries over the IDA18 period" (IDA 2016). Application of this four-stage approach ultimately results in the development of targeted and robust packages of CSA options for Zimbabwe, which are both feasible given the physical, social, and political constraints, and well-aligned with the primary goals of government and policy already in place.

1.3 Report Structure

The remainder of this report is structured in the following way:

- Chapter 2 presents relevant background information on climate change and Zimbabwe's agricultural sector;
- Chapter 3 describes the methodology of how the general CSAIP approach introduced in Section 1.2 above was applied to the specific case of Zimbabwe's agricultural sector;
- Chapter 4 presents some analytic results highlighting the challenges that will be faced by Zimbabwe's agricultural sector under an uncertain future and provides evidence in support of the role of CSA in addressing these vulnerabilities;
- Chapter 5 presents results of the process of producing prioritized packages of CSA investments and takes a detailed look at each of these recommended packages; and
- Chapter 6 concludes with a summary, a set of recommendations and next steps.

Chapter 2

Background: Climate change and Zimbabwe's agricultural sector

This chapter summarizes the current situation in Zimbabwe's agricultural sector: Section 2.1 describes the role of agriculture in the economy; Section 2.2 looks at greenhouse gas emissions and climate change vulnerability; and Section 2.3 summarizes the relevant policy context. Appendix A presents further details on policy documents addressing CSA in Zimbabwe's agricultural sector.

Zimbabwe is a landlocked country, with a population of over 16 million, and GDP of $16.3 billion in 2016 (World Bank 2019). Before 2000, Zimbabwe was one of the strongest economies in southern Africa, with diversified industrial, mining and agricultural sectors, and an extensive agro-processing industry. However, a series of political and economic crises over the past 20 years have caused major economic setbacks. Currently, the most pressing economic concern is stimulating economic growth (Benitez et al. 2018), which depends heavily on the productivity of the agricultural sector[2] . CSA investments can help achieve this objective.

[2] At the time of writing, the agricultural sector is struggling to maintain economic viability in light of high inflation rates causing rapidly rising prices for key agricultural inputs. Furthermore, the implementation of the recommended investments presented in this Plan is complicated by the current inability of International Financial Institutions to provide lending support due to Zimbabwe's existing arrears.

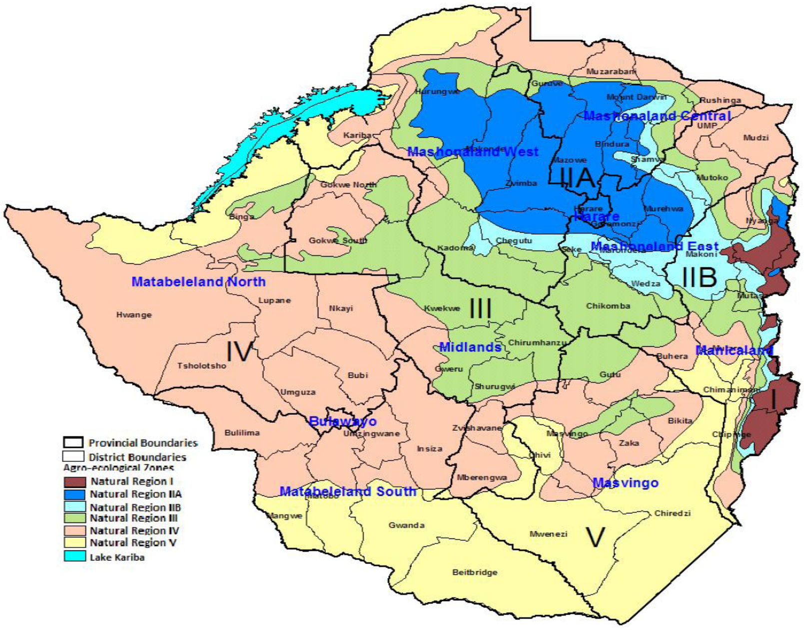
2.1 The Role of Agriculture in the Economy

Agriculture plays many important roles in Zimbabwe's economy. The sector is a source of livelihood to approximately 70% of the population, contributes 15-20% to GDP, 40% of exports, 25% to formal employment and supplies 63% of agro-industrial raw materials. It also improves the balance of payments as well as building domestic capital through savings and investment (GoZ 2013). Of the 70% of the population that relies on agriculture, 67% are involved in subsistence agricultural production, and of these, 56% are women (CIAT World Bank 2017). The main food crops produced in Zimbabwe include maize, sorghum, millet, ground nuts, and wheat (GoZ 2012a). Cash crops include tobacco, sugarcane, coffee, and tea (CIAT World Bank 2017). Livestock production includes beef, dairy, pigs, poultry and small ruminants such goats and sheep.

Zimbabwe is divided into five Agro-ecological Regions[3] (see Figure 2-1 and Tables 2-1 and 2-2). Regions I, II and III, which experience better rainfall patterns, are more suited for commercial crop production, while Regions IV and V are more suited for irrigated agriculture and livestock farming. The vast majority of farmers in Zimbabwe (89%) are smallholder farmers that are mostly reliant on rain-fed agriculture and natural resources as their livelihood (CIAT World Bank 2017), and thus face a high risk of crop failure due to drought. Most small-holder farmers live in Regions IV and V, and grow both food for subsistence and cash crops. Subsistence farming, however, is more dominant because of a poor agricultural resource base and poor support services. Large firms contract small-holders in a variety of ways to produce high-value crops (GoZ 2013). In the last 15 years there has been a notable decline in maize harvests and the price of maize has been volatile (CIAT World Bank 2017). As a result, Zimbabwe has been increasingly reliant on food imports and aid, the latter of which accounts for one third of maize on the market (CIAT World Bank 2017). This has had differential impacts on men and women, with women often resorting to negative coping strategies such as reducing their food intake. Additionally, the high prevalence of HIV/AIDS in the country impacts labor supply, contributing to reduced agricultural productivity. Agricultural output in communal areas has been estimated to decline by almost 50% in households affected by HIV/AIDS, compared to unaffected households (Kwaramba 1997).

[3] Although these are the official Agro-ecological Regions used by the Government of Zimbabwe and in this study, these regions are no longer in sync with the current realities due to changes in the biophysical and social environment, including: less predictable rainfall; reduction in the length of the growing period; land use changes, soil erosion and loss of ground cover; declining runoff; and climate change projections that suggest a hotter and drier Zimbabwe in the future. There is Government interest in completing an update of this map.

Figure 2.1 Agro-ecological Regions of Zimbabwe



Source: GoZ 2013

Table 2.1 Crop Area (ha) per Farm Type and Agro-ecological Region in Zimbabwe

Farm Type	AER 1	AER 2	AER 3	AER 4	AER 5	TOTAL
LSCF	1,069	21,845	2,441	3,656	37,018	66,028
A2	1,771	126,941	19,106	11,037	16,800	175,653
A1	11,814	128,008	66,862	62,708	69,806	339,196
Communal	11,948	205,852	225,190	502,430	195,130	1,140,550
SSC	1,159	15,374	17,831	14,592	773	49,728
Old Resettle	1,209	70,149	70,164	48,074	1,294	190,889
TOTAL	**28,968**	**568,169**	**401,593**	**642,496**	**320,819**	

Source: ZIMSTAT 2016
Key: AER = Agro-ecological Region; LSCF = Large Scale Commercial Farms; A2 = Larger commercial holdings (20 to >120ha) (A1 and A2 were formerly; LSCF prior to the Fast Track Land Reform Program); A1 = Smaller villagized holdings, (5-6ha cropping, 25 ha livestock); Communal = Smallholder subsistence farms; SSC = Small Scale Commercial operations; Old Resettle = Land acquired by government for resettlement between 1980 and mid-1990s

Table 2.2 Livestock, '000 heads, by Species and Agro-ecological Region in Zimbabwe

	AER 1	AER 2	AER 3	AER 4	AER 5
Beef cattle	41	956	840	1,584	597
Dairy cattle	6	166	130	249	136
Goats	104	847	726	539	249
Sheep	6	38	55	55	43
Chickens	459	5,005	3,146	4,411	1,861

Source: ZIMSTAT 2016

Due to low rainfall in drought-prone regions, irrigation plays a significant role in successful crop production, contributing 20% of the value of agricultural crops in Zimbabwe (Aquastat 2016; Manzungu et al. 2018a). However, the country is currently not meeting its full irrigation potential: only half of the land that is suitable for irrigated agriculture is equipped for irrigation and only 71% of this equipped land is actually under irrigation (CIAT World Bank 2017). Furthermore, Zimbabwe's reservoirs have available water standing idle that could be used to irrigate over 6,000 hectares of land (GoZ 2013).

Farmers in Zimbabwe face land tenure insecurity, reducing their ability to improve the productivity of their farms. While land reform expanded the role of smallholder farming in Zimbabwe's economy, land tenure security issues remain unresolved (GoZ 2013). Furthermore, smallholder farmers have limited savings, inadequate access to credit, and are impacted by rising input costs to their production process (GoZ 2013). Women farmers face further barriers, such as low education, a lack of agency and limited access to land.

Zimbabwe is currently already pursuing a selection of CSA adaptations. The most widely used CSA practice, Conservation Agriculture, is practiced by some 100,000 farmers on over 125,000 hectares, but needs to be dramatically scaled up. Additional CSA activities utilized include zero tillage, crop rotation, and mulching practices. However, lack of appropriate mechanization is a constraint in the widespread adoption of Conservation Agriculture. There is room for scaling up of seed multiplication of drought tolerant crops, small scale irrigation, and agroforestry efforts, in addition to the need for improved savanna and grassland management, including reducing the occurrence of veldt fires (CIAT World Bank 2017). Further detail on the current role of CSA in Zimbabwe can be found in Appendix A.

2.2 Greenhouse Gas Emissions and Climate Change Vulnerability

In terms of greenhouse gas emissions, agriculture is the third largest emitter in Zimbabwe (9% of national emissions in 2006), preceded by energy (10%) and land-use change and forestry (79%) (GoZ 2016)[4]. Most of the emissions from agriculture are attributed to the livestock subsector, with enteric fermentation accounting for 44% of agricultural emissions. Agricultural soils and burning of savanna are the largest non-livestock contributors to agricultural emissions (32% and 19% respectively).

Zimbabwe has targeted a 33% reduction per capita in emissions by 2030, as compared to Business as Usual. To mitigate the impacts of climate change, Zimbabwe committed to the Paris Agreement through its NDCs and is pursuing CSA through their National Climate Policy (CTCN 2017). Forest conservation will play an important role in meeting the NDCs, as will protecting against soil degradation, fires, and impacts of drought (CTCN 2017). CSA is a key factor in increasing food production while mitigating climate change, and will thus contribute to Zimbabwe meeting its NDCs. Zimbabwe's NDC Framework provides more information on the role of agriculture in offsetting emissions.

Zimbabwe is currently highly vulnerable to extreme events, facing frequent cycles of droughts and floods, as shown in Table 2-3[5]. The most recent extreme event, flooding caused by Cyclone Idai, displaced around 60,000 people in Zimbabwe, with 200,000 needing emergency food assistance (USAID 2019). Furthermore, the frequency of mild to moderate droughts is even higher than shown in Table 2-3: while losses to droughts of milder intensity are not as visible as those of severe droughts, they nonetheless account for large total losses in productivity. Droughts and floods negatively impact agricultural production leading to food insecurity and depressed economic performance, and damage to infrastructure such as roads, bridges and irrigation schemes.

Table 2.3 Incidence of Major Droughts and Floods in Zimbabwe in the last 40 years

Type of disaster	Year of occurrence	Number of people affected
Drought	1982	700,000
Drought	1991/2	5,000,000
Epidemic (Cholera)	1996	500,000
Drought	1998	55,000
Flood	2000	266,000
Drought	2001	6,000,000
Flood	2001	30,000
Drought	2007	2,100,000
Epidemic (Cholera)	2008	98,349
Drought	2010	1,680,000
Drought	2015	1,480,00
Flood	2017	2,820,000
Drought/Flood	2019	No data

Source: Adapted from EM-DAT 2019

As a result of climate change, Zimbabwe will become more prone to droughts and temperature extremes, which will negatively impact the agricultural sector, in addition to impacts on human safety and infrastructure systems. Climate modeling conducted for the Enhancing the Climate Resilience of Africa's Infrastructure (ECRAI) study provides evidence pointing to hotter and drier conditions in Zimbabwe by the middle of the 21st century. Specifically, by 2070, average temperatures in Zimbabwe are projected to increase by about 2 degrees. There is less agreement on the expected changes in precipitation. However the majority of General Circulation Models project a reduction in precipitation. The largest change in rainfall is likely to be distributional, with a change in the timing of the onset of the rainy season. Thus, the agricultural sector will face not just impacts from higher temperatures but also from changing precipitation patterns. For instance, under a drier climate future, the yield of maize, the key staple crop in Zimbabwe, is estimated to be 7.5% lower compared to a future with no climate change (CIAT World Bank 2017).

Given the economy's reliance on agriculture, climate change thus poses significant risks to Zimbabwe's GDP. Benitez et al. (2018) investigated the impacts of climate change on the agricultural sector, and found that without adaptation, impacts under a dry/hot climate future can be up to 2.3% of Zimbabwe's 2030 GDP (or $370 million per year based on 2016 GDP). They found that adopting CSA practices is a "win-win" situation for Zimbabwe, whether it means avoiding damages under a dry scenario or enhancing GDP gains under a wetter future.

While climate change and weather-related shocks will disproportionately impact the poor, as well as other vulnerable groups such as women and youth, impacts can be reduced by CSA. Since the 1990s, alternative income opportunities in the face of drought have diminished, leaving the rural poor particularly vulnerable. When experiencing drought, to maintain food consumption, the poor usually sell livestock or take children out of school. Promoting livestock ownership can increase household coping capacity, as can diversifying income sources and promoting savings (ZimVAC 2018).

[5] While extreme events are not captured in the analysis conducted in this work, the frequency of these events, particularly extreme El Nino events, is expected to increase in the future (Cai et al. 2014).

Furthermore, there is an important equity aspect to climate vulnerability, with vulnerable groups like women and youth tending to benefit more from increased CSA adoption. Currently, women in Zimbabwe face institutional, legal, economic and social barriers to increasing their agricultural productivity. They are particularly affected by climate change as they tend to face greater barriers in responding to climate impacts and are less able to select adaptation options in agriculture, including CSA options (FAO 2011). Some of the barriers women face in adopting CSA practices include unequal access to credit, technology and agricultural inputs as well as a lack of capacity-building (Perch and Byrd 2015). Youth comprise over 60% of the population in Zimbabwe and the economic challenges of the past decade have significantly affected their economic prospects. Some have sought employment in agriculture, but they face a variety of issues, including access to financing and agricultural land. Consequently, continuing to pay insufficient attention to issues of inequality will hinder the transition to CSA for millions of farmers.

2.3 Relevant Agricultural Policies and Public Expenditures

Overall, Zimbabwe's agricultural policy is informed by the Comprehensive Agricultural Policy Framework (2015-2035) and the new NAPF (2019-2030). The central goal of this Comprehensive Agricultural Policy Framework is to increase crop and livestock productivity and production through investment in the agricultural sector and irrigation (GoZ, 2012b). NAPF in turn details steps needed to solve the challenges facing the agricultural sector following the fast-track land reform program (GoZ, 2018b). Other policies relevant to the development of this CSAIP, including Zimbabwe's NDC and climate commitments, as well as their focus areas are shown in Table 2-4, with further detail provided in Appendix A. While the last ZAIP ended in 2017 (GoZ 2013), this CSAIP is intended to feed into the process of developing a new, climate resilient ZAIP for the future. This new ZAIP in turn aims to support the implementation of commitments made under the Malabo Declaration, in which the country committed to increased investments in agriculture. These policies are set against the backdrop of the country's TSP (which prioritizes economic stabilization, and stimulation of growth and creation of employment in light of new political leadership) (GoZ 2018d), as well as Vision 2030 (establishing the goal of becoming a prosperous upper middle income society by 2030) (GoZ 2018c).

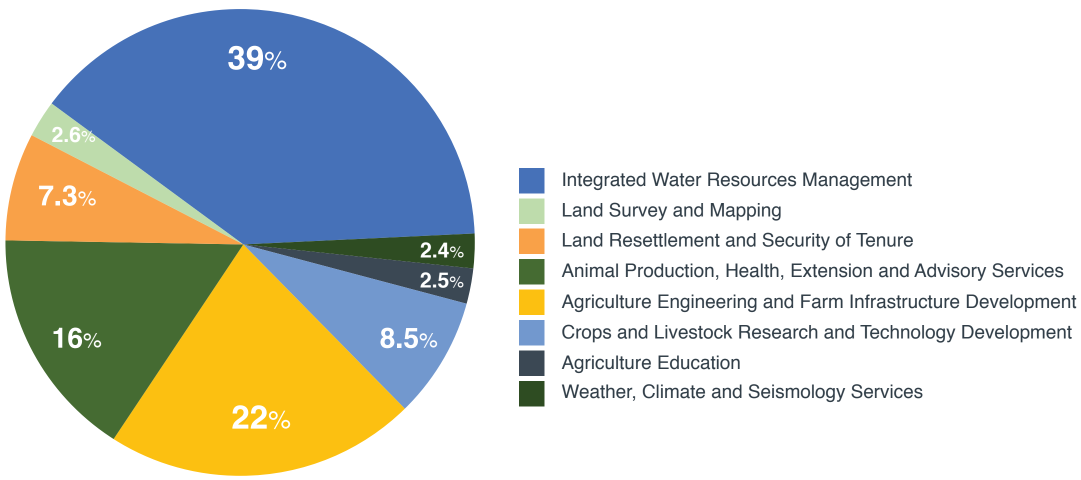
Table 2.4 Main Policy Documents and Topical Focus

Document	Productivity	Resilience	Mitigation	CSA
Comprehensive Agricultural Policy Framework (2012)	✓			
National Agricultural Policy Framework (2018)	✓	✓	✓	✓
Zimbabwe Agricultural Investment Plan (2013)	✓	✓		
Transitional Stabilization Programme (2018)	✓	✓		
Zimbabwe Agenda for Sustainable Socio-Economic Transformation (2013)	✓			
Zimbabwe Climate Policy (2017)		✓	✓	✓
Zimbabwe's Third National Communication to the UNFCCC (2016)		✓	✓	✓
Climate-Smart Agriculture Manual for Zimbabwe (2017)	✓	✓	✓	✓
CSA Profile for Zimbabwe (2017)	✓	✓	✓	✓
Climate Smart Agriculture Framework (2018)	✓	✓	✓	✓

Over time, the national agriculture budget allocation has been below the 10% goal set outin the ZAIP and Maputo Agreement, with small-holder farmers continuing to lack access to irrigation systems and other support services to increase their agricultural productivity. From 2007 to 2011, government support for the agricultural sector declined from 7.3 to 4.4% of the national budget (GoZ 2013). The ZAIP budget for 2013-2017 was allocated between land, water, forestry, and wildlife management (23%), agricultural productivity investments (58%), food security (7.5%), agricultural research and development (8.9%), and monitoring and evaluation (3%) (GoZ 2013). Much of the ZAIP budget focuses on agricultural productivity, rather than capacity building for small-holder farmers who lack access to financing (GoZ 2013). While the 2019 Public Expenditure Review with a Focus on Agriculture (GoZ and World Bank 2019) shows that government spending on agriculture has been increasing since 2016, this increase has been largely directed to the provision of agricultural inputs rather than investments in enablers of productivity and resilience. Furthermore, aside from these direct subsidy programs, Government funds are spent largely on salaries.

As described in Section 2.1, Zimbabwe is already pursuing select CSA adaptations. However, a constraint on future CSA investment is the budgetary resources available. From 2011-2018, Zimbabwe's public expenditures on agricultural programs ranged from $70-$240 million per year. Budgetary information in 2018 is more detailed than previous years, allowing for a deeper analysis of funding allocations, shown in Figure 2-2. However, determining the fraction of these expenditures that qualify as "climate smart" is challenging without additional details. Furthermore, existing CSA practices may not be sustainable in the long-run without the free or subsidized inputs currently offered (CIAT World Bank 2017).

Figure 2.2 Agricultural Expenditures by Program (excluding policy & administration)



Source: Adapted from GoZ 2018

Chapter 3

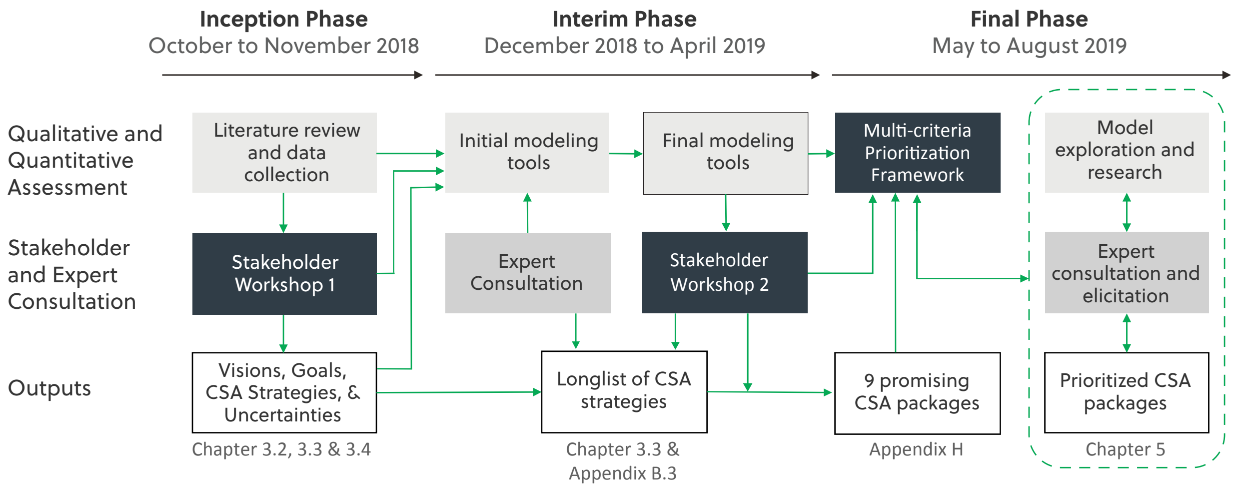
Methodology: Applying the General CSAIP Approach to Zimbabwe's Agricultural Sector

This chapter builds on the general four-step CSAIP approach introduced in Section 1.2, describing how it was applied specifically to Zimbabwe's agricultural sector. Section 3.1 first provides an overview of the various steps completed. Section 3.2 describes the formulation of visions and goals for the CSAIP, established through consultation with stakeholders from government, non-governmental organizations, policy think tanks, and international organizations, at an Inception Workshop. Section 3.3 documents the set of possible CSA options, as identified from a literature and policy review. This initial list of options was subsequently refined and expanded in consultation with stakeholders. Section 3.4 details key uncertainties identified by stakeholders as being relevant to the agricultural sector in Zimbabwe. The vulnerability of Zimbabwe's agriculture sector to these uncertainties was subsequently assessed, motivating the use of CSA investments to mitigate these vulnerabilities – the results of this analytic work are presented in Chapter 4. Having motivated the use of CSA generally, Section 3.5 describes the process of configuring specific individual CSA options into packages of investments, and evaluating and prioritizing these packages. The results of this prioritization are summarized in Chapter 5.

3.1 Overview of Methodology

The development of this CSAIP for Zimbabwe was completed using a combination of literature and policy reviews, qualitative assessment, quantitative modeling, expert consultation and stakeholder workshops (see Figure 3-1).

Figure 3.1 Workflow Schematic

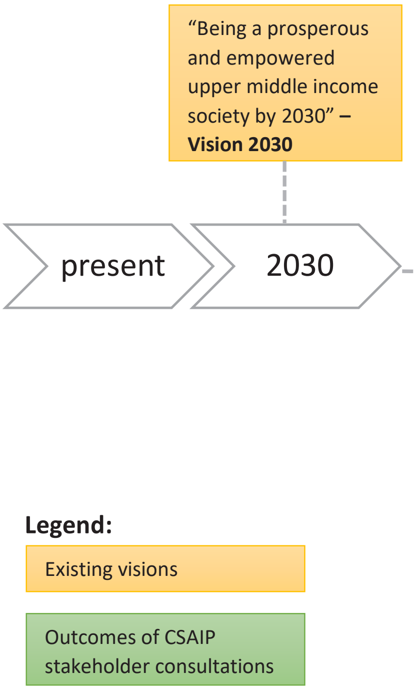


An initial set of CSA options and relevant background were compiled from a desk review. A collaborative, stakeholder-driven process was subsequently conducted to identify visions, goals and key uncertainties. Qualitative and quantitative assessment tools were used to explore the vulnerability of Zimbabwe's agricultural sector to various uncertainties, and build the case for investment in CSA generally. The output of this modeling process, coupled with expert and stakeholder consultation, informed the development of a shortlist of nine packages of CSA strategies. By developing and applying a prioritization framework, a final set of recommended packages was developed from the shortlist, on the basis of different selection criteria.

3.2 Identification of Visions and Goals

Based on feedback from and interaction with stakeholders during the Inception Workshop and a series of consultations informed by government priorities (detailed in Appendix B), the project team identified a set of normative visions of the future for Zimbabwe's agricultural sector, along with quantifiable goals for achieving those visions. These visions and goals were oriented around the three pillars of CSA (productivity, resilience, and mitigation), and are shown in green in Figure 3-2.

Figure 3.2 Visions and Goals Identified for Zimbabwe's CSAIP



Visions	Goals
Productivity: To achieve food and nutrition security and commercialization through a diversified, integrated, and sustainable agricultural sector along the whole value chain	20 percent increase in return on agricultural investments by 2030, by promoting commercialization and competitiveness
	Zero stunting by 2030 through improved nutrition
	50 percent increase in the crop and livestock varieties used by 2030 (enhanced diversification)
	50 percent reduction in the yield gap by 2030 (enhanced productivity)
Resilience: To ensure the agricultural sector is resilient to climate shocks	80 percent of farmers have access to and use timely and relevant climate information and advisories by 2030
	40 percent have adopted more resilient CSA practices by 2030
	80 percent of all policy frameworks are conducive to building resilience by 2022
Mitigation: To achieve a sustainable and evidence-based agricultural sector that reduces greenhouse gas emissions through carbon conservation and carbon sequestration	30 percent reduction in emissions through carbon sequestration and conservation by 2030

The visions and goals identified in this CSAIP are set against the backdrop of the ongoing visioning exercise being conducted for Zimbabwe's agricultural and food sector, which identifies a preferred future scenario for the sector and then determines steps that must be taken to achieve this future. This preferred future scenario envisions a productive and sustainable agriculture and food system, embedded in stable macroeconomic conditions and strong institutions. This CSAIP is oriented towards this vision of Zimbabwe's future.

3.3 Identification of the Set of Possible CSA Options

Based on research, expert elicitation, and stakeholder input during workshops held between October 2018 and April 2019, an initial set of close to 30 possible individual CSA options were identified. The options span a number of different investment categories, from options focusing on cropping (e.g. Conservation Agriculture and use of heat and drought resistant crops) and livestock (e.g. climate resilient breeding programs), to infrastructure (e.g. water harvesting), disaster risk management (e.g. weather index-based insurance), markets (e.g. economic pricing of water) and education (e.g. locally relevant agricultural research programs). Appendix B documents the multi-stage stakeholder process of identifying and refining the set of possible CSA options and provides details such as the climate smartness scores and carbon mitigation scores for each option, which were later considered when developing investment packages (see Chapter 5)[6].

[6] Further detail about many of these options can be found in the recent report Potential Impacts of Climate Change and Adaptation Options in Zimbabwe's Agricultural Sector (Manzungu et al. 2018b), as well as the ZAIP (GoZ 2013), CSA Profile (CIAT World Bank 2017), and other documents presented in Appendix A. In addition, Appendix C provides detailed information on a sub-set of these CSA options, conducted during the inception phase of work.

3.4 Analysis of the Vulnerability of Zimbabwe's Agricultural Sector given Future Uncertainties

When developing plans for the future, it is critical to consider the impacts of uncertainty. During the Inception Workshop, groups defined key drivers of current and future uncertainty, and the extent to which they will impact Zimbabwe's ability to achieve the goals listed in Section 3.2. Key uncertainties included future population growth, regional and domestic markets, domestic policies including the impacts of recently reintroducing the Zimbabwe dollar, and climate change. These uncertainties informed an assessment of the vulnerability of Zimbabwe's agricultural sector to a range of possible future conditions (as described in Section 4.1) and motivate the use of CSA investments to achieve a more robust agricultural sector under various uncertain futures (Section 4.2).

While uncertainty in population growth and regional international markets are assessed qualitatively, this study analyzes the effect of uncertainty in climate change quantitatively, based on a range of projected climate scenarios. Appendix D describes the process of developing climate change scenarios. In the climate change analysis conducted both here and in the evaluation of packages described in Section 3.5 below, temperature and precipitation output from climate models feed into models that estimate crop and livestock yields to assess the impacts of climate change on the agricultural sector. Further details on the modeling conducted are provided in Appendices E and F.

3.5 Configuration, Evaluation and Prioritization of CSA Investment Packages

The results of the modeling process described in Section 3.4 above, coupled with expert consultation, and incorporating output from a second stakeholder workshop, informed the development of a shortlist of nine promising packages of CSA strategies. The Zimbabwe CSAIP focuses on this small set of packages instead of a more comprehensive list to allow in-depth analysis of viable investment opportunities that are based on CSA objectives and in line with government priorities. An initial criterion that was applied during the process was that packages must each result in improvement across all three CSA pillars. These packages were subsequently evaluated by local and international experts across nine different criteria that are presented in Table 3-1. The criteria are divided into two categories: those that move Zimbabwe toward achieving the CSA pillars, and those that have the necessary elements of the enabling environment in place to be successful. Ratings were averaged across expert scores and then combined into CSA pillar and enabling environment scores. These resulting scores were used to create a set of five high priority investment packages, which the team investigated in depth.

Table 3.1 Descriptions of Selection Criteria for CSA Packages

Category	Selection Criterion	Basis	Source for rating			
				Analysis	Expert Input	Stakeholder Input
CSA Pillars	Increases productivity	CSA pillar and GoZ policy objective	✓	✓	✓	✓
	Increases food and nutrition security	CSA vision, NAPF objective	✓	✓	✓	✓
	Commercialization of the agricultural sector	CSA vision, Vision 2030 objective	✓	✓	✓	✓
	Improves equity (gender, socioeconomic)	CSA vision, NAPF objective	✓		✓	✓
	Moves toward GoZ NDC targets	CSA pillar and GoZ policy objective	✓	✓	✓	✓
	Builds resilience	CSA pillar and GoZ policy objective	✓	✓	✓	✓
Enabling Environment	In line with GoZ policy priorities	Requirement to be adopted	✓		✓	✓
	Expected high adoption rates	Necessary to be self-perpetuating	✓		✓	✓
	Leverages public and private finance	Important for government buy-in	✓		✓	✓

Chapter
4

Results: Vulnerability of Zimbabwe's Agricultural Sector to Uncertain Future Conditions and Motivating the Role of CSA

This chapter presents an assessment of the vulnerability of Zimbabwe's agricultural sector to key uncertainties about the future (Section 4.1) and subsequently motivates the use of CSA investments to achieve a more robust agricultural sector across these uncertain futures (Section 4.2).

4.1 Assessing the Vulnerability of Zimbabwe's Agricultural Sector to Uncertain Future Conditions

Zimbabwe's agricultural sector, which is essential to the economy, faces an uncertain future from population growth, the recent return of the Zimbabwe dollar, climate change, land degradation, domestic policies, and the state of regional and domestic markets, among other factors. Hence, it is important that Zimbabwe implements strategies that are robust across different possible futures. To address this, this section considers key uncertainties for Zimbabwe's agricultural sector and discusses how these futures would look without investment in CSA, i.e., a "no action" future.[7] Impacts of climate change on crops and livestock are evaluated quantitatively (see additional results in Appendix F), while other sources of uncertainty are assessed qualitatively.

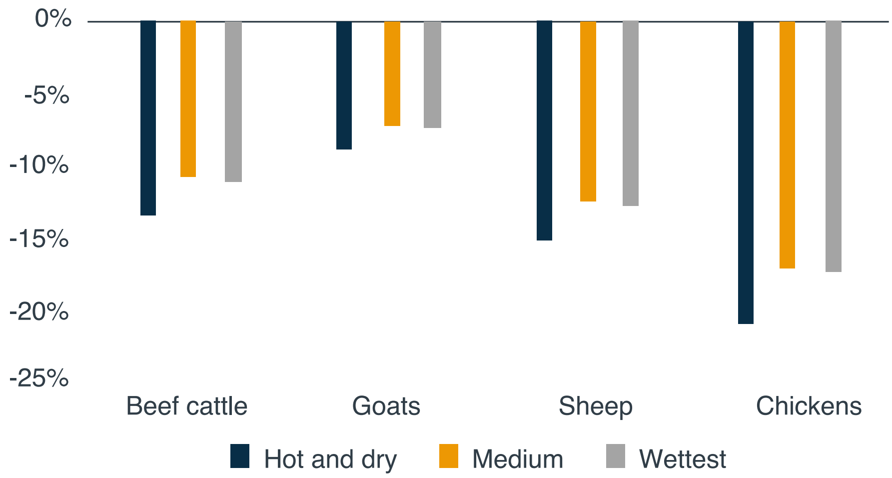
[7] This analytical work assumes no autonomous adaptation on the part of farmers; it is likely that with adaptation, the impacts of climate change could be reduced considerably. However, climate change will affect all aspects of Zimbabwe's agricultural sector, particularly poor, vulnerable farmers who have little adaptive capacity. Thus, social protection measures may be needed alongside building adaptive capacity.

Looking first at climate change, the majority of Intergovernmental Panel on Climate Change (IPCC) climate models suggest that Zimbabwe will be hotter and drier in the future (see Appendix D). Not only are rainfed crops likely to decline due to drier soils, livestock will also be impacted through changes in the quality and quantity of feed (Porter et al. 2014), heat stress effects, decreasing milk production, and increasing disease risk.

Under a changing climate, maize, the staple food crop in Zimbabwe, is expected to see a 33% yield reduction by the 2030s, with a range of expected yields from +35% to -50% across the three different climate scenarios considered (a dry/hot, a medium and a wet scenario – see Appendix D). This assessment was repeated for 10 different crops, and all but one of the 10 show an expected decline in yield, with declines ranging from 15-36%. These declines are not the same for all of Zimbabwe. The drier and poorer regions (Agro-ecological Regions IV and V) show declines of 50-60% for maize, higher than the national average of 33%. Such yield reductions would have a substantial impact on the economy and farmer livelihoods, potentially causing extensive malnutrition and starvation without foreign aid.

Increases in temperature are estimated to result in decreases in the income generated by beef cattle by 11-13% by 2040[8] (Figure 4-1). Since Zimbabwe's livestock sector is dominated by cattle in communal areas, these impacts would affect subsistence farmers who are less likely to have alternative incomes. Sheep and chickens are impacted to a greater degree, with income reductions from 13-15% and 17-21%, respectively. Goats are less vulnerable, with income reductions ranging from 7-9%. Furthermore, it is estimated that climate change-associated heatwaves will result in a 10-14% reduction in milk production in dairy cattle in Zimbabwe (GoZ and UNDP 2017). An increase in temperature is also linked with increased incidence and prevalence of livestock diseases (FAO 2008).

Figure 4.1 Impact of Hotter Temperatures on Income from Livestock by Species (using differences in temperature from the 2000 mean to a mean centered around 2040)



Thus, without action to increase resilience, climate change will likely leave Zimbabwe's agricultural sector in fast decline. These impacts are expected to be further exacerbated by population growth. The UN projects that the population in Zimbabwe will increase by between 30-52% by 2040 (UN 2019).

[8] These changes in income from livestock in Zimbabwe are evaluated for the same three climate scenarios, using the methods developed by Seo and Mendelson (2008). This method does not take into account effects of reduced water availability for livestock, although these impacts may be severe if future conditions are considerably drier.

A future with higher population growth rates would have higher food demand, requiring additional food imports or the expansion of agricultural land, likely into areas less amenable to traditional farming practices, adding to the pressures from climate change. Of course, climate change also impacts the suitability of agricultural land if or when new land is farmed. Using a cropland suitability analysis (Sys et. al 1993), it was found that maize is especially vulnerable to a hotter and drier future climate, with land suitable for growing maize decreasing from 19% of the country to only 2% of the country by 2050. Hence, expanding agricultural land to meet increasing food demand in Zimbabwe may not be possible unless significant action is taken to offset these pressures.

Additionally, there is the potential for increased competition of humans and livestock for natural resources and disintegration of the wildlife-human interface. As described above, the human population is anticipated to increase by 30-52% by 2040, with encroachment into grazing lands (which are currently already in poor condition and overstocked) for residential development and crop production, as well as increased competition for water bodies. These ecosystem services are already under pressure from overexploitation and poor resource management and they will become further depleted through climate change. Losses and even extinction among many plant, animal and other species are anticipated, as parts of the country become drier and temperatures increase. As wildlife struggle to survive on dwindling resources, they are likely to encroach on human settlements, threatening people, livestock and crops (Brazier 2015). This will pose a risk of increased livestock and human emerging and re-emerging diseases. Brazier predicts that rising temperatures will lead to a greater incidence of heat stress and increased infestations of pests and outbreaks of diseases, thus reducing productivity of crops and livestock and driving up expenditures on pesticides, herbicides and veterinary drugs.

4.2 The Role of CSA in Achieving a More Robust Agricultural Sector

This section explores an indicative range of possible futures that do include CSA investment, motivated by the results presented in Section 4.1, which show that without action, Zimbabwe's agricultural sector is expected to be severely impacted by exogenous uncertainties like climate change and population growth. To illustrate the benefits of CSA practices generally, simulation models are employed to assess the effectiveness of a selection of the more easily quantifiable CSA practices[9]. Modeling details can be found in Appendix F.

A relatively straightforward, low-tech option to combat drier future conditions would be to switch to crops that are less reliant on water. Maize, for example, requires considerably more water than sorghum, which could serve as an alternative cereal crop. While maize yields are expected to see a decline averaging 33% across the country for the medium climate scenario considered, sorghum is expected to have more modest reductions of 18% (Figure 4-2). Similarly, cotton and groundnuts are expected to see declines of 36% and 34%, while alternative oilseeds like sunflower and soybeans only decrease by 21% and 23%.

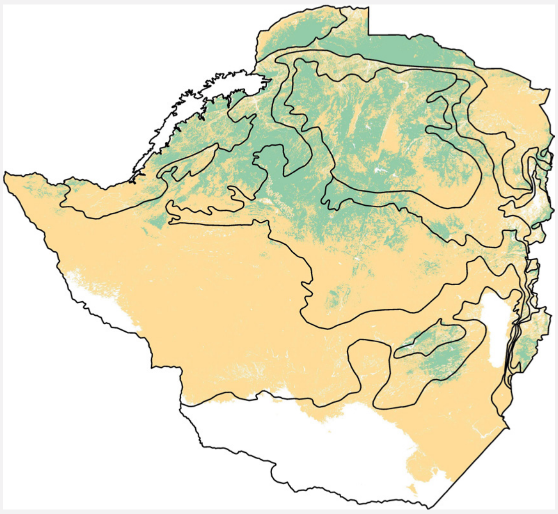
Drought and heat tolerant crop varieties represent a relatively inexpensive CSA option for farmers, with estimated yield increases of 3-12% across all crops evaluated. This result does not take into account market realities for different crops and possible cost implications on farmers. Table 4-1 shows the benefits of this CSA option for different crops, and indicates that switching to drought and heat tolerant varieties alone would not be enough to bring future yields back up to historical levels, since climate change threatens reductions of 15-36%. Thus, two further CSA options are shown in Table 4-1, namely irrigation, and the combination of irrigation with fertilizer.

[9] AquaCrop is employed to evaluate the subset of crop-focused CSA options, the Global Livestock Environmental Assessment Model (GLEAM) for livestock options.

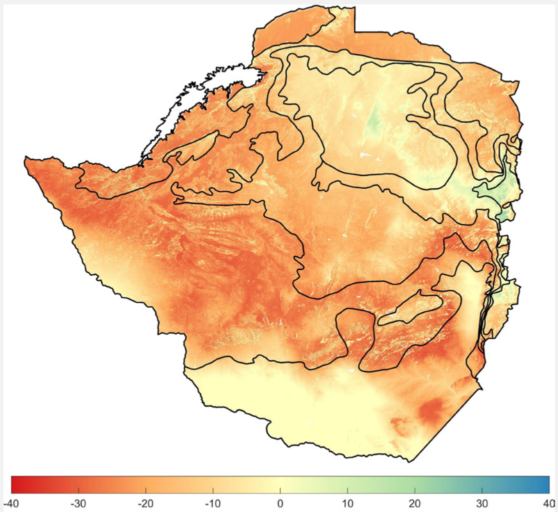
Figure 4.2 Suitability of Maize and Sorghum under Current Climate and the Changes in Suitability under a Hot and Dry Climate Future[10] (suitability is based on a 100 point score with 100 being the most suitable)

Maize

Current climate

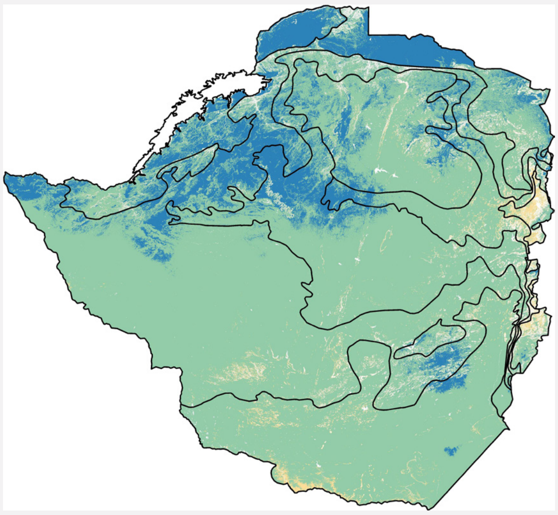


Hot and dry future (change in suitability)

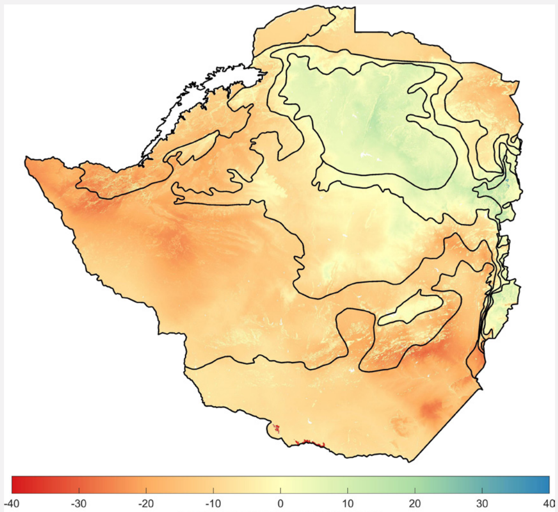


Sorghum

Current climate



Hot and dry future (change in suitability)



[10] The hot & dry scenario is used to demonstrate the robustness of crops/CSA options to harsher future climates

Table 4.1 Benefits of CSA Adaptation Options for Small-holder [11] Farms, Ordered from Most Harvested Area to Least, for the Hot & Dry Climate Scenario

Crop	Impacts under current practices	Improvement factor with CSA option		
		Drought & heat tolerant variety	Irrigation	Irrigation & fertilizer
Maize	-33%	1.11	2.96	4.3
Cotton	-36%	1.1	3.69	4.87
Groundnut	-34%	1.13	3.05	4.11
Sorghum	-18%	1.11	2.09	3.0
Tobacco	-18%	1.16	1.86	2.44
Soybean	-21%	1.03	2.05	2.45
Dry Bean	5%	1.09	1.88	2.74
Sunflower	-23%	1.04	1.86	2.75

Irrigation alone increases yields by 50-140%, assuming the high initial capital cost required can be raised and the necessary water harvesting infrastructure is in place. When evaluating this option for a hot and dry future climate, even greater improvements are observed with yields often doubling or tripling compared to no action (see Table 4-1). Better access to water, from increasing soil moisture to water harvesting and small-scale irrigation, will be key in realizing these gains.

Full commercialization (irrigation + fertilizer) is the highest cost strategy but provides the best production, increasing yields by 100-210%. This option is even more effective in a hot and dry future climate, with yields almost five times higher than they would be without action (see Table 4-1). With even a modest rate of implementation, an expensive option such as this one could alleviate climate change and population pressures. Furthermore, having better information about soil fertility would help farmers target fertilizers more efficiently, reducing emissions while increasing productivity. Given stable domestic and regional markets, this higher productivity would contribute to bringing prosperity to Zimbabwe.

A promising CSA strategy that focuses on livestock, involves upgrading to commercial breeds and management practices, which would increase productivity and reduce emissions. This option does however require high upfront costs, infrastructure, and market access to higher quality feed and nutrients. Commercialization of livestock, even on smaller scales, provide higher and more consistent meat production, as compared to communal cattle which are often malnourished during the dry season. However, commercialization requires not only large upfront costs for farmers, but also the need for more access to supplemental feed and nutrients. Since the food is of higher quality, commercial cattle consume less but produce considerably more meat and protein, while producing fewer greenhouse gases (Table 4-2). While commercialization of livestock in Zimbabwe would alleviate the pressures of climate change and population growth by significantly increasing protein production per head and reducing feed intake to about a third, this CSA option is expensive given the need for additional infrastructure.

[11] Small-holder farms represent the majority of land area for these crops, often well over 90% of cropland

Table 4.2 Comparison of Performance of Existing Communal Cattle against Three CSA Options

Indicator	Units	Communal cattle	CSA option		
			Upgrade to commercial practices	Improve fodder (50% velvet beans)	Switch to goats
Food Intake	kg dry matter / year / head	6,701	2,841	2,482	260
Meat Production	kg carcass / head	30	49	30	5.5
Protein Production	Kg protein / head	4.9	7.4	4.9	0.74
Protein Per Unit Feed	kg protein / 1000 kg dry matter	0.73	2.6	2.0	2.8
Emission Intensity of Meat	kg CO_2-eq/kg protein	1,071	317	469	282.3

Two other less expensive CSA options show promise, namely improving fodder by introducing velvet beans (Mucuna pruriens) as supplemental feed for communal cattle[12], and promoting goats as replacement livestock. Velvet beans are a high protein legume that can be processed into silage or hay for the dry season. The results shown in Table 4-2 indicate that improving communal cattle's diet (supplementing up to 50% of their diet with velvet beans) increases protein production by approximately 300% (from 0.73 to 2.0 kg of protein per 1000 kg of dry matter feed), while reducing emissions intensity of meat production by approximately 50% (from 1,071 to 469 kg of CO_2e per kg of protein produced). Looking at the second promising option, goats are more drought resistant, easier to breed, and can digest fodders with higher lignin content (e.g., grasses, weeds, and brush) than cattle. The results show that goats provide almost four times more protein per kg of feed intake than communal cattle (Table 4-2).

With these substantial improvements in yields due to various CSA actions, it is clear that an agricultural sector with CSA is better than one without, regardless of which uncertain future ends up manifesting itself. Having demonstrated the ability of CSA generally to cope with and provide benefits across various uncertain futures, the remaining chapters now take a closer look at developing and evaluating specific packages of CSA investments that will contribute to improved productivity, resilience, and mitigation in Zimbabwe's agricultural sector in spite of the pressures posed by a hotter and drier future and the likelihood of significant population growth increasing the need for food and water.

[12] Cattle of communal and resettled smallholders, which make up 90% of the 5 million national herds (CTCN 2017

Chapter
5

Results: Prioritized CSA Investment Packages

This chapter describes recommended packages of desirable CSA investments that achieve improvement across each of the three CSA pillars. Section 5.1 summarizes the results of configuring individual options into a shortlist of packages, with five packages ultimately recommended for investment. These five recommended packages are examined in detail in Sections 5.2 through 5.6, providing information on the context, focus, policy relevance, investment opportunities, and potential impact of each package. A more comprehensive description of each package is available in Appendix G.

5.1 Configuring, Evaluating and Prioritizing Individual CSA Options into Investment Packages

Having established that CSA is a robust short- and long-term strategy in Zimbabwe, the study aimed to identify no regret investment packages that maximize positive outcomes and minimize negative outcomes for the agricultural sector given an uncertain future. To do so, the team worked with local and international experts to configure a shortlist of nine high-impact, promising investment packages made up of combinations of individual CSA options. This shortlist is presented in Appendix H.1. Multi-criteria analysis was subsequently completed, using the criteria presented in Table 3-1. Experts rated each package based on analytical results, their own experience and insight, and input from stakeholders during workshops. The results of this scoring are shown in Appendix H.2.

Finally, five proposed final packages were synthesized from the initial set of nine packages, based on consideration of analytical results, government and CSA priorities, and expert judgment (see Appendix H.3 for more detail). The final five synthesized packages integrate key characteristics from other packages, emphasizing those with higher expert scores. This synthesis ensured that the full set of government and stakeholder priorities were captured in the set of high priority packages ultimately recommended in the CSAIP. The final five high-priority packages, which are inclusive of all subsectors and focus on key CSA goals, are summarized in Table 5-1 and discussed in detail in Sections 5.2 to 5.6. Cost estimates of these packages are developed based on the costs of comparable investment components in prior World Bank Project Appraisal Documents. Illustrative unit cost estimates for various investment opportunities used in that The Project Appraisal Documents considered for various investment opportunities are summarized in Appendix I.

Table 5.1 Characteristics of Final Five High Priority Packages

Package	Focus			CSA vision categories					
	Sectoral	Farm Type	Region	Commercialization & Competitiveness	Crop and Livestock Productivity	Food and Nutrition Security	Crop and Livestock Diversification	Climate Resilience	Reduced Emissions
A. Enhanced Agricultural Knowledge and Innovation System	Maize, small grains, horticultural crops	Small-holders	Agro-ecological Regions III, IV, V		++	++	++	+++	
B. Sustainable Livelihoods through Diversified Livestock Systems	Cattle, sheep, and goats	Small-holders	Southern Zimbabwe	+	+++	++	++	++	++
C. Water Harvesting for Resilient Crop and Livestock Production	Crops and livestock	Small-holders	Agro-ecological Regions III, IV, V		+++	+++	+	++	+
D. Women- and Youth-Focused Value Chain Development	Poultry, vegetables, small livestock	Women- and youth-run farms	Urban and peri-urban areas	++	++	+		++	+
E. Resilient Commercial Dairy Farming	Dairy cows	Commercial A2 farms	Central and Eastern Zimbabwe	+++	+++	+	+	++	+

Note: Empty cells indicate that a package is not expected to significantly impact that particular CSA vision category

5.2 Package A: Enhanced Agricultural Knowledge and Innovation System

Brief Description

This package strives to enhance Zimbabwe's Agricultural Knowledge and Innovation System (AKIS) to build capacity among extension workers and train farmers on climate smart agronomic practices and technologies, with the aim of improving productivity and resilience in the smallholder farming sector. This section summarizes key characteristics of this package, with further details provided in Appendix G.1.

Focus

This package focuses on small-holder farmers in Agro-ecological Regions III-V, with an emphasis on Regions IV and V where most of these farmers are located. The focus is on maize, small grains, and horticultural crops.

Context and Background

Zimbabwe's agricultural sector has faced several decades of declining crop yields. Maize has consistently had average yields of less than 1 ton/ha since the early 2000's, down from peak yields of around 2.2 tons/ha in the mid-1980s. This decline in productivity is driven by several factors, including poor seed and fertilizer availability.

Widespread food insecurity and poor nutrition at the household level for the majority of the country's rural population are two critical consequences of these declining yields. Food insecurity is deepened by Zimbabwe's failure to meet its strategic grain reserve of 500,000 tons/year, as well as its variable climate and the occurrence of frequent floods and droughts. Climate change and population growth will further intensify these challenges, with small-holder yields projected to fall by as much as 36% by the 2030s due to climate change impacts.

Currently, AKIS is a largely public program with limited private sector involvement through contract farming and research by large seed companies.

Specific Investment Opportunities

- **Invest in building capacity of public extension workers** in terms of 1) provision of knowledge of climate resilient crop production systems, practices and technologies, 2) expanding extension reach to farmers, and 3) practical demonstrations of climate smart agricultural practices.
- **Invest in innovation platforms based on strong public, private and civil society service partnerships** to facilitate farmers adopting climate resilient crop production practices incorporating: 1) drought and heat tolerant varieties; 2) crop substitution and or diversification (e.g. replacing maize with small grains such as sorghum); and 3) efficient agronomic practices (e.g. sowing dates, plant populations, crop protection, fertilizer management).
- **Invest in Information Communication Technology (ICT)-enhanced information dissemination systems** incorporating 1) the bringing together of private mobile service providers, cell phone vendors, the Meteorological Services Department, extension services, universities etc., 2) the design of appropriate applications and information packages, and 3) the development of communication hubs that service farmers efficiently and effectively.

These proposed investments will be supported by recent actions to operationalize a national Agriculture Observatory which will access, synthesize, and deliver high resolution weather information to stakeholders of agricultural value chains. This will help facilitate climate-informed decision making at various levels.

Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **NAPF:** This package addresses several pillars, most prominently Pillar 2: Agricultural Knowledge, Technology, and Innovation Systems.
- **GoZ CSA Framework:** This package addresses Objectives 1, 2, and 4, focused on access to information, application of CSA practices, and capacity for implementation.
- **Vision 2030 and TSP:** This package enhances farm productivity and incomes.

The following SWOT Analysis summarizes which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

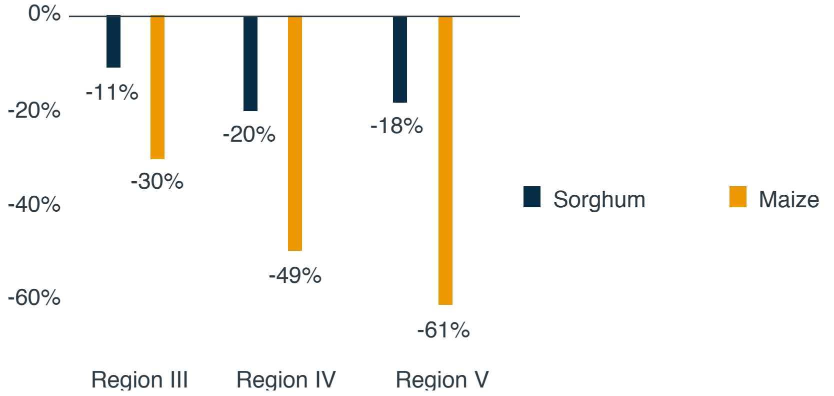
	Helpful	Harmful
Internal	Strengths • Climate resilient production systems and practices are generally known. • Many players (research institutes, universities, and civil society) are promoting climate smart crop production systems and practices. • The country has developed climate resilient policies, strategies and manuals. • Agriculture-ICT has been piloted.	Weaknesses • Farmers lack knowledge and information to adopt climate resilient production practices and systems. • Public extension service lacks capacity to spread appropriate message to farmers. • ICT systems are poorly developed and coordinated. • Innovation service providers are poorly coordinated.
External	Opportunities • Three strong cell phone providers exist. • Cellphone penetration is high and increasing. • Strong donor support directed at small-holder farmers exists. • There is public provision of crop inputs to vulnerable groups through the Presidential Input Scheme. • Other complementary initiatives include the Government's "Command Agriculture" program.	Threats • Poor supply and availability of crop inputs and markets. • Crops suffer moisture stress due to frequent and intense droughts. • Cellphone providers face high operational costs resulting in high data costs. • Small-holder farmers are poorly organised to receive knowledge and information. • Presidential Input Scheme is poorly structured to ensure maximum crop resilience.

Potential Impact

This package is expected to enhance information dissemination to improve small-holder farmer productivity and resilience in crop production. By doing so, the package would increase farm incomes, food and nutrition security, and reduce poverty and vulnerability to extreme events and climate change. The potential benefits of three specific components of this package were quantified, namely

Switching to more suitable crops: Sorghum requires less water than maize making it more resilient to drought or future climate change. Simulating the yield response to climate change, it was found that maize yields decline significantly for Agro-ecological Regions III-V as shown in Figure 5-1. Maize yield reductions are 61% in Agro-ecological Region V, while sorghum proves to be more resilient to drier conditions with only moderate reductions of 11-20%. These results do not take into account market realities for the two different crops, nor possible cost implications for farmers.

Figure 5.1 Changes in Yield for Maize and Sorghum for the Median Climate Scenario



Drought and heat tolerant varieties: Switching to improved crop varieties can increase yields by 6-21% under conditions consistent with historic climate, with greater benefits in the drier regions. Under drier future conditions, these benefits increase substantially in Agro-ecological Regions IV and V, with a smaller increase in Agro-ecological Region III.

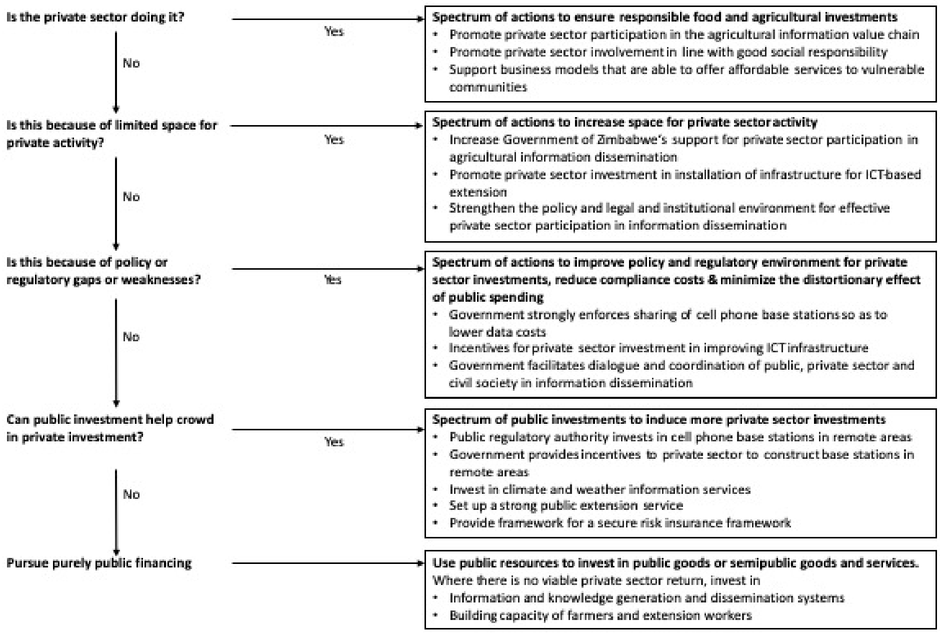
Promoting crop diversification: Moving away from monoculture not only increases productivity and climate resilience but can also increase soil carbon through soil sequestration. A compilation of studies in Sub-Saharan Africa have shown that crop diversification can contribute to increasing soil carbon by about 0.5 tC/ha/yr (Powlson et al. 2015), which equates to over 1.8 tons CO_2-equivalent per hectare per year. If 10% of small-holder maize farmers in Agro-ecological Regions III to IV were to switch from monoculture to a diversified crop portfolio, national emissions would reduce by over 300,000 tCO_2-eq per year.

Cost Assessment

Projects focusing on capacity building and information dissemination have a significant range of costs. The components of past World Bank projects that are similar in their objectives to this package range from US$39 million to US$121.5 million. Based on these prior projects and the 600,000 Region IV and V farmers that may benefit, the initial estimated cost of Package A is US$50-$75 million, or $83-$125 per beneficiary.

Maximizing Finance for Development

This Maximizing Finance for Development chart shows a roadmap of actions that can be taken to encourage increased private sector involvement in this investment package. The yes/no answers to the questions on the left hand side are not intended to offer a stagnant characterization of the current situation, but provide guidance as to the array of actions that could be undertaken in a particular situation.



5.3 Package B: Sustainable Livelihoods through Diversified Livestock Systems

Brief Description

This package aims to secure the livelihoods of small-holder farmers through increased livestock productivity and diversified production systems. This section summarizes key characteristics of this package, with further details provided in Appendix G.2.

Focus

The focus of this package is on small-holder livestock farmers in southern Zimbabwe, with livestock including cattle, sheep, and goats.

Context and Background

The cattle population in Zimbabwe is estimated to be between 4-5 million, with almost 90% of these animals located in the country's communal areas. The herd is predominantly found in the southern and western parts of the country, in regions that are semi-arid and characterized by poor grazing and limited access to water. Cattle fulfil a variety of important roles in communal areas, including the provision of milk, meat, hides, manure and draught power, generating income through the sale of animals or their products.

Attaining commercial production and productivity levels among smallholders in Zimbabwe continues to be a challenge for a variety of reasons: reliance on low nutrient feed, high prevalence of diseases and parasites, lack of access to extension services, low levels of livestock management, inadequate breeding programs, and low off-take rates. Successfully increasing livestock productivity has the potential to greatly improve household coping capacity because, compared to crops, livestock essentially function as a calorie reservoir and can help communities cope with difficult times. For the small-holder livestock sector, some public sector funding is provided through extension services, but private sector involvement is limited. Both need to be enhanced.

Specific Investment Opportunities

- **Invest in improved/alternative feeding systems** incorporating production and transportation of grass, fodder, hay, crop residues and supplements in the dry season
- **Invest in climate resilient livestock breeding programs and extension services** incorporating (1) the adoption of indigenous and small breeds, (2) screening of future diseases and pests whose prevalence is expected to worsen because of climate change, (3) switching to small ruminants (goats and sheep), and breeds of goats that provide both meat and milk, and (4) improved animal husbandry and health, climate resilient fodder production and processing.
- **Invest in commercialization of livestock in the small-holder farming sector** which is home to the bulk of the country's cattle herd through i) improved livestock management, 2) access to markets and value addition by resuscitating the leather industry.

Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **NAPF:** This package addresses several pillars, most prominently Pillar 8: Resilient and Sustainable Agriculture.
- **GoZ CSA Framework:** This package addresses Objectives 1, 2, and 4, focused on access to information, application of CSA practices, and capacity for implementation.
- **Vision 2030 and TSP:** This package enhances farm productivity and incomes.

The following SWOT Analysis summarizes which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

	Helpful	Harmful
Internal	Strengths • There is a significant cattle herd owned by small-holder farmers. • Indigenous livestock breeds are generally more climate resilient than exotic breeds. • Farmers have experience in raising small livestock (mainly goats), indicating good potential for diversification away from cattle. • Government has a strong restocking livestock program. • Many actors are promoting livestock production in the small-holder farming sector.	Weaknesses • Poor quality feed and low water availability result in poor cattle performance. • Common livestock breeds are not resilient to climate change. • Poor extension services for sustainable and resilient livestock production. • Low commercialization indicated by low productivity, poor markets and low commercial offtake.
External	Opportunities • Current low meat consumption in the country represents a growing market opportunity. • High demand for leather as a raw material. • There is donor interest in the small-holder livestock farming sub-sector.	Threats • Lack of available finance for strengthening public extension services. • Limited funding for small-holder livestock production and poorly structured Command Livestock Programme. • Low purchasing power due to current macroeconomic conditions. • Private sector is poorly linked to the small-holder livestock farming sector. • Poor and deteriorating rural infrastructure.

Potential impact

This package is expected to enhance livestock farmers' productivity, resilience, and food and income security while reducing poverty and emissions. The potential benefits of two specific components of this package were quantified, namely

Improved feed: Improved feed for cattle has been shown to reduce methane emissions significantly and improve cattle health for better milk production, slaughter yield, and birth success rates. Velvet beans are ideal for providing leguminous hay because they are not labor-intensive, are native to tropical regions, are drought- and heat-tolerant, and have had success in the drier regions of Zimbabwe. By providing velvet bean fodder during the dry season, total food intake reduces by 63% and methane emissions from cows reduce by 56% (Table 5-2). A program like this would increase profits for non-dairy cattle farmers with a benefit-to-cost ratio of about 1.5 to 1.9.

Table 5.2 Changes Associated with the CSA Options of Improved Feed and Switching to Goats, as compared to Communal Cattle

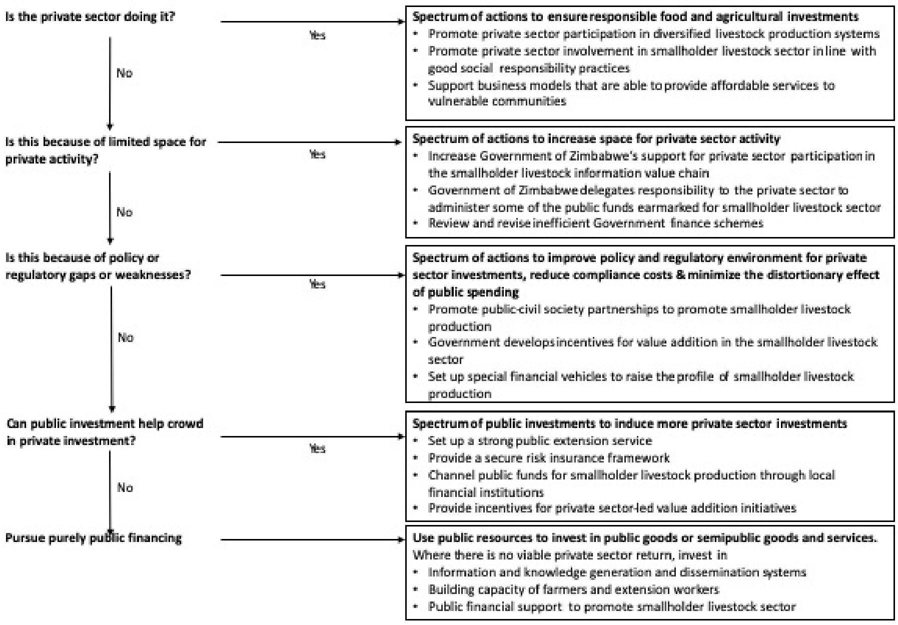
Indicator	Improve feed	Switch to goats
Food Intake	-63%	-96%
Protein Per Unit of Food	174%	284%
Emission Intensity of Meat	-56%	-74%

Switching from cattle to smaller livestock: Switching to smaller livestock increases protein production, provides a more climate resilient food source, and significantly reduces greenhouse gas emissions. For example, modeling indicates that goats produce 74% less emissions per unit of protein produced than communal cattle in Zimbabwe (see Table 5-2). In addition, goats are less susceptible to heat impacts: while climate change drives reductions in the income from beef cattle by 11-13% by 2040, income from goats only decreases by 7-9% (see Figure 4-1 presented earlier in the report).

Cost Assessment

Projects focusing on the diversification of livestock systems have a significant range of costs. The components of past World Bank projects similar in their objectives to this package range from US$8 million to US$66 million. Based on these prior projects and an estimated 300,000 small-holder beneficiaries, the initial estimated cost of Package B is US$30-$60 million, or $100-$200 per beneficiary.

Maximizing Finance for Development



5.4 Package C: Water Harvesting for Resilient Crop and Livestock Production

Brief Description

This package promotes water harvesting to enhance resilient crop and livestock production, secure water for livestock and domestic purposes, and sustainable soil and water conservation through in situ water harvesting, Conservation Agriculture and small-scale infrastructure. This package complements Packages A and B. This section summarizes key characteristics of this package, with further details provided in Appendix G.3.

Focus

This package focuses on small-holder farmers in Agro-ecological Regions III-V, characterized by low and erratic rain.

Context and Background

89% of farmers in Zimbabwe are small-holders that are mostly reliant on rain-fed agriculture. Yet only 37% of Zimbabwe's land area receives sufficient rainfall to be considered suitable for rain-fed crop production, and many farmers face a high risk of crop failure each year due to unpredictable rainfall. Access to additional water would reduce this vulnerability, securing water not just for domestic purposes, but for livestock and crop production. However, formal, large-scale irrigation schemes require substantial up-front investment. In contrast, water harvesting, incorporating in situ water harvesting at field scale, small scale infrastructure and Conservation Agriculture, can improve the productivity and resilience of small-holder farmers at a fraction of the capital cost required for formal irrigation infrastructure. In addition, water harvesting has a variety of additional benefits, including controlling soil erosion, catchment protection, and groundwater recharge.

Thus, it is key to promote integrated systems operating within a watershed framework that simultaneously support both crop and livestock production. Improved crop and livestock productivity in turn have a positive impact on household food, water and income security in the face of a variable and changing climate.

At present, private sector involvement in this area is low. As discussed in the maximizing finance flowchart **below, a range of activities** conducted by **the private sector can help to boost water management among small-holders.**

Specific Investment Opportunities

- **Invest in soil and water conservation techniques as part of integrated catchment management that** incorporates water, land and environment sectors. The first step will be a holistic study of the relevant catchment to evaluate current land use and agronomic practices in order to tailor the interventions to the catchment context. This is essential to avoid measures that fail or are not adopted. E.g. constructing a community pond may require soil conservation techniques in order to avoid rapid sedimentation of the reservoir.
- **Invest in in situ water harvesting** (e.g. enhanced soil water retention) that improves and complements Conservation Agriculture practices. These practices may include mulching, limited or zero till agriculture, crop rotations, agro-forestry approaches, or other practices that enhance water retention in the soil.
- **Invest in small scale water infrastructure** for supplementary irrigation, livestock watering and domestic water. This could include rain barrels or small scale water harvesting such as community-level ponds. The aim would not be to develop large scale irrigation infrastructure, but instead to focus on providing water for supplemental irrigation to improve incomes in a cost-effective way.
- **Invest in building the capacity of extension workers and farmers** in sustainable water harvesting. This training will focus on soil and water conservation techniques, operation and maintenance of new infrastructure, and Conservation Agriculture practices.

Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **NAPF:** This package addresses Pillars 1, 2, 3 and 8, which include Resilient and Sustainable Agriculture.
- **GoZ CSA Framework:** This package addresses Objectives 1, 2, and 4 focused on access to information, application of CSA practices, and capacity for implementation.
- **Vision 2030 and TSP:** This package enhances farm productivity and incomes.

The following SWOT Analysis summarizes which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

	Helpful	Harmful
Internal	Strengths • In situ water harvesting technologies and techniques are well known and have been tried in the country. • Small scale water infrastructure exists in the country. • Conservation Agriculture is being widely promoted in the country.	Weaknesses • Low adoption of in situ water harvesting and small scale water infrastructure by farmers. • Conservation Agriculture is too manual. • Poor farming methods and poor soil and water conservation, resulting in poor catchment management. • Extension services do not include a strong soil and water conservation and water use efficiency component.
External	Opportunities • A number of projects that include elements of soil and water conservation are being implemented in the country. • Environmental Management and Water Acts promote sustainable catchment protection. • Environment Fund and Water Fund can support sustainable soil and water conservation.	Threats • Limited public financing for soil and water conservation extension services and adoption. • Limited financing for adoption of water-efficient technologies. • Poor appreciation of the benefits of environmental services. • Unsustainable groundwater exploitation. • Lack of integrated natural resource management.

Potential impact

This package is expected to enhance water availability for crops and livestock, allowing for increased income through different channels: increasing yields of existing crops or livestock, adding a second crop, or moving toward commercial production. The potential benefits of three specific components of this package were quantified, namely

Conservation tillage: Conservation tillage helps reduce erosion, improve soil fertility, and reduce emissions. Mitigation benefits from conservation tillage include carbon sequestration and reduced diesel emissions from tractor use. While decreased tractor use may not apply to many farmers, increased soil carbon uptake reduces emissions by about 0.18 tCO_2e/ha/year. If conservation tillage were adopted in Agro-ecological Region V, soil carbon sequestration alone would decrease emissions by 6,400 tCO_2e / year.

Table 5.3 Benefits of Irrigation for Agro-ecological Region V (Yield Factor is 1 for historical rainfed yield)

Indicator	Historical	Climate Change
Maize	4.52	11.62
Tobacco	2.94	4.28
Soybean	3.22	6.20
Cotton	3.45	6.76
Dry Bean	1.64	3.41
Sunflower	1.48	2.14
Sweet Potato	2.10	2.91
Groundnut	3.47	9.31
Sorghum	1.95	2.38

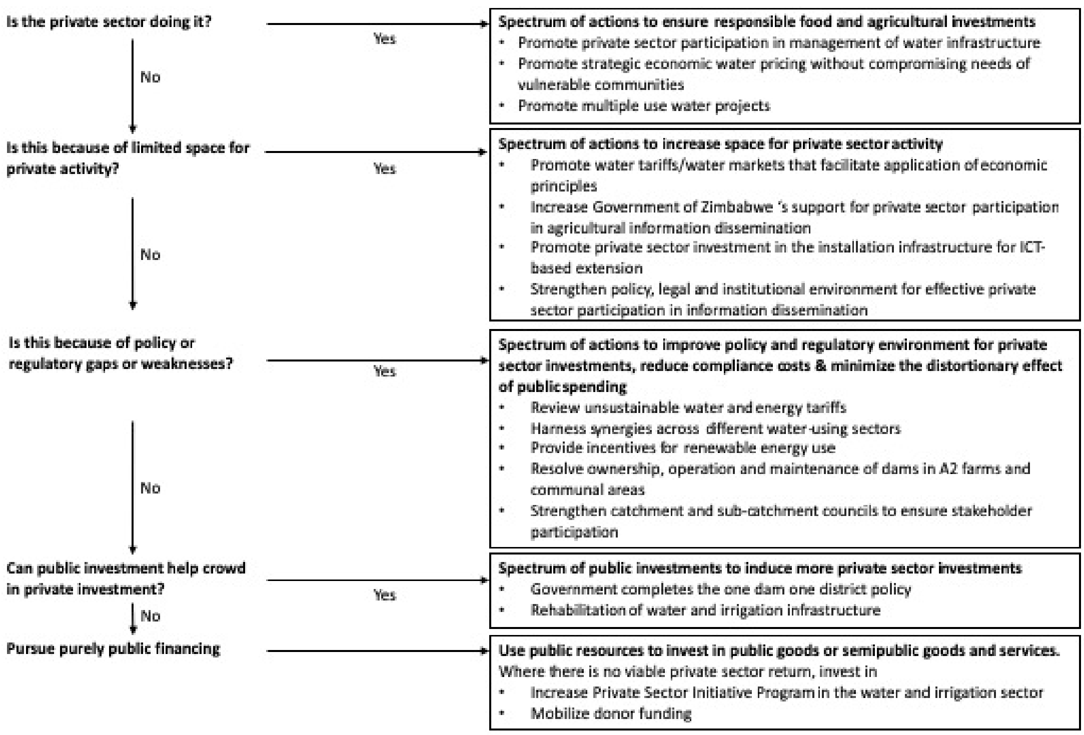
Agro-forestry approaches: Practices like mulching and shading from tree crops planted around row crops can reduce soil evaporation after rainfall by 15-24% and increase soil wetness by 9-18% compared to sole crop methods (Siriri et al. 2012).

Water harvesting: In situ rainwater harvesting systems can provide supplemental irrigation, which can reduce the volatility of crop yields and food prices. Table 5-3 shows the benefits of irrigation in Agro-ecological Region V, where irrigation for maize results in yields of 4.5 times higher compared to no irrigation, under a historic climate.

Cost Assessment

Projects incorporating water and soil conservation measures have a modest range of costs. The components of past World Bank projects that include similar objectives, including Conservation Agriculture, in-situ rainwater harvesting, soil conservation, and extension services, to those in this package range from US$3.1 million to US$12 million. Based on these prior projects and the 800,000 Region III-V small-holder farmers that may benefit from this package, the initial estimated cost of Package C for Zimbabwe is US$75-$100 million, or $95-$125 per beneficiary.

Maximizing Finance for Development



5.5 Package D: Women- and Youth-focused Value Chain Development

Brief Description

This package aims to increase the productivity and resilience of women- and youth-run small-holder farms in peri-urban areas by developing all aspects of crop and livestock value chains. This section summarizes key characteristics of this package, with further details provided in Appendix G.4.

Focus

This package focuses on women and youth-owned farms in peri-urban and urban areas. Agricultural products focused on in this package include poultry, vegetables, and potentially goats.

Context and Background

Women and youth face a particular set of issues compared to other sectors of the population active in agriculture. They face diverse institutional, legal, economic and social barriers to increasing their agricultural production. Women for instance face lower access to productive inputs such as land, labor, fertilizer, improved seed, and agricultural information. They subsequently also experience lower returns to these inputs due to cultural and social norms, institutional constraints, and market failures. Incentivizing private sector engagement would help to address some of these challenges.

Women, youth and other vulnerable populations are particularly affected by climate variability and extreme events. Women in poverty are heavily reliant on natural resources for their livelihoods and generally have fewer available resources to cope with shocks such as droughts, floods and food shortages. Globally, women are more vulnerable to disasters than men. For example, Cyclone Idai which hit Southern Africa in March 2019, affected 270,000 people in Zimbabwe alone, half of whom are children, leaving more than 15,000 displaced women and girls in Zimbabwe at risk of gender-based violence due to disruptions caused by the storm.

Furthermore, the anticipated impacts of climate change and urbanization will further intensify the pressure on these already-vulnerable populations, as they tend to have lower adaptive capacity than the general population. Women and youth typically have less voice and agency to institute change and may also be less able to select adaptation options in agriculture, including CSA. Their lower levels of participation in all levels of decision making significantly limit their potential to contribute to climate resilience and adaptation efforts, despite their perspectives and knowledge being unique and vital in climate-related decision making.

Specific Investment Opportunities

- **Invest in climate resilient organic vegetable and poultry/small livestock** production on women and youth-owned farms. Lower land and capital requirements make these products ideal for peri-urban farms.
- **Invest in sustainable financial inclusion mechanisms** that cater to women and youth, targeting more widespread affordable access to financing for inputs.
- **Invest in marketing networks and capacity building** Invest in women- and youth-oriented production and marketing networks, including gender- and youth-sensitive extension services, aimed at conveying climate smart agronomic practices.

Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **NAPF:** This package addresses pillars on resilience and knowledge systems, and most centrally the Guiding Principal on Mainstreaming Gender, Youth, and Other Vulnerable Groups.
- **GoZ CSA Framework:** This package addresses Objectives 1, 2, 3, and 4, focused on access to information, application of CSA practices, participation in markets, and capacity for implementation.
- **Vision 2030 and TSP:** This package enhances employment and opportunities for youth.

The following SWOT Analysis summarizes which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

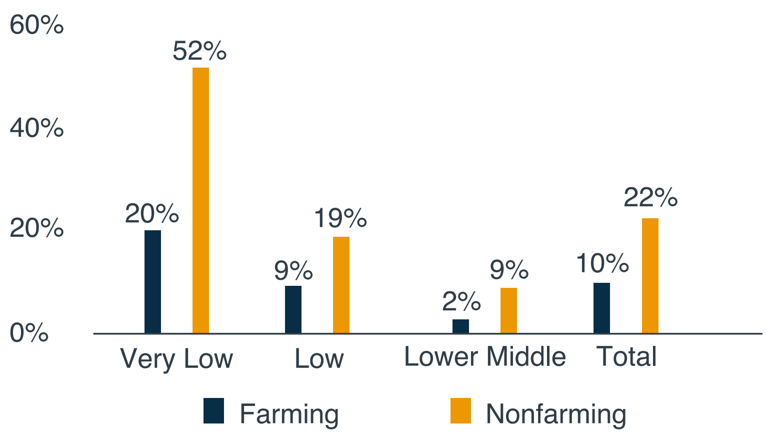
	Helpful	Harmful
Internal	Strengths • There is experience in organic vegetable production and poultry production. • Organisations exist that promote organic vegetable production (Zimbabwe Organic Producers Association) and poultry (Zimbabwe Poultry Association). • Government has put in place pro-gender and youth policies.	Weaknesses • Poor extension for climate resilient vegetable and poultry production. • Low awareness of the potential economic and environmental benefits of organic products. • Poorly developed markets for organic vegetables • Poor access to resources such as land and water. • Poor access to funding by women and youth.
External	Opportunities • Organic vegetable and poultry production do not require a lot of land and therefore women and youth can easily enter these sub-sectors. • Dedicated funding streams for women and youth exist e.g. Women's Bank. • Package can take advantage of NDC targets.	Threats • Lack of export incentives. • Lack of credit lines at the country level. • Inadequate research and development on organic and poultry production. • The Women's Bank is poorly capitalised.

Potential impact

This package would enhance income and food security among women- and youth-owned farms, and decrease poverty in these two vulnerable groups. Urban farming helps to reduce household food costs through the consumption of home grown products. The potential benefits of a number of specific components of this package were quantified, including

Reduced malnutrition among mothers involved in urban farming: Evaluation of survey data from Kampala, Uganda suggests that households involved in agriculture in urban areas are less likely to have malnourished children than non-farming households (Maxwell et al. 1998). This relationship holds true from very low to lower middle socioeconomic status, but is especially true for very low socioeconomic status where malnourishment reduces from 52% to 20% from non-farming to farming families (see Figure 5-2).

Figure 5.2 Malnourished Children in Urban Farming Families compared to Urban Non-farming Families by Socio-economic Class (Source: Data from Maxwell et al. 1998)

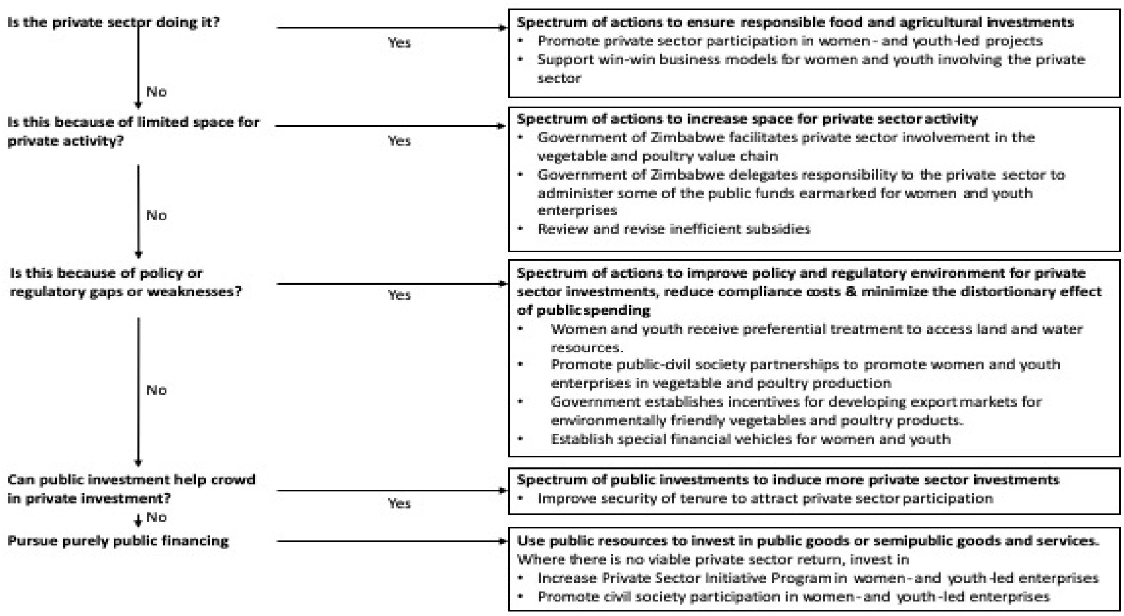


Drought resilient poultry production: While poultry production has steadily increased in Zimbabwe over the years, drops in broiler (chicken) meat production are often correlated with droughts and heat waves in Zimbabwe. For example, production of day-old broiler chicks dropped from above 70 million to less than 40 million in response to a drought in 2015/16 (World Bank 2019a) as broilers are very sensitive to temperature changes. Indigenous or cross-bred chickens that are accustomed to warmer climates have a better chance of survival.

Cost Assessment

Projects focusing value chain development that foregrounds the inclusion of women and youth have a wide range of costs. The components of past World Bank projects that include similar objectives to those in this package range from US$17.75 million to US$107 million. Based on these prior projects, the initial estimated cost of Package D for Zimbabwe is US$20 million to US$40 million. Potential beneficiaries include an estimated 60,000 women engaged in agriculture around Harare, alongside any young farmers in the region. Including only women-owned farms, costs per beneficiary would range from $330 to $670.

Maximizing Finance for Development



5.6 Package E: Resilient Commercial Dairy Farming

Brief Description

This package aims to boost commercial dairy farming through alternative and improved feeds and nutrition products, breeding programs for more climate resilient cattle breeds and climate smart production practices. This section summarizes key characteristics of this package, with further details provided in Appendix G.5.

Focus

This package focuses on commercial A2 dairy farmers (20 to >120ha) in Manicaland and Midlands, in the central and eastern parts of the country.

Context and Background

Over the course of the last two decades, Zimbabwe has lost its self-sufficiency in dairy production. It is estimated that around 180 million liters of milk are necessary for domestic consumption. Currently, the dairy herd is between 26,000 and 40,000 cows (excluding beef cattle and communal milking cows used for home consumption), producing between 50 and 65 million liters of milk per year. This drop in production has resulted in significant increases in milk imports, as well as reduced local milk consumption, leading to food and nutrient insecurity.

Improving milk production and productivity has to take into account the new realities of small dairy farm sizes. The dairy sector is currently made up of around 230 large producers and more than 1,700 smallholders, geographically clustered around 35 milk collection centers. The majority of these largely A2 smallholdings were large scale commercial farms prior to the Fast Track Land Reform Program undertaken in the early 2000s. Smallholder dairy farmers typically have herds of between three and ten animals, and their contribution to national production remains insignificant. Issues contributing to low smallholder productivity include breed quality, a lack of affordable improved feed and insufficient access to medicines and veterinary services.

There is export market potential. Dairy consumption in African countries, which is now among the lowest worldwide, is expected to grow substantially, about 7% per year by some estimates (Davis 2013). Free school milk programs in are already offered in some countries, such as Kenya, and others may follow, opening up new opportunities for processed milk exports to nearby countries (KSN 2019). Currently there is demand for long-life milk in Zambia and Botswana and sterilized milk in Mozambique, Botswana, and Zambia, that is at least partially fulfilled by Zimbabwean milk producing companies (Zimbabwe Standard 2019).

Specific Investment Opportunities

- **Invest in programs that promote increased feed and fodder production** (including local level feed formulation), as well as nutrition systems and products. Feed is one of highest costs for a dairy enterprise, and the production of feed at the farm level will significantly reduce the cost of feed. This in turn reduces emissions and also contribute to carbon sequestration.
- **Invest in breeding programs that incorporate the adoption of smaller and climate resilient mixed breeds that are more disease and pest resistant.** Zimbabwe's cattle population declined from approximately 6.1 million in 2000 to 5 million in 2011, while dairy production dropped from over 100,000 cows in 2000 to approximately 22,000 cows in 2010. More work is needed to close the local demand gap and meet export market demands.
- **Robust extension service provision,** including dairy cow management (dry and lactating cows), herd health and biosecurity. Milk hygiene is of paramount importance and farm level practices should ensure high milk quality.
- **Invest in climate smart production systems and practices** such as efficient milk bulking and cold chain management, appropriate animal housing and circular agriculture (e.g. use of biogas from animal waste).

Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **NAPF:** This package addresses several pillars, most prominently Pillar 5: Agricultural Marketing and Trade Development.
- **GoZ CSA Framework:** This package addresses Objectives 2 and 3 focused on application of CSA practices and improved participation in markets.
- **Vision 2030 and TSP:** This package reduces imports, increases exports, and improves the country's fiscal situation.

The following SWOT Analysis summarizes which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

	Helpful	Harmful
Internal	Strengths • A well-developed dairy industry exists in Zimbabwe. • Adequate knowledge and information about certain aspects of the dairy industry exists. • Zimbabwe Association of Dairy Farmers exists and looks after the interests of dairy farmers. • Value addition is strong.	Weaknesses • Available feed is often of low quality and limited in quantity. • High production costs. • Low dairy herd size. • Sectoral competition from milk imports. • Farm sizes are potentially too small for commercial dairy. • Breeding program is poorly developed. • Low use of animal waste to produce energy due to lack of institutionalisation of circular agriculture.
External	Opportunities • Low milk demand presents an opportunity for growth in the sector. • Government is implementing a Command Livestock Policy. • Dairy industry can take advantage of NDC targets.	Threats • Lack of suitable funding. • Lack of collateral due to the unacceptability of 99-year lease by financiers. • Low research and development budget. • Command Livestock program is poorly structured. • Lack of a coherent export/import policy to stimulate local production.

Potential impact

This package is expected to enhance productivity among commercial A2 dairy farmers, and thus both reduce Zimbabwe's milk imports and increase exports. This would increase incomes and help address poverty, as well as enhance food and nutrition security while lowering emissions. The potential benefits of three specific components of this package were quantified, namely

Enhanced livestock farming practices: Improving on-farm conditions for dairy farmers can greatly increase production, reduce emissions, and instigate the need for breeding programs in Zimbabwe. Currently milk production in communal areas is low per dairy cow compared to commercially focused farms. Gross output of milk production per cow for small scale commercial farmers is 7.8 times higher than in communal dairy farms (ZIMSTAT 2013). This disparity in production in communal farms is in large part due to the quality of feed, farming practices, and better breeds that would be associated with the commercialization of dairy production.

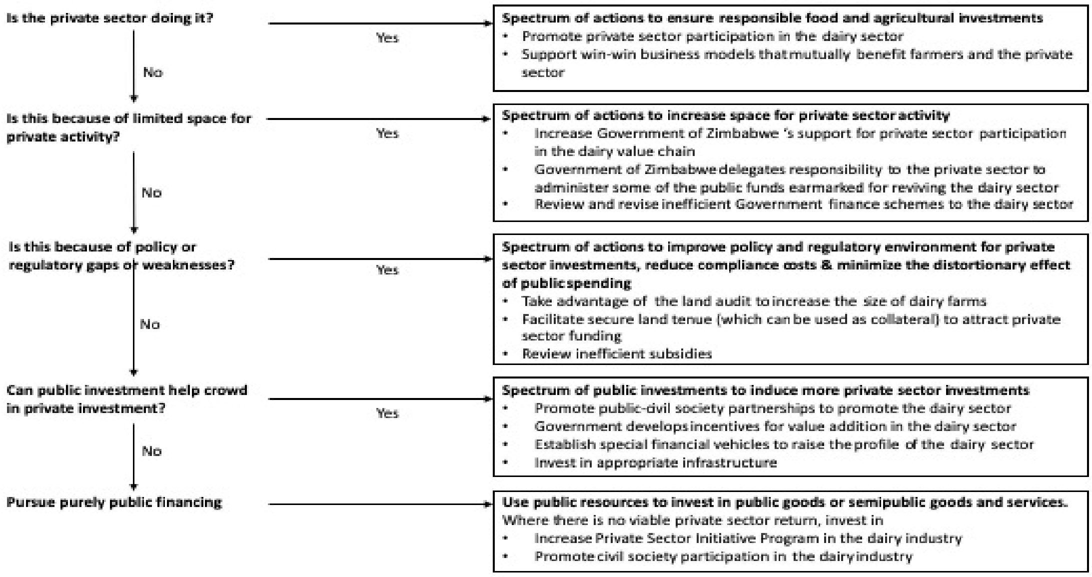
Reduced malnourishment in children: Many health problems associated with child undernutrition can be overcome with access to affordable milk products. Milk provides iron to prevent anemia and is a good source of vitamin A, important for the immune system and vision. A daily glass of milk provides a 5-year old child with 21% of daily protein needs, 8% daily calories, and key micronutrients for overall health and growth (Dugdill 2008).

Job creation based on higher productivity: An increase in milk production would reduce milk imports and create jobs in Zimbabwe. Milk is expensive to import and there are huge energy costs associated with importing milk. To transport milk over long distances, it is usually first dried and then on arrival must be converted back into liquid form. Producing milk locally eliminates the need for processing on the front and back end, increasing efficiency and reducing emissions from the energy required. Milk production also creates jobs for both on-farm and off-farm. One off-farm job is created for every 10-20 liters of milk collected, processed, and marketed. In Kenya, 77 people are employed full time for every 1,000 liters of milk produced daily (FAO 2013).

Cost Assessment

Projects focusing on fostering resiliency among commercial dairy farming have a large range of costs. The components of past World Bank projects that are similar in their objectives to this package range from US$40 million to US$258 million. Based on these prior projects and the large number of potential beneficiaries of the program, the initial estimated cost of Package E for Zimbabwe is US$30 million to US$60 million.

Maximizing Finance for Development



Chapter 6

Summary and Recommendations

This chapter provides an overall summary of the CSAIP development process (Section 6.1) and summarizes the recommended investment packages and next steps (Section 6.2).

6.1 Summary of CSAIP Development Process

Given the sector's vulnerability to climate change, the adoption of CSA as a way to improve productivity, as well as an adaptation and mitigation strategy, is becoming increasingly important. This CSAIP was developed in accordance with the general approach utilized in other previously completed CSAIP processes conducted for Bangladesh, Zambia and Lesotho. First, visions and goals for the sector were identified in consultation with key stakeholders. A longlist of possible CSA options was developed based on research, and stakeholder and expert consultation. Key uncertainties about the future were identified, and a qualitative and quantitative assessment of the vulnerability of the agricultural sector to these uncertainties was conducted, assuming a "no action" future where CSA investments are not pursued. This served to motivate investment in CSA generally, given its robust performance across a variety of uncertain futures. Insights from this modeling process, coupled with expert and stakeholder consultation, informed the development of a shortlist of nine promising packages of CSA strategies. By developing and applying a prioritization framework, a final set of five recommended packages was developed from the shortlist, based on nine different selection criteria. A number of study caveats are described in Appendix K.

6.2 CSA Investment Recommendations and Next Steps

The CSAIP develops five high priority recommended investment packages, which collectively encompass the key Zimbabwean agricultural subsectors and would advance CSA goals identified by stakeholders:

Package A: Enhanced Agricultural Knowledge and Innovation System. This package would build the capacity of the research and extension system, as well as invest in innovation platforms. Building extension systems will include investments in information communication technology systems supporting the dissemination and adoption of climate resilient production practices. The package would focus on small-holder farmers in Agro-ecological Regions III-V, with an emphasis on Regions IV and V, where 75% of these farmers are located. This proposed package aligns with government policy priorities, and fits into the National Agricultural Policy Framework pillar on Agricultural Knowledge, Technology, and Innovation Systems. The initial estimated cost of Package A for Zimbabwe is US$50 million to US$75 million, benefiting approximately 600,000 Region IV and V farmers.

Package B: Sustainable Livelihoods through Diversified Livestock Systems. This set of investments would help secure the livelihoods of small-holder farmers in southern Zimbabwe through increased livestock productivity and promotion of diversified production systems. Investments would be in improved feeding systems, climate resilient breeding programs that target indigenous and small cattle breeds, and commercialization of existing livestock production systems. Programs would target disease and pest screening, improved animal husbandry and health, and encourage farmers to switch from cattle to more heat resilient livestock like goats and sheep. Collectively, these moves to higher quality feed and small livestock would have significant productivity and mitigation benefits. By enhancing farm productivity and incomes, this package is in alignment with the Government of Zimbabwe's stated aim in the Transitional Stabilization Programme. The initial estimated cost of Package B for Zimbabwe is US$30 million to US$60 million, benefiting about 300,000 small-holders.

Package C. Water Harvesting for Resilient Crop and Livestock Production. This package would promote water harvesting to enhance resilient crop and livestock production. It will secure water for livestock and support sustainable soil and water conservation through in situ water harvesting, Conservation Agriculture and small-scale infrastructure. Investments would focus on small-holder farmers in Agro-ecological Regions III-V, areas characterized by low and erratic rainfall. Benefits of this program would include improved water availability resulting in increased crop and livestock productivity and food and nutrition security, as well as catchment protection. This proposed package aligns with government policy priorities, and fits into several of the National Agricultural Policy Framework pillars, including on Resilient and Sustainable Agriculture and Development of Agricultural Infrastructure. The initial estimated cost of Package C for Zimbabwe is US$75 million to US$100 million, benefiting about 800,000 Region III-V small-holder farmers.

Package D. Women- and Youth-Focused Value Chain Development. This package would increase productivity and resilience of women- and youth-run smallholder farms in peri-urban and urban crop and livestock value chains. Investments would focus on organic vegetable and poultry production, and potentially goats, promoting sustainable financial inclusion mechanisms that provide affordable access to financing for inputs, and women- and youth-oriented production and marketing networks including women- and youth-sensitive extension services. These would generate increased production and productivity of poultry and high value vegetables, reduced emissions through higher quality feed, and higher income security for these vulnerable populations. This package is in alignment with the National Agricultural Policy Framework Guiding Principal on Mainstreaming Gender, Youth, and

Other Vulnerable Groups. The initial estimated cost of Package D for Zimbabwe is US$20 million to US$40 million. Potential beneficiaries include an estimated 60,000 women engaged in agriculture around Harare, as well as young farmers in the region.

Package E. Resilient Commercial Dairy Farming. This package would boost commercial dairy farming through alternative and improved feed and fodder production (including local level feed formulation), breeding programs for more climate resilient dairy cow breeds and climate smart production practices (including efficient milk bulking and cold chain management systems). The investments would focus on A2 farms (20 to >120ha) in Manicaland and Midlands in the eastern and central parts of Zimbabwe. Benefits of this program would include higher and more efficient milk production, improved export earnings and food security, and reduced emissions through improved feed. By providing opportunities to decrease imports, and increase exports, this package is closely aligned with Vision 2030 and the Transitional Stabilization Programme. The initial estimated cost of Package E for Zimbabwe is US$30 million to US$60 million.

The next steps for this CSAIP will focus on further development of these investment packages, and integration with Government policies, with the aim of ultimately identifying investors. As part of this process, a broader dissemination and outreach strategy will be initiated. Additionally, the Government of Zimbabwe is in the process of developing a revised Zimbabwe Agricultural Investment Plan, for which the CSAIP will provide important inputs.

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Appendix A: Review of Key Planning Documents Addressing CSA Objectives in Zimbabwe

This appendix summarizes the main planning and policy documents relevant to Zimbabwe's agricultural sector, which together set the backdrop for any proposed CSA investments. The documents summarized are:

- The Comprehensive Agricultural Policy Framework (2012)
- The National Agricultural Policy Framework (2018)
- The Zimbabwe Agricultural Investment Plan (2013)
- The Transitional Stabilization Program (2018)
- The Zimbabwe Agenda for Sustainable Socio-Economic Transformation (2013)
- The Zimbabwe Climate Policy (2017)
- Zimbabwe's Third National Communication to the United Nations Framework Convention on Climate Change (2016)
- Climate-Smart Agriculture Manual for Zimbabwe (2017)
- The CSA Profile for Zimbabwe (2017)
- Climate Smart Agriculture Framework (2018-2028)
- Zimbabwe Vulnerability Assessment Committee (ZimVAC) Rural Livelihoods Assessment Report (2018)

A.1 The Comprehensive Agricultural Policy Framework (2012)

The Comprehensive Agricultural Policy Framework of 2012 offers a situation analysis of the agricultural sector, highlighting the vision, goals, objectives and detailed policy statements and strategies for the development of the Zimbabwean agricultural sector during the period 2012 – 2032. The main objectives of this framework are to:

1. Assure national and household food and nutrition security;
2. Ensure that the existing agricultural resource base is maintained and improved;
3. Generate income and employment to feasible optimum levels;
4. Increase agriculture's contribution to GDP;
5. Contribute to sustainable industrial development through the provision of home-grown agricultural raw materials; and
6. Expand significantly the sector's contribution to the national balance of payments.

A.2 The National Agricultural Policy Framework (2018)

The National Agricultural Policy Framework (NAPF) (2018) was released by the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement in November 2018. This document updates the prior 1994 policy framework, with an aim to "provide policy guidance and direction on how to promote and support the sustainable flow of investments to transform the agricultural sector through increased and sustained agricultural production, productivity and competitiveness" (GoZ 2018b). It covers the period 2019 to 2030. The focus of the document is primarily on enhancing productivity, although resilience, mitigation, and CSA are mentioned as crucial objectives.

A.3 The Zimbabwe Agricultural Investment Plan (2013)

The Zimbabwe Agricultural Investment Plan (ZAIP) (2013) was initiated by the Ministry of Agriculture, Mechanization and Irrigation Development. This document provides the most comprehensive and recent investment plan from the Government of Zimbabwe for the agricultural sector for 2013-2017. The overall goal of the ZAIP is: "to facilitate sustainable increase in production, productivity and competitiveness of Zimbabwe agriculture through building capacity of farmers and institutions, improving the quality and quantity of public, private and development partner investment and policy alignment". Importantly, the Comprehensive Africa Agriculture Development Program (CAADP) technical review of the ZAIP recommends that climate change interventions under ZAIP should be broadened to include biodiversity and wetland management issues (CAADP 2018). A new ZAIP is currently being developed for the coming years.

A.4 The Transitional Stabilisation Program (2018)

The Transitional Stabilization Program (TSP) is scheduled to be implemented between October 2018 – December 2020, and prioritizes fiscal consolidation, economic stabilization, stimulation of growth and creation of employment. The TSP aims to consolidate gains made under The Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZimASSET) and to that end seeks to address 'macro economic fundamentals that hinder Smart Agriculture, which includes modernization of irrigation'. The TSP was crafted against the backdrop of the country's desire to embark on implementation of national development policy initiatives and programs to realize Vision 2030 of being a prosperous and empowered upper middle income society by 2030, the United Nations Sustainable Development Goals, and the AU Agenda 2063. To this end, the TSP outlines policies, strategies and projects that guide Zimbabwe's social and economic development interventions, targeting immediate quick-wins and laying a robust base for economic growth in the period 2021-2030. It is expected that economic growth will be driven by the private sector, with the government facilitating a supportive macro-economic and business environment. The focus will be on value addition and beneficiation, to realize higher value exports, and cushion the economy from the vagaries of international commodity price fluctuations associated with over-dependence on export of raw commodities.

The TSP supports agricultural development in the following areas, among others:

- Inputs Availability
- Farm Mechanization
- Harvesting and Drying Status
- Repair of Equipment
- Local Manufacture of Implements
- Access to Tillage & Harvesting Services
- Demand Driven Mechanization
- Productivity & Yields
- Irrigation Support Program

A.5 Zimbabwe Agenda for Sustainable Socio-Economic Transformation (2013)

The ZimASSET (2013) offers a coherent plan to achieve sustainable development and tackle climate change, by addressing the need to attain sustainable socio-economic transformation in four key clusters:

1. Food security and nutrition
2. Social services and poverty reduction
3. Infrastructure and utilities
4. Value addition and beneficiation

All government ministries and departments fall under the various clusters, while ministries falling under each cluster are coordinated by the Presidency. The ZIMASSET recognizes the need to respond to climate change. For example, the Food Security and Nutrition Cluster aims to strengthen climate and disaster management policy; promote conservation agriculture; rehabilitate irrigation infrastructure; promote drought-resistant, high yielding and heat tolerant varieties; promote biofuels and renewable energy. Box A.1 presents an overview of the components of the clusters.

Box A1. Overview of the ZimASSET Transformation

1. Food Security and Nutrition

- Build the capacity of AGRIBANK to provide concessionary loans
- Implement contract farming
- Provide smallholder farmers with subsidized agriculture inputs
- Implement livestock drought mitigation programs
- Initiate a rehabilitation program for irrigation equipment
- Implement low-cost mechanization programs
- Rehabilitate, build and modernise irrigation schemes
- Increase power available and affordable for irrigation
- Establish loan facilities for farmers to access machinery at low cost
- Increase mobile workshops to repair and maintain farm equipment
- Acquire and install solar powered and alternative sources of energy for equipment
- Undertake awareness building/demos on conservation agriculture machinery
- Manufacture conservation agriculture machinery
- Review utility charges and tariffs
- Review fees, levies and charges

2. Social Services and Poverty Eradication

- Undertake a national blitz to rehabilitate water supplies
- Strengthen Public Private Partnerships
- Increase the number of women groups benefiting from the women's development fund

3. Infrastructure and Utilities

- Rehabilitation of infrastructural assets in the following areas
- Water and Sanitation infrastructure

- Public Amenities
- Information Communication Technology
- Energy and Power Supply
- Transport (road, rail, water and air)

4. Value Addition and Beneficiation

- Promotion of alternative sources of energy (bio-gas, solar and wind)
- Encourage and enforce the use of solar energy for lighting and heating
- Commercialise the growing of jatropha
- Increase hectarage of sugar cane plantations from 7000ha to 10,000ha
- Develop captive water supply for irrigation
- Establish honey producing clusters in each province
- Resource mobilization for hives and kits
- Facilitate market linkages
- Establish honey processing centres
- Promote strategic linkages between the informal and formal sectors
- Support cooperatives and small and medium entreprise development
- Build capacity in entrepreneurial technical and business management and training.

Source: GoZ (2012a)

A.6 Zimbabwe Climate Policy (2017)

The Zimbabwe Climate Policy (2017) builds on the ZimASSET blueprint with a focus on directing policy toward "a climate resilient and low carbon Zimbabwe" as the vision. This policy document revolves around four thematic areas, which highlight the focus and direction of this policy:

1. Weather, Climate Modelling and Change
2. Vulnerability and Adaptation
3. Mitigation and Low Carbon Development
4. Enablers/Cross Cutting Issues

A.7 Zimbabwe's Third National Communication to the United Nations Framework Convention on Climate Change (2016)

Zimbabwe's Third National Communication to the United Nations Framework Convention on Climate Change (2016) provides an up-to-date summary of information on climate change issues in Zimbabwe. This document lays the groundwork for Zimbabwe's current greenhouse gas emissions, the Business-As-Usual emissions projection, as well as the mitigation goals and potential across various sectors.

A.8 Climate-Smart Agriculture Manual for Zimbabwe (2017)

Climate-Smart Agriculture Manual for Zimbabwe (2017) was developed by the United Nations Environment Program in collaboration with the Government of Zimbabwe and Climate Technology Centre and Network. This manual describes in detail various CSA practices and their usefulness for farmers within the context of Zimbabwe, and lays the groundwork for educating those involved in the agricultural sector in Zimbabwe about CSA practices. This document covers the following topics in detail:

1. **Enabling Environments:** Discusses institutional and policy engagement, climate information systems, weather index-based insurance, and gender and social inclusion.
2. **System Approaches:** Lists landscape management approaches to achieve CSA goals.
3. **Practices:** Describes the approach to address CSA options related to soil, water, crop production, livestock and rangeland management, agroforestry, fisheries, aquaculture, and energy management.

A.9 Climate Smart Agriculture Profile for Zimbabwe (2017)

Climate Smart Agriculture Profile for Zimbabwe (2017) was developed by the International Center for Tropical Agriculture. This profile adapts general CSA practices into a comprehensive and digestible layout, highlighting the main challenges faced by Zimbabwe, and the practices most effective by crop and region. Smartness scores are attributed to various CSA practices under consideration to provide a tangible measure of each CSA practice under different evaluation categories such as yield, income, water, soil, risk/information, energy, carbon footprint, and nutrition.

A.10 Climate Smart Agriculture Framework (2018)

Climate Smart Agriculture Framework (2018), authored by the Ministry of Lands, Agriculture, Water, Climate, and Rural Resettlement, focuses on the government's efforts to address the impacts of climate change on the agricultural sector through policy, education, and finance. The framework provides for the establishment of a CSA Unit within the government to mobilize funding and technology development (GoZ 2018b).

A.11 Zimbabwe Vulnerability Assessment Committee Rural Livelihoods Assessment Report (2018)

Zimbabwe Vulnerability Assessment Committee (ZimVAC) 2018 Rural Livelihoods Assessment Report, coordinated by the Food and Nutrition Council, provides data on food availability and nutritional access of rural populations. Household-level surveys provide key information, including food consumption patterns, community livelihood challenges and development priorities, shocks and hazards of rural life, and types of resilience to those shocks and hazards.

Each of these documents address some aspect or goal of CSA in various forms, as well as provide the perspective of the Government of Zimbabwe within the agricultural sector.

Appendix B: Findings from Stakeholder Consultations

Between October 2018 and April 2019, three stakeholder consultation activities were held to refine the focus of the CSAIP, validate findings with local experts, and prioritize investments and scenarios:

- The Inception Workshop in October 2018
- Preliminary Interim Workshop in March 2019
- Interim Workshop in April 2019.

This appendix summarizes the findings of each of these workshops.

B.1 Findings of Pre-inception Mission Survey and Inception Workshop Small Group Activity – October 2018

Two stakeholder engagement activities were run, with the aim of identifying the visions, goals, the set of possible CSA options, and relevant uncertainties for the Zimbabwe CSAIP. The first activity was a Google Survey in advance of the Inception Workshop, and the second was a small group discussion activity that occurred during the Inception Workshop on October 30, 2018. Both activities were similar in terms of questions asked, but the Inception Workshop activity was considerably more involved and designed as a group rather than as an individual activity.

Pre-Inception Mission Survey

The survey was sent out to all workshop participants, and asked each participant to select one of the three CSA pillars (productivity, resilience, or mitigation). The survey asked participants to identify visions, goals, options, uncertainties, and key metrics related to their selected pillar. Figure B-1 shows the welcome page of the Google survey sent to participants. Of the 12 respondents, six selected productivity, five chose resilience, and one selected mitigation. Most respondents had more than 10 years of experience, and had areas of expertise including agronomy; climate change adaptation; sustainable development; water, sanitation and hygiene; governance; farming; research; nutrition; and crop science.

Figure B1. Welcome Page of the Google Survey

Vision Statements

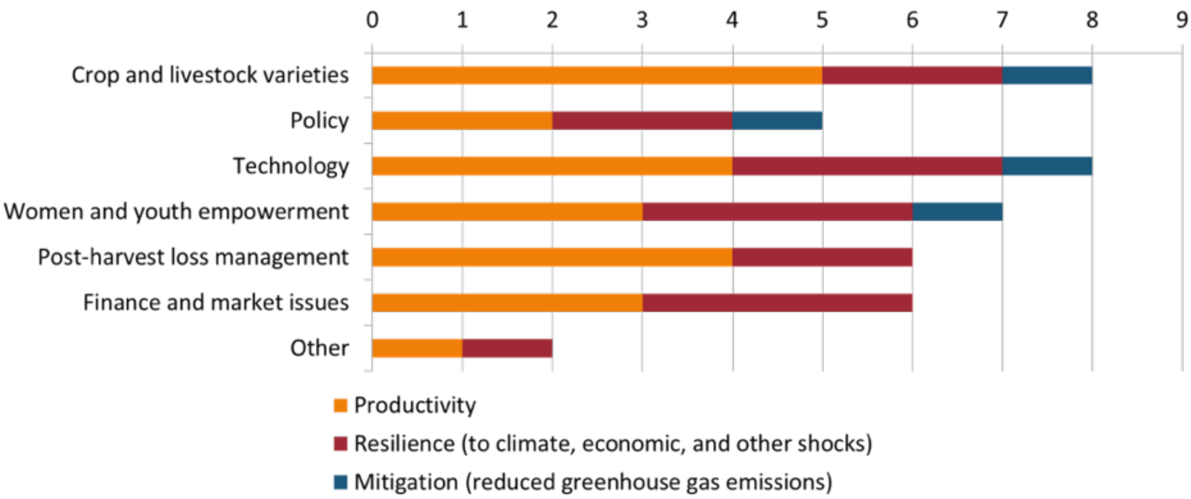
Some examples of vision statements received are:

- **Food security:** Increase food security at both national and household levels
- **Climate resilience:** Enhance resilience to climate shocks through investment in water infrastructure
- **Food self-sufficiency:** Food self-secure nation through increased productivity
- **Diversity and resilience:** Move toward agro-biodiversity of resilient cropping systems

Goals

The identified goals aimed at achieving these visions had a wide range of themes (Figure B-2), with technology and crop/livestock varieties being the most frequently identified.

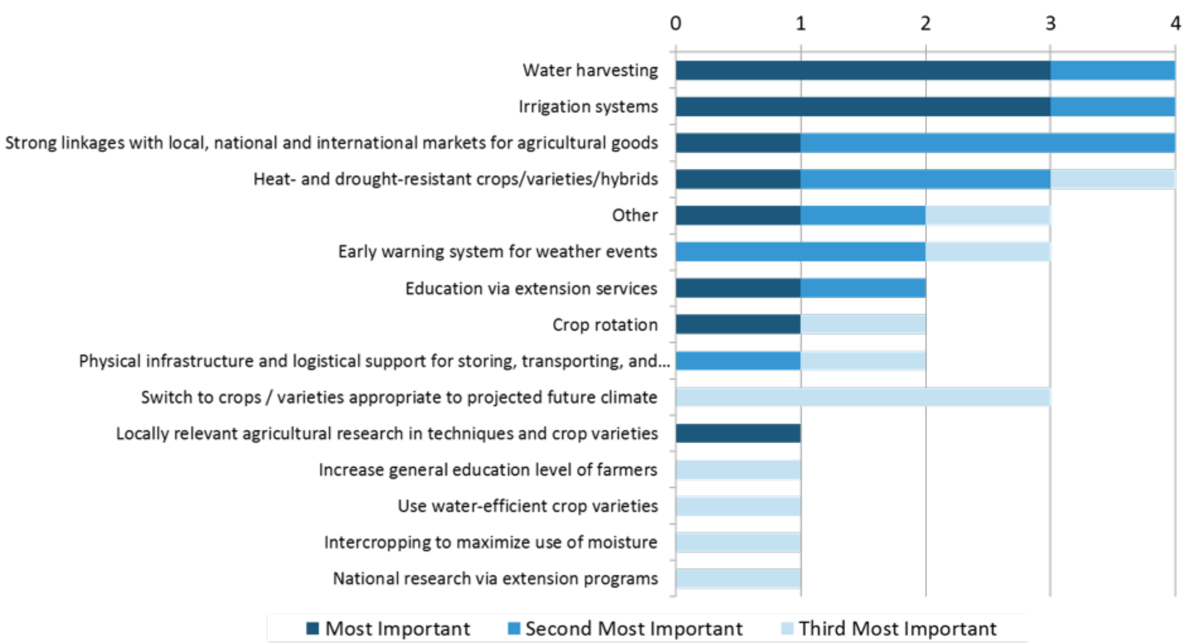
Figure B2. Goal Themes from the Google Survey



CSA Options

The participants were also presented with 28 preliminary CSA options to achieve the goals listed, and asked to rank these and add any that were omitted. Participants identified water-focused CSA options as the most important, including options such as water harvesting and irrigation system development. Market linkages and heat- and drought-tolerant crops/varieties/hybrids were also listed as important.

Figure B3. Priority Options from the Google Survey



Relevant Uncertainties

Among major categories of uncertainty that could potentially affect Zimbabwe's ability to reach its CSA goals, climate change was the most significant challenge, followed by concerns about domestic development, and lastly regional and international markets.

Inception Workshop Small Group Activity

During the Inception Workshop, participants were divided into three groups, one per CSA pillar (productivity, resilience, and mitigation). The facilitators asked each group to fill out a form that included the elements of vision, goals, options, uncertainties, and metrics and funding mechanisms. After the small group activity, participants presented their findings and discussions followed to clarify results and ask questions. At the end of the session, the facilitators convened a large group discussion around scenarios for the Zimbabwe CSAIP. On October 31, these workshop findings were vetted and augmented through a follow-on discussion with five stakeholders who were unable to attend the workshop.

Vision Statements

Participants were asked to provide a set of words that came to mind for their selected CSA pillar, and then a sentence that combined the group's ideas into a single vision statement. The three groups developed the following vision statements:

- **Productivity:** To achieve food and nutrition security through a diversified, sustainable, and commercially-driven agricultural sector.
- **Resilience:** By 2030, the agricultural sector is resilient to climate shocks.
- **Mitigation:** Achieve a sustainable agricultural sector that reduces greenhouse gas emissions through carbon conservation and carbon sequestration.

Goals

The groups were each asked to provide a set of measurable goals that the sector can use to achieve the vision the group has identified. Not all groups identified quantifiable goals.

- **Productivity:** Although this group did not identify quantified goals, the goals were oriented around enhancing diversification, commercialization, improved nutrition, and productivity. For the last goal, the group identified a target of closing the yield gap by 55%.

- **Resilience:** The resilience group provided three goals, two of which have quantitative targets:
  - 40% of farmers have access to climate information and advisories by 2030;
  - 40% have adopted CSA practices by 2030;
  - all policy frameworks are conducive to building resilience

- **Mitigation:** This group identified three goals:
  - reduce emissions from energy use in agriculture;
  - adopt production practices that reduce emissions;
  - adopt agricultural practices that conserve the resource base.

CSA Options

Participants were asked to characterize the top CSA options to achieve their particular pillar, and discuss whether those options have been tried before and were successful. Participants were presented with a preliminary table of CSA options, and were asked to add any additional options not included in that list. Based on this exercise, the top five specific goals by CSA pillar, in terms of both priority and prior demonstrated success, were as follows:

Productivity	Resilience	Mitigation
Enhance water harvesting	Enhance water harvesting	Adoption of grid and off-grid renewable energy options
Expand and rehabilitate irrigation	Education via extension services and research	Improving investment policy
Extend farmer education via education services	Developing private sector partnerships	Locally relevant agricultural research in techniques and crop varieties
Physical infrastructure and logistical support for storing, transporting, and distributing farm outputs	Conservation farming practices	Improved livestock and pasture management
Use of improved crop varieties	Move toward more holistic livestock management practices	Agroforestry

In the discussion that followed on October 31, several refinements to these top options were introduced:

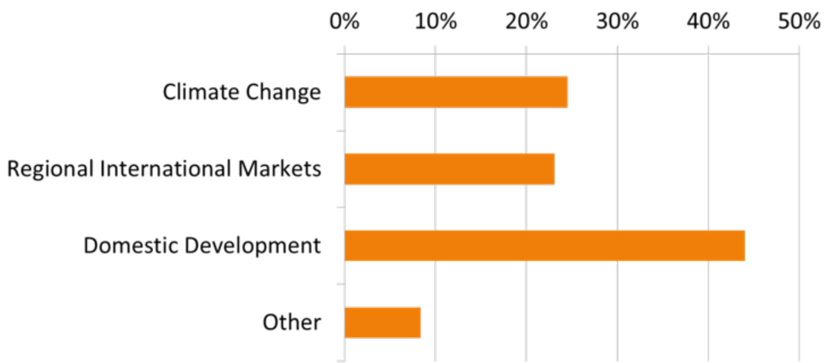
- Extension services are underdeveloped and underfunded; farmers often receive new technologies directly and extension personnel are not familiar with their use. Instead, the group recommended that new technologies first be introduced to extension, who can then be equipped to educate farmers on their use.
- The role of water harvesting was underscored, with an important emphasis on harvesting at the household level for supplemental irrigation, and rehabilitating dams. Participants emphasized the importance of adequate water for livestock, which provides a greater degree of resilience because animals are a mobile reservoir of capital.
- The country currently relies on large machines and animal draft for much of its production. There is a deficit in smaller machines with attachments – this should be an investment priority.
- Farmers have a difficult time accessing loans, particularly with the current land tenure situation. A number of microfinance institutions have emerged over the past several years – these should be further enabled by the government.
- Crop insurance programs need to be improved by enlarging the insurance pool and making insurance a requirement to receive a loan.

From a broader perspective, the difference between uptake and adoption of investments was emphasized. The goal of an investment program is ultimately adoption, but often uptake (i.e. initial application of the investment) is strong early on, but longer term adoption is poor. Investments need to employ techniques to enhance adoption.

Relevant Uncertainties

Groups defined the key drivers of current and future uncertainty, and the extent to which they will impact Zimbabwe's ability to achieve the goals listed. Common sources of uncertainty across all three groups were domestic policy, climate factors, and commodity prices. The productivity group also defined water and input availability as key uncertainties. Groups were also asked to categorize the uncertainties they listed into broad categories – the percentage of uncertainties relating to domestic policy, regional and international markets, and climate variability and change are presented in Figure B-4.

Figure B4. Percentage of Zimbabwe's CSA Uncertainties Falling into Broad Categories



Metrics and Funding Mechanisms

Lastly, the small groups ranked a set of strategy performance metrics, and listed sources of possible financing. In order, the top metrics were net farm revenues, agricultural production, food security/nutrition, employment, import/export implications, and mitigation benefit. In the discussion that followed on October 31, it was suggested that the implications on female labor requirements would be an important evaluation metric, if this were possible. For instance, potholing is an intervention that would require an increase in women's labor, which is undesirable. On the other hand, moving from flood to drip irrigation would reduce women's farm labor requirement. Sources of financing listed included the private sector, the public sector, and donors and climate funds. The Infrastructure Development Bank of Zimbabwe was listed as a possible source of funding, along with the Global Environment Facility and the Green Climate Fund.

Workshop Participants and Affiliations

	NAME	ORGANISATION	POSITION
1	Rachel Manyifu	Independent	–
2	Nyce Mugabe	PHI	
3	Hazel Kwaramba	CUT	
4	Ademola Braimoh	World Bank	CSA Specialist
5	Leonard Unganai	Oxfam	P. Manager
6	DAHLIA GARWE	TRB	GM
7	Brent Boehlert	IEc	Consultant
8	MEETA SEHGAL	WB	
9.	EASTHER CHIGUMIRA	WB	CONSULTANT
10.	Antonnette Chigwe	CFU	Economist
11	Emmanuel Manzungu	UZ	Professor
12	kudakwashep@gmail.com	CCMD	PRINCIPAL RESEACHER
13	Jeremiah Evers	ZCFU	Director
14	Kenneth Moono	LMAC	Economist

1.	Charity R. Hodzi-Sibanda	IDBZ	Gender Expert Climate Fina
2	PATRICIA S GUNDA	MECHANISATON	CHIEF ENGINEER -Train
3	LUNGOCWE SEPO MARONGWE	AGRITEX	Cons. Agric. Agronomist
4	Desire Nemachakwe	GREEN IMPACT	Executive Director
5	Brent Boehlert	IEc	Principal
6	Ademola Braimoh	World Bank	Snr NRM Spec
7	Andrew Mutanga.	HEIFER INT.	ANIMAL WELLBEING MANAGER
8	MEETA SEHGAL	WB	SR. AG. SPEC
[illegible]	Newrashe Brian	DR&SS	chief R.O.
20	KUDZAI NDIDZANO	CCMD	CC COMPLIANCE
21	KERDINGTON KUSENA	ZCFU	Economist
22	Christopher Shangurai	DVS	Dairy officer

B.2 Findings of Preliminary Interim Workshop – March 2019

A World Bank workshop was held in Harare on March 7, 2019 to further the development of the CSAIP for Zimbabwe's agricultural sector. The goal of the workshop was to convene a small group of experts to review progress on the CSAIP and provide input on next steps. Participants included Easther Chigumira of the World Bank; Brent Boehlert and Charles Fant of the consulting firm Industrial Economics, Inc. (IEc); and six experts from government, private sector, donor community, and academia. Drs. Boehlert and Fant participated in the workshop remotely from the U.S., and all others from the World Bank office in Harare.

Overview of the Workshop

During the workshop, Dr. Boehlert presented an overview of where the IEc team is in the CSAIP process, and Dr. Fant then presented some preliminary results from IEc's crop suitability modeling work. The modeling showed that sorghum is more suitable under current conditions than maize, and is more resilient to a changing climate. A discussion followed, led by Dr. Boehlert.

Workshop Summary and Findings

Key Government Priorities

- **Consolidation of CSA plans.** The current Minister of Agriculture (Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement) recognizes there are many climate smart agriculture plans/policies being developed, and wants them consolidated within six months. The timing of the CSAIP is good in that regard, as the plan is to wrap up in draft form by June.

- **Growth-focused.** With the recent Vision 2030 document seeking middle income status in the near future, the government appears to be primarily focused on economic growth and commercialization. Although funding is still being directed toward communal agriculture and livestock, in the medium term this may shift. Minerals and agriculture are the primary industries for achieving the economic elements of Vision 2030.

- **Focus on diversification of exports.** There were 26 agricultural commodities exported in 1999, but exports hit a low point of only 10-12 commodities more recently. A major goal is to increase this number with plantation crops such as macadamia nuts and others.

Priority CSA Options Identified by Stakeholders

- **Conservation Agriculture.** A key aspect here is bringing in appropriate mechanization across the value chain, e.g. smaller trailers and cheaper maize shellers, so that small-scale farmers can make their operations more efficient and profitable.

- **Crop switching.** In light of the maize/sorghum suitability findings, some useful discussions were had about how to integrate sorghum or other small grains into markets and diets. One key issue with small grains is post-harvest management – i.e. poor processing leads to a product that is not desirable to consumers. This and other options would help utilization of small grains. In addition, the subsidies provided to maize make small grains comparably more expensive.

- **Livestock management.** In 1999 there were 11 million cattle; the number now is closer to half that. Smallholders own 90% of livestock, and breeding improvement and commercialization are needed in the sector. Yet because most of the people formulating agricultural policy are on the crop side, livestock is not as emphasized. Participants agreed the key is market development and productivity (by way of animal health improvements).

- **Long-term financing.** A 10-year investment horizon is useful, but when the aim is development of new crops and infrastructure/mechanization, a 20-year investment horizon is more realistic. These longer-term loans with concessionary interest rates early on are needed to promote development.

- **Other options.** It is critical to consider land management, agro-forestry, and water-efficient irrigation.

Policies and Uncertainties

- **Land reform policies.** It is critical to take into consideration the 300,000 families on 6 million hectares that currently do not have access to land rights and thus do not have collateral to get loan financing. This limitation may be lifted soon through a policy shift, which would mean more private sector funding opportunities for vast areas of the country.

- **More inclusive agricultural policy.** With the shift toward smaller landholdings, there are fewer laborers and more farmers in the agricultural sector. There is a business-minded perspective among these farmers, and they need access to markets.

- **Source of sustained funding for agriculture.** The key is moving government and private sector funding toward achieving CSA goals and visions. Although donors provide investment, it is often project-based and thus does not reliably help promote a long-term Zimbabwean agricultural strategy.

B.3 Findings of Interim Workshop – April 2019

A World Bank workshop was held in Harare on April 4, 2019 to continue development of the CSAIP for Zimbabwe's agricultural sector. The goal of the workshop was to convene a larger group of stakeholders and local experts to review progress on the CSAIP and provide input on next steps. Participants included experts from the government, private sector, donor community, and academia.

Overview of the Workshop

During the workshop, Dr. Boehlert presented an overview of where the IEc team is in the CSAIP process, and Prof. Manzungu presented a situation analysis on the Zimbabwean agricultural sector, and ways to move forward. Comments were provided by participants on the framework and scope, investment options being considered, and key assumptions. Small group discussions followed that were led by Dr. Boehlert, and participants presented their findings. The focus of these small group discussions was to refine the visions, goals, and investment options for the three CSA pillars.

Workshop Summary and Findings

The key findings of this workshop are presented in Chapter 3 of the main CSAIP report, in the form of refined visions and measurable goals. Further findings of this workshop are summarized in Table B-1 below showing an initial assessment of CSA investment option priority and suitability across the different Agro-ecological Regions.

Table B1. Initial Assessment of Potential of Various CSA Options

CATEGORY	MEASURE*	POTENTIAL**			PILLARS BY AER***				
		PROD	RESIL	MITIG	1	2	3	4	5
Cropping	Conservation agriculture	***	**	***	*	**	***	***	*
	Heat- and drought-resistant crops/"water efficient" varieties/hybrids	***	***	**		*	**	***	***
	Switch to crops / varieties appropriate to projected future climate	***	***	*	***	***	***	***	***
	Agro-forestry	-	**	***	**	**	***	***	**
	Crop rotations	**	**	*	***	***	***	***	***
	Use of improved varieties (pest-resistant; GMOs; breeding and use)	**	***	*	***	***	***	***	***
	Crop specialization / substitution / diversification	***	***	*	***	***	***	***	***
Extension/ Research	Education via extension services (farmer needs based)	***	***	***	***	***	***	***	***
	National research via extension programs	***	**	***	***	***	***	***	***
	Locally relevant agricultural research in techniques and animal and crop varieties	***	***	***	***	***	***	***	***
	Increase general education level of farmers	*	*	***	***	***	***	***	***
Infrastructure	New or rehabilitated irrigation systems (with improved water use efficiency)	***	***	*	**	*	***	***	***
	Water harvesting (small scale)	***	***	*			**	***	***
	Water harvesting (large scale)	***	**	*			*	**	**
	Solar-powered groundwater pumping (improve use of renewable energy sources)	**	***	**			*	**	**
	Infrastructure and support for storing, transporting, and distributing farm outputs	**	***	**	***	***	***	***	***
	Increase area under supplementary irrigation	***	***	*	**	**	*	**	**
	Modernization of irrigation e.g. change to more efficient systems and practices	***	**	***	***	***	***	***	***

Disaster Risk Management	Early warning system for weather events	***	***	-	***	***	***	***	***
	Weather index-based crop and livestock insurance	**	****	-	***	***	***	***	***
Institutional/ Markets	Private enterprises, as well as public or cooperative organizations for farm inputs	**	**	-	***	***	***	***	***
	Resilient value chains	***	***	***	**	**	**	**	**
	Strong linkages with local, national and international markets for agricultural goods	***	***	***	**	**	**	**	**
	Economic pricing of water	**	**	-	**	**	**	**	**
	Import crops that cannot be irrigated competitively e.g. wheat	*	**	***	**	**	**	**	**
Livestock	Intensive livestock production systems incorporating less dependence on rangelands	**	**	***	*	*	**	***	***
	Prescribed burning of Savannas	*	-	***	*	*	***	***	***
	Climate resilient breeding programs and systems	***	***	***	**	**	**	**	**
	Find alternative feedstuffs and systems (local and indigenous)	***	***	***	**	**	**	**	**
	Enhanced livestock diseases prevention and treatment	**	***	*	***	***	***	***	***
	Increased small livestock production and fisheries	***	***	***	*	*	**	***	***
	Livestock diversification	***	***	***	***	***	***	***	***

Notes

* One group noted several other options not evaluated here, including processing mechanization; animal health centers, diptanks, game fences; reducing production costs; and consumer education to change consumption patterns

** Ranking by stakeholders, where 3 is highest, 2 is medium, and 1 is lowest, - means that no response was provided.

*** The number of CSAs pillars selected by stakeholders as important for each AER-measure combination.

Workshop Participants and Affiliations

	NAME OF PARTICIPANT	ORGANIZATION	TITLE
1	Collen Mutasa	University of Zimbabwe	Mr.
2	Eunice Chivunga	Zimplow t/a Mealie Brand	Mrs.
3	Emmanuel Manzungu	University of Zimbabwe, Dept of Soil Science	Prof.
4	Milton T. Makumbe	Dept of Research & Specialist Services	Mr.
5	Anna Brazier	Consultant	Mrs.
6	Brent Boehlert	Industrial Economics Incorporated (IEc)	Senior Consultant
7	Praise Penyai	Farmer	Ms.
8	Witness Kozanayi	Researcher	Dr.
9	Takudzwa Mashakwe	Researcher	Mr.
10	Aisha Mashingauta	Researcher	Miss
11	Nesbert Tadzoka	World Vision International	Mr.
12	Rachel Marufu	ZTA	Ms.
13	Hazel Kwaramba	Independent Consultant	Dr.
14	Sepo Marongwe	Agritex	Mrs.
15	Kudzanai Chimhanda	Ruzivo Trust	Miss
16	Tawanda Manyangadze	Bindura University of Science Education (BUSE)	Dr.
17	Zingwari Obey	Bindura University of Science Education (BUSE)	Mr.
18	Bertha Nherera	i) ORSHA Wholesome Foods & TRAD ORG F. Forum	Director
19	Dorah Mwenye	Dept of Research & Specialist Services	Dr.
20	Kerdington Kusena	Zimbabwe Commercial Farmers Union	Economist
21	Elijah Rusike	WeEffect	Programme Manager
22	Shylock Muyengwa	CFIERD	Consultant
23	Brian Neurashe	Dept of Research & Specialist Services	CRO (Agronomist)
24	Norah Samupunga	Heifer International	Program Manager - Agribusiness
25	Desire Nemashakwe	Green Impact	Executive Director
26	Chrispen Mununga	Commercial Farmers Union	Economist
27	Oxwell Madara	Christian Care / Zimbabwe Council of Churches	Project Officer - Livelihoods
28	Mabel Hungwe	BEAT	Programs
29	Easther Chigumira	Consultant	Dr.
30	Alfa Ndlovu	Food & Nutrition Council	Program Assistant
31	Jeffrey Jinya	Gwebi Agricultural College	Lecturer/ CA Coordinator
32	Tirivanhu Muhwati	Climate Change Dept, MLAWCRR	Acting Deputy Director
33	Grant Milne	World Bank	Snr Natural Res Mgt Spec
34	Pablo Benitez	World Bank	Snr Env Economist

Appendix C: Additional Details on CSA Options

As part of an initial review of CSA options during the Inception phase of work, several options were evaluated in more depth. This section describes eleven of the CSA options considered in more detail, namely those which appear in both the ZAIP and the CSA Profile, and presents a table detailing the characteristics of the options. The options examined are:

- Expansion and Improvement of Irrigated Areas
- Water Harvesting
- Early Warning System for Weather Events
- Weather Index-Based Insurance
- Conservation Tillage
- Crop Rotation
- Heat- and Drought Resistant Crops/Varieties/Hybrids
- Agroforestry
- Livestock Management
- Intercropping
- Information Communication Technology

C.1 Expansion and Improvement of Irrigated Areas

Expansion and improvement of irrigated areas includes increasing the land area under irrigation to address the volatility of rainfall, as well as converting defunct or old irrigation systems to more efficient drip systems. In Zimbabwe, less than half of the 365,000 hectares that are suitable for irrigated agriculture are equipped for irrigation (CIAT World Bank 2017). Expansion of irrigated areas would improve food security and reduce the volatility of crop yields and food prices (CIAT World Bank 2017). In the areas where irrigation equipment is inefficient or defunct, drip irrigation would focus on installing small tubes that apply water in a targeted manner (CTCN 2017). Drip irrigation is highly efficient and allows farmers to save money on water in the long run, after paying the higher upfront cost to install a drip system (Manzungu et al. 2018a). Irrigation adaptations are most applicable in Agro-ecological Regions I and II but can also be utilized in Regions IV and V among smallholder farmers (CTCN 2017). Drip irrigation also reduces the disturbance of soils and thereby reduces soil carbon emissions as compared to flood irrigation.

Zimbabwe's agricultural policy primarily focuses on expanding irrigated land area, but is beginning to include support for more efficient drip irrigation systems. The ZAIP contains the key performance indicator of increasing area under irrigation from 102,000 hectares in 2012 to 175,000 hectares in 2016, while also ensuring at least 50% of Zimbabwe's priority irrigation systems are rehabilitated (GoZ 2013). Drip irrigation is only mentioned as an illustrative activity under the goal to increase the area under efficient and sustainable irrigation technology (GoZ 2013). Drip irrigation has varying rates of adoption in Zimbabwe depending on the crop – for wheat and sugarcane, drip irrigation has an adoption rate of greater than 60% while the rate is less than 30% for tobacco and between 30-60% for vegetables (CIAT World Bank 2017). Installation of new irrigation technology for smallholders is often funded by the government as farmers cannot meet the upfront capital cost (Manzungu et al, 2018a).

C.2 Water Harvesting

There are three methods of water harvesting: (i) in situ rainwater harvesting, (ii) external water harvesting, and (iii) domestic rainwater harvesting. In situ rainwater harvesting refers to techniques which increase infiltration of rainwater and promote water retention in soils. Such methods include contour planting and potholing. External water harvesting includes collection from runoff, floods, and groundwater (CTCN 2017). Domestic rainwater harvesting refers to capture of runoff from roofs, streets, and courtyards.

The Agro-ecological Regions of Zimbabwe with greatest water insecurity are Regions IV and V, due to irregular and unreliable rainfall in these areas. Water harvesting would be particularly beneficial for winter crops, fruits, and vegetables. Livestock owners could also benefit from water harvesting, as improved water availability enables stable production. Current adoption rates of water harvesting practices are low, at rates of less than 30% (CIAT World Bank 2017). Currently, agriculture uses 60% of all water in dams in Zimbabwe. As sedimentation continues to reduce the capacity of these dams, viable alternative sources of water will become increasingly important. Water harvesting interacts directly with many CSA options; conservation tillage, crop rotation, early warning systems for weather events, and agroforestry may improve water harvesting, while expansion of irrigated areas and livestock management may rely on successful water harvesting.

C.3 Early Warning System for Weather Events

Early warning systems for weather events would disseminate information about droughts, floods, and disease outbreak through radio, television, cell phone, computers, and social media. Early warning systems allow for a coordinated response in providing emergency service, aid, and support for erosion prevention, if necessary. Early warning systems in Zimbabwe currently struggle to reach some of the most vulnerable populations, including rural, female-headed households (CTCN 2017). Furthermore, these systems require funding to monitor key climate indicators and disseminate the information through several media forms. However, these early warning systems could be useful in every region of Zimbabwe to ensure the best possible response to drought, floods, and other crises.

The ZAIP identifies early warning systems as critical to reaching the key goal of food security in Zimbabwe. The ZAIP has an Agriculture Coordination Working Group that brings together many stakeholders in Zimbabwean agriculture, including the Famine Early Warning Systems Network (GoZ 2013). Furthermore, the ZAIP budget allocates over $600,000 a year for strengthening these early warning systems and improving meteorological monitoring as part of the system (GoZ 2013). While there are already early warning systems in place in Zimbabwe, there is limited information about how wide of an audience these programs actually reach.

C.4 Weather Index-Based Insurance

Weather index-based insurance for crops and livestock would provide farmers who buy the insurance with a payment when, for example, rainfall goes below a certain threshold level in their area. This insurance could be purchased on a crop-by-crop basis and for individual types of livestock to allow farmers to insure crops that are most vulnerable to weather-related shocks. This type of insurance benefits farmers by allowing them to take risks and invest in more CSA practices, technological innovations, and improved livestock husbandry. However, this type of insurance requires an extensive and accurate weather monitoring network as well as a sufficiently strong legal and regulatory environment (CTCN 2017). Weather index-based insurance may be most suitable for Agro-ecological

Regions IV and V as they are most prone to drought conditions (CIAT World Bank 2017).

In Zimbabwe, weather index-based insurance has been piloted for smallholder farmers and is allocated funding in the ZAIP. One of the key goals of the ZAIP is to increase participation of farmers in domestic and export markets through efficient agricultural marketing and competitive agricultural production. The Zimbabwean government views crop and livestock insurance schemes as key to reaching this goal, although they do not specify weather index-based insurance as the only insurance method (GoZ 2013). However, weather index-based insurance has already been tested in Zimbabwe by EcoFarmer, a pilot program in micro-insurance (CIAT World Bank 2017). Overall, the adoption rate of micro-insurance remains low in Zimbabwe as most programs are in their pilot stage and many farmers are not yet familiar with weather index-based insurance.

C.5 Conservation Tillage

Zero tillage and minimum tillage practices involve disturbing the soil as little as possible during the planting process in order to reduce soil erosion and nutrient loss (CIAT World Bank 2017). When paired with crop rotation and mulching in a suite of Conservation Agriculture practices, minimum tillage can increase the productivity of water applied to the crops, thereby reducing crop failure. However, while zero or minimum tillage requires less fuel and labor over time, the upfront cost of no-till equipment for planting may be prohibitive for small farmers (CTCN 2017). Furthermore, benefits of no-till in terms of increased water retention by the soil and reduced costs may have a time lag of over a decade (Pannell et al 2014; Baudron et al. 2012).

Conservation Agriculture, including zero or minimum tillage, is a key part of the vision of the agricultural sector in Zimbabwe according to the ZAIP. The ZAIP allocates $1.5 million (USD 2013) a year to promoting Conservation Agriculture through extension services and advertising about the techniques (GoZ 2013). In Zimbabwe, zero or minimum tillage has already been adopted by some maize farmers, sorghum farmers, and groundnut and cotton producers (CIAT World Bank 2017). Overall, zero and minimum tillage practices have largely been taken up in Agro-ecological Regions III, IV, and V, largely due to provision of training and free or subsidized inputs (CIAT World Bank 2017).

C.6 Crop Rotation

Crop rotation is focused on switching the type of crops planted on a given area from year to year. Crop rotation often includes a nitrogen fixing crop (i.e. legumes) to improve soil quality. When paired with zero tillage and mulching as part of Conservation Agriculture practices, crop rotation can increase the productivity of water applied to crops (CTCN 2017). In the long run, crop rotation can lead to increased yield and reduced reliance on fertilizers, as well as contribute to mitigation of greenhouse gases with higher soil carbon retention.

Like conservation tillage, crop rotation is considered a part of Conservation Agriculture, and is a central part of the vision of the agricultural sector in Zimbabwe according to the ZAIP. Crop rotation has a less than 30% adoption rate among groundnut farmers, but a 30-60% adoption rate among soybean and wheat farmers. Overall, crop rotation practices have largely been taken up in Agro-ecological Regions III, IV, and V, mostly due to provision of training and free or subsidized inputs (CIAT World Bank 2017).

C.7 Heat- and Drought-Resistant Crops/Varieties/Hybrids

Plant breeding for drought tolerance has resulted in an increase in availability of better-suited hybrids for farmers (CTCN 2017). Adoption of improved varieties has been high, at rates of 60% or higher for wheat, sugarcane, and maize. Improved varieties of soybean have been adopted at similarly high rates in Region III, but remain below 30% in Region IV. Policy to recognize the rights of smallholder farmers to save, use, and exchange indigenous seeds and take into account the need for drought and heat tolerant seed varieties is currently being developed. Zimbabwe has access to funds for agricultural climate change adaptation projects to implement various CSA-related practices including drought and heat tolerant varieties and breeds through the Special Climate Change Fund (CIAT World Bank 2017). While stress-resilient crops are more likely to produce productive yields, successful seasons will also depend on implementation of other CSA options to reduce the impact of stressors such as drought, heat, and pests. Additionally, effective communication regarding best practices for use of new varieties of crops will be essential to ensure sustained adoption.

C.8 Agroforestry

In agroforestry, trees and forests are planted or cultivated on farms in an integrated system with more traditional agricultural crops. Agroforestry can increase the absorptive capacity of the soil and reduce soil erosion while increasing carbon sequestration in both the trees and the soil. Furthermore, agroforestry can provide non-timber forest products to help diversify landowner diets and income sources, while shielding humans and livestock from heavy rains, landslides, and floods. The main costs of agroforestry are the requisite planning to avoid competition between crops and trees, and acquiring trees to plant (CTCN 2017). Agroforestry has the potential to be paired with many types of crops as well as livestock production in Zimbabwe (CIAT World Bank 2017). For example, Zimbabwe could put more focus on perennial, multi-purpose non-deciduous species. Alley cropping these trees will also satisfy all the desirable properties mentioned here including improving soil fertility, and will provide fodder for livestock throughout the year.[13]

The ZAIP identifies agroforestry as a key intervention in order to attain agricultural sector objectives (GoZ 2013). Within the ZAIP, agroforestry currently falls under the pillar of improving agricultural research, dissemination, and adoption in Zimbabwe (GoZ 2013). The budget for the ZAIP allocates $480,000 (USD 2013) a year toward capacity building for extension services and farmers directly on agroforestry interventions (GoZ 2013). In addition, agroforestry is being promoted through national research stations, as they provide African acacia seedlings to farmers (CIAT World Bank 2017). At this time, there is limited information on the adoption rate of agroforestry in Zimbabwe; however, research from several countries including Zimbabwe suggests an adoption rate of up to 25% for retaining trees on farmland and 33.7% for mixed intercropping of trees (Mwase et al. 2015).

C.9 Livestock Management

Although livestock management can encompass a wide variety of practices, Zimbabwe's livestock management priorities include improving livestock husbandry, increasing livestock production, and diversifying livestock. For livestock, improving the quality of livestock feed and avoiding overstocking of livestock in one area can reduce methane emissions and improve livestock health and efficiency overall (CIAT World Bank 2017). Furthermore, diversifying livestock to include goats and sheep can offer farmers and ranchers security in case of livestock disease or adverse weather conditions (CIAT World Bank 2017). The main costs of improving livestock management are paying for improved livestock feed, investing in smaller livestock, and accessing information on livestock management (CTCN 2017).

[13] Comment received from Andrew Mutanga of Heifer International on November 7, 2018.

Livestock management is particularly applicable in Agro-ecological Regions IV and V of Zimbabwe, where conditions are better for livestock ranching than crop production, and drought and extreme heat are more common (CIAT World Bank 2017).

While the ZAIP focuses largely on improving livestock production, it does provide some support for CSA livestock management practices. Since livestock productivity is important in poverty reduction and livelihoods among smallholders in Regions IV and V in particular, the ZAIP focuses on ensuring and augmenting livestock yield (GoZ 2013). The ZAIP specifies increasing livestock production and strengthening rural livestock markets as key objectives (GoZ 2013). However, the budget includes funding for livestock marketing, subsidies or social assistance for livestock rearing inputs, and extension programs to improve livestock husbandry, with the goal of 50% farmers in Regions IV and V being trained by 2017 (GoZ 2013). However, improved feeding management and reduction in stock size has had a low adoption rate in Zimbabwe (less than 30%) (CIAT World Bank 2017). Other practices such as ultra high density grazing and selecting for veld productive genotypes is causing some disruptive thinking in the discourse.[14]

C.10 Intercropping

Intercropping is the practice of planting two or more crops in the same area, typically one of which is a leguminous or nitrogen-fixing crop. Intercropping is one of the most important CSA practices for female-headed households in Zimbabwe as it provides additional food security and is less risky than only planting one crop. Furthermore, intercropping increases water retention in the soil and can prevent crop loss by ensuring the other crops receive sufficient nitrogen (CTCN 2017). Unlike other CSA practices like drip irrigation and agroforestry, intercropping does not require as high of an upfront investment. However, intercropping has an opportunity cost associated with not growing maize or another more profitable crops in the areas where a legume is grown (CIAT World Bank 2017). Evidence suggests that intercropping maize with cowpea and pigeonpea can increase the profitability of the land overall (Rao and Mathuva 2000). Intercropping may be particularly applicable in Agro-ecological Regions III, IV and V of Zimbabwe, which face water shortages and greater likelihood of crop failure.

While the ZAIP does not focus explicitly on intercropping, it does emphasize ensuring food and nutrition security while increasing agricultural productivity. The ZAIP acknowledges the role of agricultural extension workers in helping train farmers to take up new agricultural practices. Through their efforts and other outreach campaigns, Zimbabwe hopes to have 70% of trained farmers adopting sustainable production practices, like intercropping, by 2017 (GoZ 2013). Intercropping in particular can provide the farmer with a supply of groundnuts for food security while increasing maize crop yield and maintaining soil health. Intercropping has been taken up in Regions III, IV, and V of Zimbabwe, with an adoption rate of less than 30% for small grains like sorghum and groundnut (CIAT World Bank 2017).

C.11 Information Communication Technology

Information Communication Technology (ICT) includes radio, TV, phones, and online communication. Information relevant to agriculture may include weather advisories and warnings, general meteorological data, and market prices (CTCN 2017). Expansion of access to ICT can supplement extension services and provide farmers with immediate and relevant information. ICT may also

[14] Comment received from Andrew Mutanga of Heifer International on November 7, 2018.

increase access to digital financial services, allowing previously un-served and low-income customers in remote locations to use more efficient and cheaper banking and payment tools (GoZ 2018a). Current adoption of ICT may be gendered, as adoption rates of ICT are lower in rural areas and for smallholder farmers, of which the majority are women and youths (GoZ 2018b, CTCN 2017). Increased access to ICT for women may help reduce gender differences in access to credit and agricultural inputs for CSA (CTCN 2017).

Currently, there are several information services available or in development for agriculture in Zimbabwe. Agricultural Technical and Extension Services are working to develop a short message service (SMS) platform to deliver information with ECONET Services through Ecofarmer. Additional services include e-Mkambo, the Zimbabwe Farmers' Union bulk SMS, emails, and newsletters (GoZ 2018b). While it is estimated that 94% of the population has access to a mobile phone, this estimate does not account for individuals with multiple phones (GoZ 2018b). Adoption of ICT will require further development of telecommunication networks; approximately 650 additional telecommunication towers are scheduled to be built in remote areas as some rural areas still do not have network access (GoZ 2018b).

Table C1. Initial Assessment of Potential of Various CSA Options

ADAPTATION MEASURES AND INVESTMENTS	MENTIONED IN DOCUMENT			CLIMATE SMARTNESS SCORE (If Available)					MITIGATION POTENTIAL	
	ZAIP	3rd National Communi-cation	CSA Profile	Maximum	Minimum	Average	Most Effective Crop & Locations	Least Effective Crop & Location	Mitigation Impact	Carbon Score
Irrigation systems: new, rehabilitated, or modernized	✓		✓	6.0	2.4	3.6	vegetables; Region IV &V	tobacco; Region III	Minimize CO_2 emissions from energy used for pumping while maintaining high yields and crop-residue production.	3.6
Water harvesting and efficiency improvements			✓						Carbon retention from increased yields and soil carbon	
Potholing (holes in the field where seed, fertilizer/ manure, lime ¾, and other inputs can be concentrated)			✓	5.7	5.7	5.7	small grains; Regions III, IV, V	small grains; Regions III, IV, V	Carbon retention from increased yields and soil carbon	
Education and training of farmers via extension services (new technology and knowledge-based farming practices)	✓									
National research and technology transfer through extension programs	✓									

ADAPTATION MEASURES AND INVESTMENTS	MENTIONED IN DOCUMENT CLIMATE SMARTNESS SCORE (If Available)			CLIMATE SMARTNESS SCORE (If Available)					MITIGATION POTENTIAL	
	ZAIP	3rd National Communi-cation	CSA Profile	Maximum	Minimum	Average	Most Effective Crop & Locations	Least Effective Crop & Location	Mitigation Impact	Carbon Score
Private enterprises, as well as public or cooperative organizations for farm inputs (e.g., seeds, machinery)	✓									
Strong linkages with local, national and international markets for agricultural goods	✓									
Estimates of future crop prices	✓									
Improve monitoring, communication and distribution of information (e.g., early warning system for weather events)	✓		✓							
Weather index based crop and livestock insurance			✓							
Locally relevant agricultural research in techniques and crop varieties	✓									
Change fallow and mulching practices to retain moisture and organic matter			✓	5.7	5.7	5.7	small grains; Regions III, IV, V	small grains; Regions III, IV, V	Increases carbon inputs to soil and promotes soil carbon sequestration; Reduces energy used in transportation; Reduces energy consumption for production of agrochemicals.	5
Conservation tillage	✓	✓	✓	6.0	2.7	3.6	maize; Mazome	groundnut; Regions IV & V	Minimizes the disturbance of soil and subsequent exposure of soil carbon to the air; Reduces soil decomposition and the release of CO_2 into the atmosphere; Reduces plant residue removed from soil thereby increasing carbon stored in soils; Reduces emissions from use of heavy machinery.	3.4

ADAPTATION MEASURES AND INVESTMENTS	MENTIONED IN DOCUMENT CLIMATE SMARTNESS SCORE (If Available)			CLIMATE SMARTNESS SCORE (If Available)					MITIGATION POTENTIAL	
	ZAIP	3rd National Communi-cation	CSA Profile	Maximum	Minimum	Average	Most Effective Crop & Locations	Least Effective Crop & Location	Mitigation Impact	Carbon Score
Crop rotation	✓		✓	1.6	1.6	1.6	groundnut; Regions IV & V	groundnut; Regions IV & V	Rotation species with high residue yields help retain nutrients in soil and reduces emissions of greenhouse gases by carbon fixing and reduced soil carbon losses. Also increase carbon inputs to soil and fosters soil carbon sequestration.	1.5
Heat- and drought-resistant crops/ varieties/hybrids			✓						Carbon retention from increased yields and soil carbon	
Strip cropping, contour ploughing and farming			✓	1.5	1.2	1.6	tobacco; Region II	tobacco; Region III	Increases carbon inputs to soil and fosters soil carbon sequestration.	
Switch to crops, varieties appropriate to temp, precipitation			✓							
Agroforestry	✓	✓	✓						increases above and below-ground carbon retention in trees	
Livestock management (including animal breed choice, heat tolerant, change shearing patterns, change breeding patterns)	✓		✓						Reduces CH_4 emissions.	
Match stocking densities to forage production			✓						Reduces CH_4 emissions by speeding digestive processes.	
Pasture management (rotational grazing, etc) and improvement		✓							Increases soil carbon retention and carbon retention in crops. Also reduces CH_4 emissions.	
Manure management		✓	✓	6.6	4.8	5.4	small grains; Regions III, IV, V	vegetables; Regions I & II	Reduces CH_4 and nitrous oxide emissions	4.7
Switching fodder type		✓	✓	7.7	7.7	7.7	cattle; Regions IV & V	cattle; Regions IV & V	Reduces CH_4 emissions	9
Use of improved varieties (pest-resistant)			✓	6.0	1.8	4.3	maize; Mazome	sugarcane; Regions IV & V		
Intercropping to maximize use of moisture	✓		✓	6.6	6.6	6.6	small grains; Regions III, IV, V	groundnut; Regions IV & V	Increases carbon inputs to soil and fosters soil carbon sequestration.	7

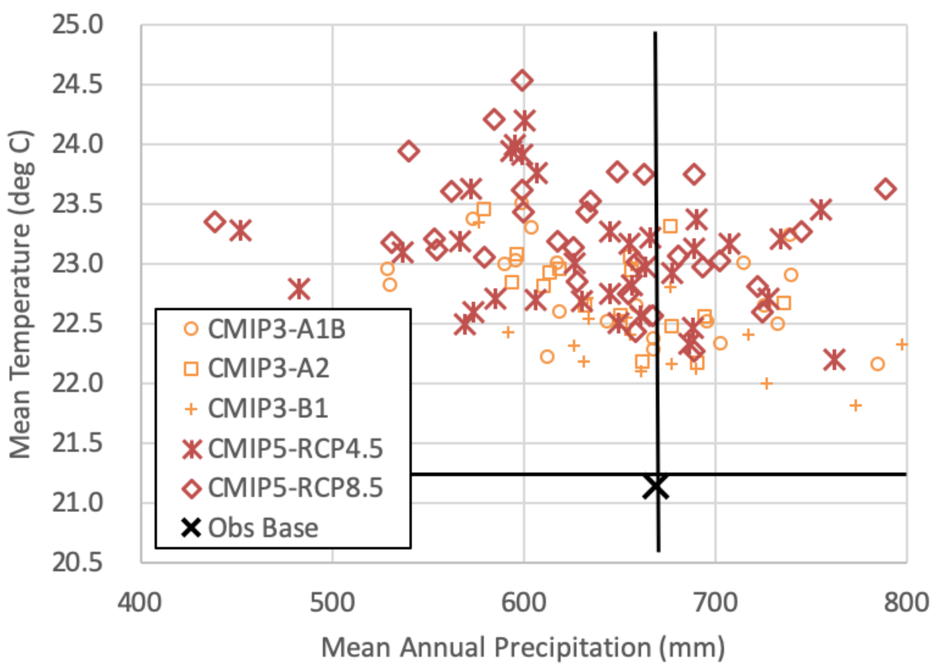
ADAPTATION MEASURES AND INVESTMENTS	MENTIONED IN DOCUMENT CLIMATE SMARTNESS SCORE (If Available)			CLIMATE SMARTNESS SCORE (If Available)					MITIGATION POTENTIAL	
	ZAIP	3rd National Communi-cation	CSA Profile	Maximum	Minimum	Average	Most Effective Crop & Locations	Least Effective Crop & Location	Mitigation Impact	Carbon Score
Use water-efficient crop varieties			✓						Minimize CO_2 emissions from energy used for pumping while maintaining high yields and crop-residue production.	
Physical infrastructure and logistical support for storing, transporting, and distributing farm outputs	✓									
Increase general education level of farmers	✓									

Appendix D: Incorporating Climate Change Uncertainty through Scenario Analysis

Key sources of uncertainty affecting the agricultural sector in Zimbabwe are population growth rate, developments in regional and international markets and how climate change unfolds. While the impacts of population growth and regional markets are assessed qualitatively in this work, the impact of climate change uncertainty is evaluated using scenario analysis. This appendix describes available sources of information used to characterize climate change uncertainty and the development of scenarios that were used to test the robustness of CSA to different future climatic conditions.

The scenario analysis relied on a set of climate change scenarios selected from the latest set of IPCC runs (Coupled Model Intercomparison Project (CMIP) phase 5 (CMIP5)). These selected climate scenarios were drawn from a much broader set of bias-corrected and spatially disaggregated climate runs developed in the Enhancing the Climate Resilience of Africa's Infrastructure (ECRAI) study. Figure D-1 presents the change in mean annual nationwide temperature and precipitation across the 121 ECRAI climate futures through the 2040s. These 121 climate futures include climate outputs from both the IPCC CMIP3 and CMIP5 archive (i.e., from the 2007 Fourth Assessment Report, and 2013 Fifth Assessment Report). The majority of climate futures agree on hotter and drier conditions in Zimbabwe by the middle of the 21st century. Of the ECRAI futures, 39 are available at a daily temporal resolution for the CMIP5 archive. These are 0.5-degree in spatial resolution with the historical period from 1950-1999, and projections through 2050.

Figure D1. **Change in Mean Annual Temperature and Precipitation in Zimbabwe from Base Year to 2040, across 121 Climate Futures**



In a prior study of the economic effects of climate change on Zimbabwe's agricultural sector to 2030 (Benitez et al. 2018), three possible representative climate futures were selected. These same climate scenarios are relevant to the current analysis and are thus also utilized in this study. These three climate futures span the range of possible climate conditions to evaluate the resilience of options to climate change in the agricultural sector. These selected climate futures are the driest, the wettest, and a medium case of the 39 model runs for Zimbabwe. These particular climate scenarios were selected to represent a range of potential 2021-2040 climates, jointly considering changes in temperature, precipitation, rainfed maize yield and irrigated sugar cane yield. It is inevitable that when selecting just 3 scenarios from this group of 39 possible model runs, some level of detail is lost. An additional climate path that generates weather patterns consistent with the historic record is also referenced in this study, in order to show the degree of change expected under the three different climate scenarios.

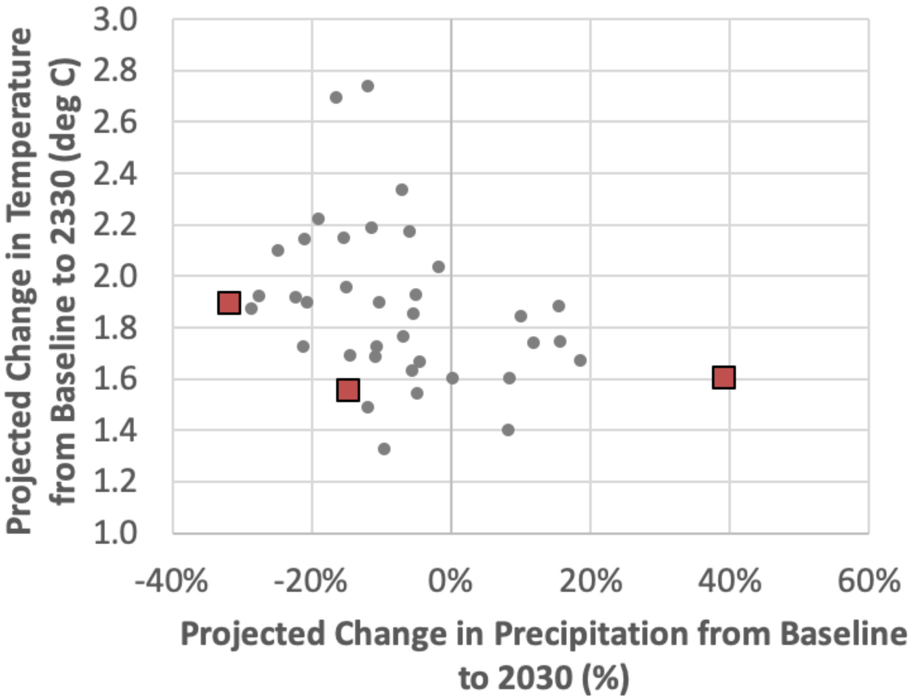
Table D-1 shows several characteristics of these three climate scenarios. Average projected changes in precipitation through the 2021-2040 period range from -32 to +39%, and average temperature increases range from 1.6°C to 1.9°C. These climate drivers affect maize yields significantly, with average changes from -64 to +43% predicted. Increased evapotranspiration cause sugarcane irrigation water requirements to rise between 10 and 19%. Additionally, Table D-1 also shows the specific climate model associated with each climate future.

Table D1. Characteristics of CMIP5 Climate Futures

GCM/RCP	2021-2040 Precipitation		2021-2040 Temperature		Maize Yield Dev (%)	Sugar Change in Irr (%)	Designation
	Mean Daily (mm)	Dev from Base	Mean (deg C)	Delta from Base			
MIROC-ESM_rcp85	1.246	-32%	23.38	1.90	-64%	19%	**Dry/Hot**
MIROC-ESM-CHEM_rcp45	1.560	-15%	23.05	1.56	-17%	10%	**Medium**
GFDL-ESM2G_rcp85	2.537	39%	23.09	1.61	43%	12%	**Wettest**

Figure D-2 shows projected changes in precipitation and temperature under the 39 different climate futures, with the three climate futures used in this study highlighted. As expected, the dry/hot and wettest futures show the most extreme drying and wetting trends over the period, whereas the medium future is near the center of the distribution.

Figure D2. Average Projected Changes in Precipitation and Temperature over Zimbabwe under the 39 CMIP5 Climate Futures, through the 2021-2040 Period



Appendix E: Modeling Framework

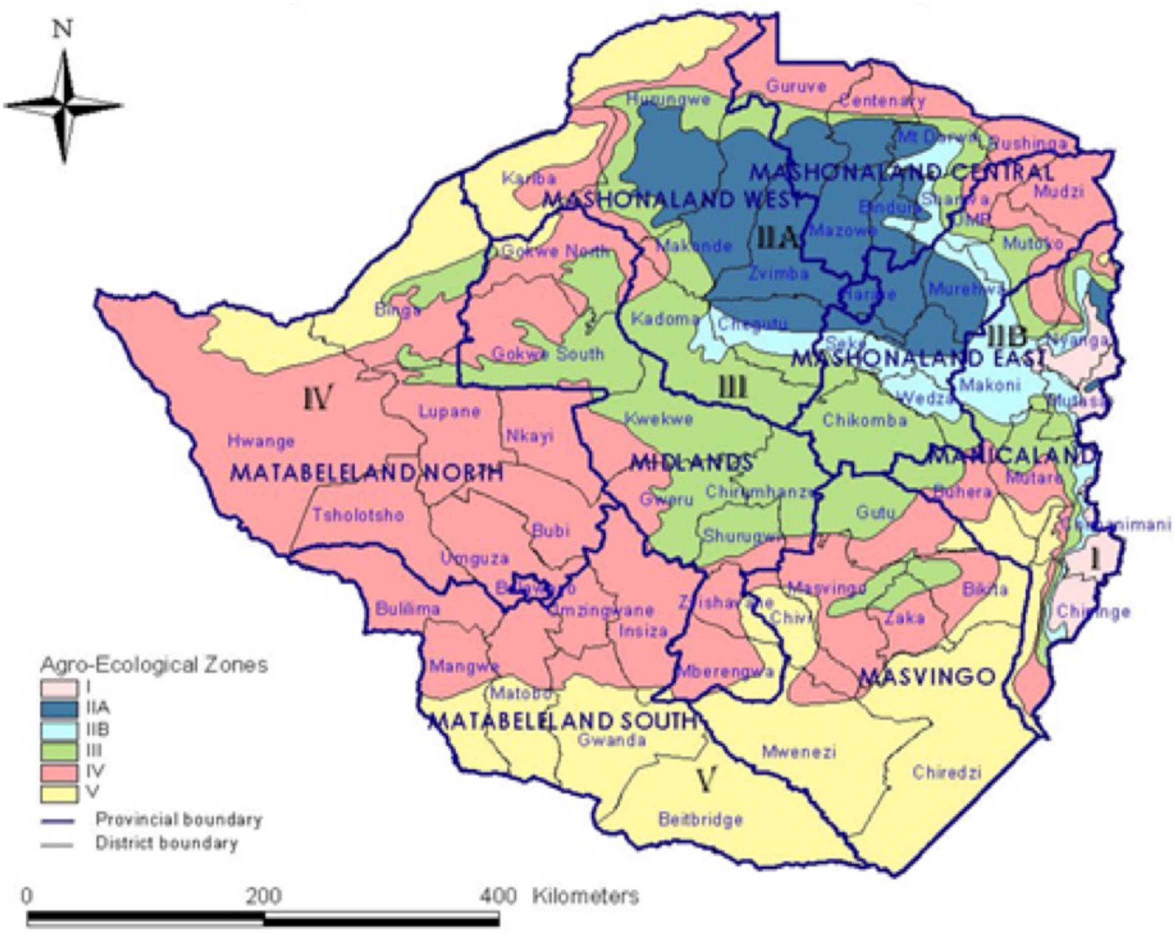
This study uses a combination of climate change, biophysical and economic models to assess the economic impact of climate change on the Zimbabwean agricultural sector, and the benefits of sets of different possible responses. Climate models are the first step in this modeling chain. Temperature and precipitation output from these climate models subsequently feed into a biophysical crop model (AquaCrop), crop suitability model, and livestock model, which produce crop and livestock yields and suitability metrics. These are then directed into engineering cost and greenhouse gas models, which collectively assess the impacts of climate change on the agricultural sector, and the benefits of a range of interventions during the period up to 2030. The results of these analyses suggest climate change will have significant economic impacts that can be partly offset by cost effective CSA responses. This appendix provides an overview of the analytical framework used for the study, while Appendix F provides more detailed descriptions of each modeling element, along with detailed results.

E.1 Spatial Scale of Models Used

The models used in this study are run at a number of different spatial scales. The climate models used in this study are drawn from the World Bank's ECRAI study that bias corrected and spatially downscaled 39 models for the African continent to a 0.5 degree spatial resolution. These models were from the latest IPCC effort (5th Assessment), and have a daily time step. AquaCrop was processed at the Agro-ecological Region level for engineering cost analysis of the impact of climate change and potential adaptation responses. The crop suitability model is at a 1km resolution, and the livestock model is at the national level.

Figure E-1 shows the different Agro-ecological Regions of Zimbabwe, and Table E-1 provides a breakdown of the total cropped area across the 13 crops analyzed in each of the five different agro-ecological regions and six different farm types (large scale commercial farms (LSCF), A1, A2, communal, small scale commercial (SSC), old resettlement), according to a ZimStat survey. The majority of LSCF areas are in Agro-ecological Regions II and V, with Agro-ecological Region II containing the highest area of A2 and A1 farms. Communal areas, which make up over half of the total number of farmed hectares, are most concentrated in Agro-ecological Region IV. Across crops, maize covers the highest total cultivated area at 1.25 million hectares (ha), followed by cotton (238,000 ha), groundnuts (183,000 ha), tobacco (118,000 ha), and sugarcane (53,000 ha). The remaining crops (soybeans, dry beans, sunflower, sweet potato, rice, potato, wheat, and barley) cover less than 50,000 ha each.

Figure E1: Zimbabwe's Agro-ecological Regions



Source: GoZ 2013

Table E1. Crop Area (ha) Grown in each Farm Type and Agro-ecological Region within Zimbabwe

Farm Type	AER 1	AER 2	AER 3	AER 4	AER 5	TOTAL
LSCF	1,069	21,845	2,441	3,656	37,018	66,028
A2	1,771	126,941	19,106	11,037	16,800	175,653
A1	11,814	128,008	66,862	62,708	69,806	339,196
Communal	11,948	205,852	225,190	502,430	195,130	1,140,550
SSC	1,159	15,374	17,831	14,592	773	49,728
Old Resettle	1,209	70,149	70,164	48,074	1,294	190,889
TOTAL	28,968	568,169	401,593	642,496	320,819	

Source: ZIMSTAT 2016

Key:
AER = Agro-ecological Region
LSCF = Large Scale Commercial Farms
A2 = Larger commercial holdings (20 to >120ha) (A1 and A2 were formerly LSCF prior to Fast Track Land Reform Program)
A1 = Smaller villagized holdings, (5-6ha cropping, 25 ha livestock)
Communal = Smallholder subsistence farms, generally of lower productivity
SSC = Small Scale Commercial operations
Old Resettle = Land acquired by government for resettlement between 1980 and mid-1990s

E.2 Modeling Tools and Inputs

This study employs a variety of methods to evaluate the performance of various CSA options across a number of uncertain futures. One tool utilized is a physically-based crop model to simulate a subset of the CSA options at the farm level for the five Agro-ecological Regions (shown in Figure E-1), six farm types (shown in Table E-1), and all crops appropriate for the intervention. Another is a screening-level crop suitability analysis that maps the potential future locations where crops will be suitable. Yet another tool used is a livestock model run at the national scale to evaluate the benefits of various management approaches. Using a simple economic model, various outcome indicators were derived, which support the final prioritization of options and the development of the investment plan.

Table E-2 provides average crop yields within each of the different farm types.[15] As expected, differences across farm type are quite significant. For example, maize yields are over 3 tons/ha on LSCF and closer to 0.5 tons/ha on communal lands. The pattern of declining yields from LSCF to A2 to A1 to communal is fairly consistent across the 13 crops examined.

Table E2. Average Crop Yields (tons/ha) within each Farm Type

Crop	Farm Type						Weighted Average
	LSCF	A2	A1	Communal	SSC	Old Resettle	
Maize	3.1	1.8	0.8	0.5	0.6	0.8	0.7
Tobacco	2.2	1.7	1.2	1.1	1.0	0.9	1.3
SugarCane	115.0	61.1	NA	NA	NA	NA	98.7
Soybean	2.3	1.4	1.0	0.5	0.3	0.6	1.3
Potato	12.9	7.4	4.1	3.6	0.7	2.4	6.0
Cotton	0.4	0.8	0.5	0.6	0.6	0.6	0.6
Wheat	2.2	NA	0.7	0.3	NA	0.3	1.7
Rice	NA	0.3	0.4	0.3	0.2	0.2	0.3
DryBean	0.8	0.5	0.4	0.4	0.3	0.3	0.4
Barley	8.2	NA	NA	NA	NA	NA	8.2
Sunflower	1.2	0.5	0.5	0.3	0.3	0.4	0.4
SweetPotato	2.2	1.7	3.4	2.8	1.0	2.8	2.7
Groundnut	0.6	0.7	0.3	0.3	0.4	0.4	0.3
Sorghum	0.6	1.2	0.2	0.2	0.2	0.3	0.2

Table E-3 presents the total crop areas and the breakdown between large scale and smallholder areas, where large scale includes the large scale commercial farm and A2 categories, and smallholder includes the remaining four categories of farm types. The last column compares yields between the two categories. For the majority of crops, smallholders comprise the larger share of the area planted, particularly following redistributive land reform, while large scale farms have yields between 50% and 200% higher than smallholder farms.

[15] Note that this list of crops does not include sorghum or millet, both of which are important for communal food production. This list of modeled crops was based on available data from ZIMSTAT.

Table E3. Crop Areas and Breakdown between Large Scale and Smallholder Farms

Crop	Total Crop Area (ha)	Share of Crop Area		Large scale : Smallholder Yield Ratio
		Large Scale	Smallholder	
Maize	1,246,444	8%	92%	3.27
Cotton	237,548	3%	97%	1.32
Groundnut	183,236	3%	97%	2.0
Tobacco	118,257	33%	67%	1.73
Sugarcane	52,952	100%	0%	NA
Soybean	47,277	59%	41%	1.96
Dry Bean	39,596	17%	83%	1.59
Sunflower	18,283	6%	94%	1.78
Sweet Potato	11,427	5%	95%	0.61
Rice	4,248	3%	97%	0.86
Potato	2,444	40%	60%	2.8
Wheat	279	74%	26%	6.6
Barley	56	100%	0%	NA

The analysis of economic impacts and adaptation benefits relies on projected time series of 2017 to 2030 crop prices. The starting prices in 2017 are drawn from available information on the latest crop prices in Zimbabwe. Prices in 2030 are drawn from forecasted world crop prices produced by the International Food Policy Research Institute, with prices rising between 10% and 40% from 2017 prices across crops. Table E-4 provides the prices per ton for the top crops by area in Zimbabwe. Maize prices were taken based on offers from the Grain Millers Association, which better reflect market conditions and international parity than the higher price set by the Zimbabwean government.

Table E4. Recent Indicative Producer Price/ton for Top Six Crops by Area in Zimbabwe

Crop	Price/ton	Year	Comments
Maize	$335	2016	Grain Millers Association price. Gov't price set at $390/ton.
Cotton	$550	2016	Government price.
Groundnut	$1,300	2014	
Tobacco	$5,840	2016	Price of cured tobacco. AquaCrop yields downward adjusted.
Sugarcane	$550	2016	Price of sugar. AquaCrop yields adjusted to sugar yields.[16]
Soybean	$600	2013	

Source:
Maize: http://www.herald.co.zw/millers-set-maize-price-at-335-per-ton/
Cotton: http://www.financialgazette.co.zw/zim-cotton-farmers-unlikely-to-benefit-from-rising-prices/
Groundnut: http://bulawayo24.com/index-id-news-sc-national-byo-49891.html
Tobacco: https://www.theindependent.co.zw/2017/04/07/slight-improvement-tobacco-prices/
Sugarcane: http://www.herald.co.zw/raw-sugar-producer-price-up-26-percent/
Soybean: http://www.financialgazette.co.zw/imports-affect-local-soya-bean-prices/

[16] Assumed 7.9 tons sugarcane convert to 1 ton sugar. (Thangavelu, 2004).

Appendix F: Details of Modeling Approach and Results

This appendix is complementary to Appendix E: Appendix E provided an overview of the analytical framework used for this study, while this appendix presents more detailed descriptions of each modeling element, along with detailed results.

F.1 Crop Suitability

The crop suitability analysis provides a starting point for the evaluation of CSA options with spatially resolved mapping and statistics of crop-specific preferences across Zimbabwe's landscape. The intention of this analysis is to highlight the crops and regions that are suitable or unsuitable for these crops given the soil, slope, and climate. Other important factors for farm location such as proximity to demand, crop prices, or access to roads for transportation are not considered in this analysis. Crop suitability provides the capability of the land and climate to support the crop without additional cost (e.g., irrigation systems, fertilizers, etc) to the farmer. However, in some cases, crops are not suitable without additional costs. This is especially true for certain cash crops in Zimbabwe. For example, sugarcane and tea grow throughout the year and typically would not survive the dry season without irrigation.

Model Details

To evaluate the suitability of crops across Zimbabwe, the parametric approach of Sys et al. (1993) was adopted, which uses a numerical rating of the different limitation levels of a location's characteristics. A location with an optimal characteristic is given a value of 100, while sub-optimal locations receive smaller values, with an unfavorable land characteristic a minimum of 0. A final continuous suitability rating is made by simply multiplying each characteristic, ranging from 0 to 100, as

$$\text{Suitability} = 100 * A/100 * B/100 * C/100$$

where A, B, C, etc. are location- and crop-specific indices such as precipitation or soil organic matter. The continuous suitability ranking is then broken into four broad suitability classes to derive a final suitability map for each crop: Not Suitable is the range 0 to 10; Marginally Suitable from 10 to 40; Moderately Suitable (40 to 80); and Very Suitable (80 to 100).

Model Implementation

Eleven crops were evaluated for Zimbabwe using this approach. These crops are shown in Table F-1, along with their respective growing season and climate preferences (i.e. temperature and precipitation).

Table F1. List of Crops and Climate Preferences

	Crops	Growing Season	Precipitation (mm/month)	Cold stress	Heat stress
Cereals	Maize	Nov-Apr	122	19	30
	Wheat	Nov-Mar	35	10	25
	Sorghum	April-Oct	83	18	35
Oilseeds	Cotton	Oct-Apr	114	22	0
	Groundnuts	Nov–Apr	78	14	34
	Soyabeans	Nov-Apr	62	18	35
	Sunflower	Nov-Feb	63	16	28
Export	Sugar Cane	All Year	153	20	35
	Tobacco	Sep-Mar	92	20	30
	Tea	All Year	92	15	26
Horticulture	Tomato	Aug-Jan	76	16	30
Pulse	Cowpea	Nov-Feb	72	18	32

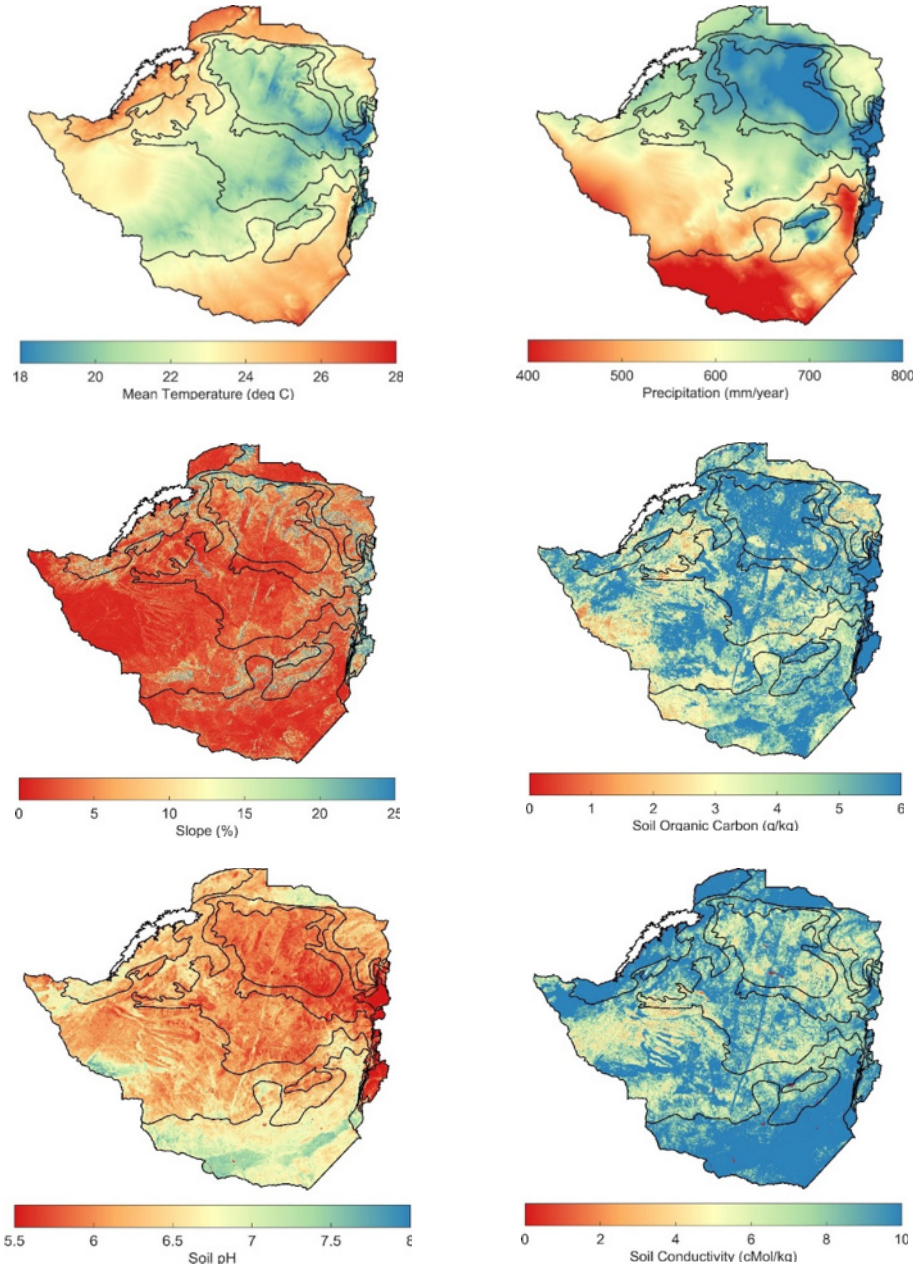
These eleven crops were compared on the basis of eleven different indices of suitability, shown in Table F-2 below. These suitability indices represent the characteristics of a farm, which are later compared to the crop preference (shown in Table F-1 above) to determine crop suitability for that farm. These specific indices were chosen to represent the most important factors that impact crop growth in Zimbabwe.

Table F2. List of Suitability Indices used for Zimbabwe

Index	Description
Precipitation	The location is penalized if the total precipitation during the crop's growing season is below the crop preference.
Cold stress	Using mean temperature over the growing season, the location is penalized for temperatures too cold given the crop preference.
Heat stress	Similar to cold stress, the location is penalized for temperatures too hot given the crop preference.
Slope	Using topography, the location is penalized for slopes that are too high.
Soil texture	Due to many factors including the ease of water movement in the root zone and root characteristics, crops prefer certain soil textures such as sand, clay, and silt content. The location is penalized for soil textures that are unsuitable.
Soil depth	Each crop has an ideal root depth when fully grown. If the soil depth is impeded because of bedrock, crop growth and, as a result, yield is often reduced due to lack of access to the required water and minerals.
Organic carbon	An import indicator of soil organic matter and is the basis for soil fertility. Low organic matter impacts the carbon cycle of the crop.
Soil pH – Acid	Crops have a preference for a particular soil pH. This index penalizes the land if the soil pH is too low (acidic).
Soil pH - Alkaline	Similarly, this index penalizes the location if the soil pH is too high (alkaline).
Soil conductivity	Each crop has an electrical conductivity preference and a location is penalized if the conductivity is not suitable.

To estimate values for these indices across Zimbabwe, high-resolution open-source global datasets were used. All soil data was sourced from soilGrids.org, which includes many soil-related parameters. For climate, monthly mean precipitation and temperature from worldclim.org were used. Figure F-1 shows these variables across Zimbabwe.

Figure F1. Maps of Six Climate and Land Parameters over Zimbabwe. (Note: climate shown is the average for Nov-April, the maize growing season)



Model Results - Maize

Maize is a warm weather crop and does not grow well in areas where the mean temperature during the growing season is below 18oC. Although the minimum temperature for germination is 10oC, germination is faster and less variable at soil temperatures of 16oC to 18oC. The chances of the maize crop being affected by soil water shortages are also high. Maize grows on a wide variety of soil types but deep, naturally rich and easily tilled moist soils are preferred. Maize production is highest when grown in fertile, friable, well-drained loam and silty loam soils. Tables F-3 and F-4 and Figures F-2 and F-3 summarize the results of the crop suitability analysis for maize in Zimbabwe.

Table F3. Maize Suitability in Zimbabwe across Indices (values in percent of total area)

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	2%	64%	24%	10%
Cold stress	94%	6%	1%	0%
Heat stress	100%	0%	0%	0%
Slope	83%	12%	4%	2%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	99%	1%	0%	0%
Soil pH - Alkaline	98%	2%	0%	0%
Soil conductivity	96%	3%	0%	1%
Suitability	0%	19%	66%	16%

Table F4. Maize Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	18%	49%	33%
Region II	0%	43%	52%	4%
Region III	0%	24%	72%	4%
Region IV	0%	13%	81%	7%
Region V	0%	9%	44%	48%
Total	0%	19%	66%	16%

Figure F2. Map of Maize Suitability in Zimbabwe

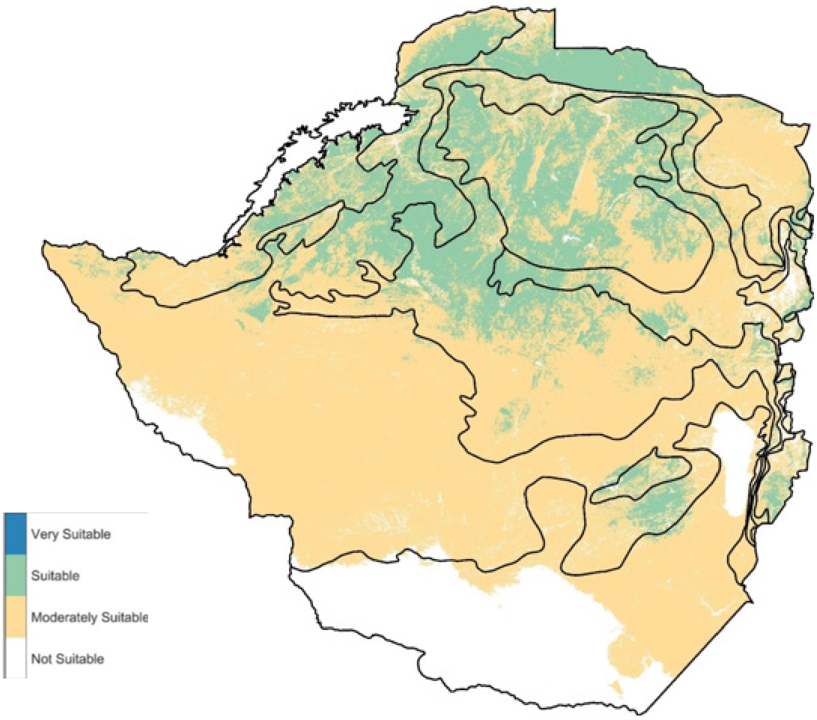
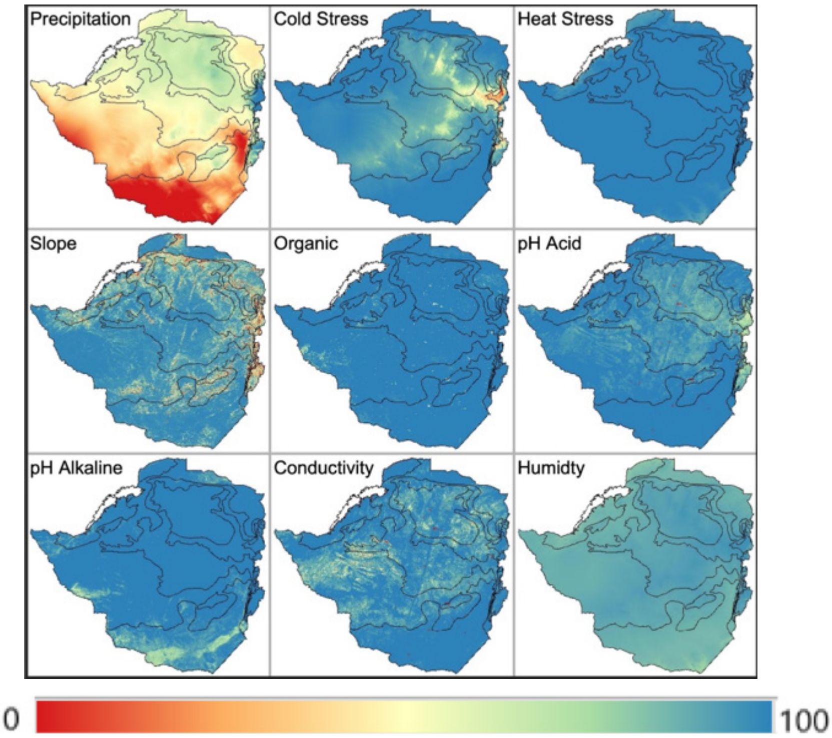


Figure F3. Map of Maize Suitability Indices



Having explored the suitability of different parts of Zimbabwe for growing maize, the same analysis is done for conditions altered by climate change impacts. To capture climate change impacts, a climate projection from MIROC-ESM with RCP 8.5 was used. The climate projected with this model is characterized as hot and dry over Zimbabwe. Under this projected hotter and drier climate, maize suitability declines substantially in the vast majority of Zimbabwe (see Figure F-4 and Table F-5). This reduced crop suitability is driven by the reduced precipitation experienced in this drier climate future. In small areas, where precipitation is less limiting, maize suitability increases because of a reduction in cold stress in the highlands and Agro-ecological Region I.

Figure F4. Map of Maize Suitability Change for a Hotter and Drier Future Climate

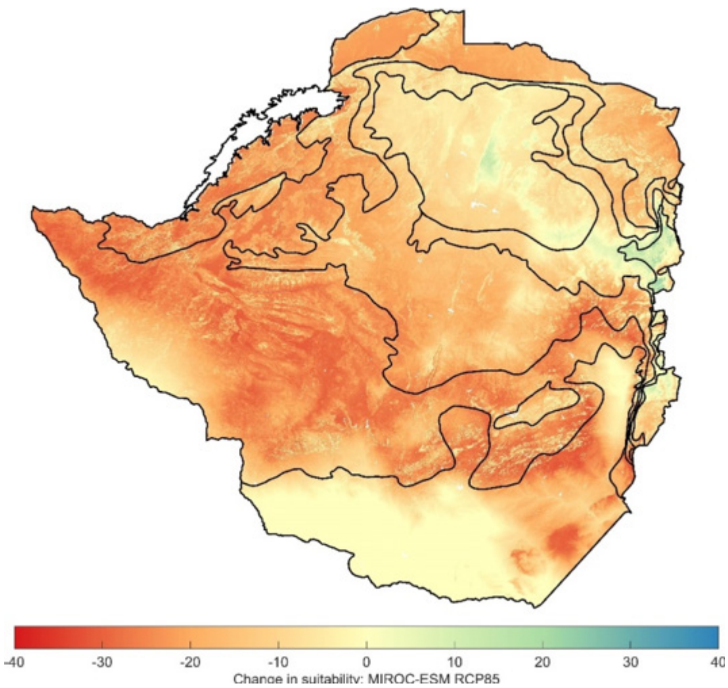


Table F5. Change in Maize Suitability for a Hotter and Drier Future Climate (values in change in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	-10%	20%	-10%
Region II	0%	-32%	32%	0%
Region III	0%	-24%	12%	12%
Region IV	0%	-13%	-51%	63%
Region V	0%	-9%	-27%	36%
Total	0%	-17%	-19%	36%

Model Results - Sorghum

Small grains such as sorghum or millet may offer an alternative to maize that is more climate resilient to current droughts as well as more extreme conditions under climate change. Sorghum requires less water and has less of an impact on soil fertility in the long-term than maize.

Table F6. Sorghum Suitability in Zimbabwe across Indices (values in percent of total area)

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	70%	30%	0%	0%
Cold stress	91%	9%	0%	0%
Heat stress	100%	0%	0%	0%
Slope	82%	14%	0%	4%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	100%	0%	0%	0%
Soil pH - Alkaline	100%	0%	0%	0%
Soil conductivity	99%	1%	0%	0%
Suitability	13%	79%	4%	4%

Table F7. Sorghum Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	1%	39%	33%	27%
Region II	11%	79%	5%	5%
Region III	13%	80%	3%	5%
Region IV	15%	80%	2%	3%
Region V	13%	80%	5%	2%
Total	13%	79%	4%	4%

Figure F5. Map of Sorghum Suitability in Zimbabwe

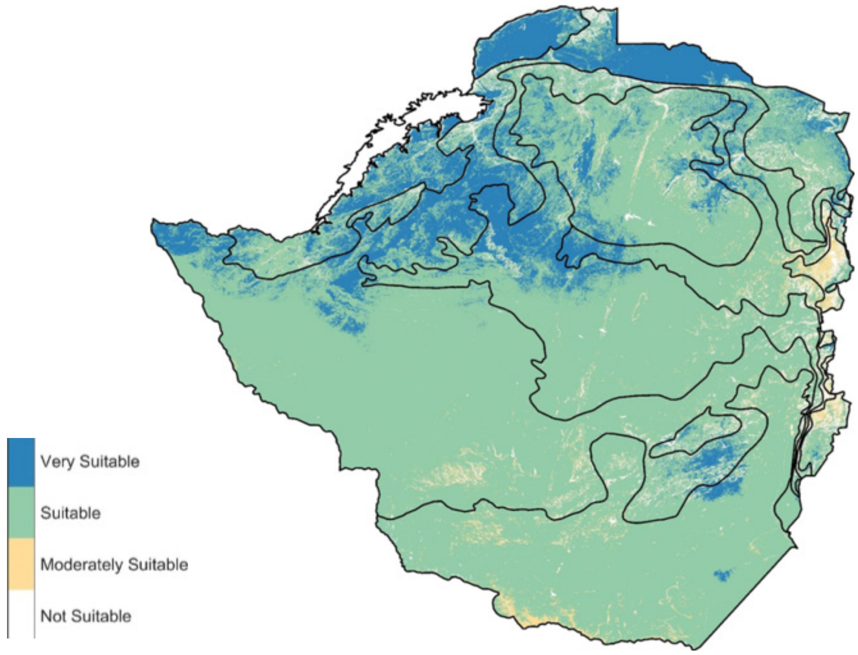


Figure F6. Map of Sorghum Suitability Indices

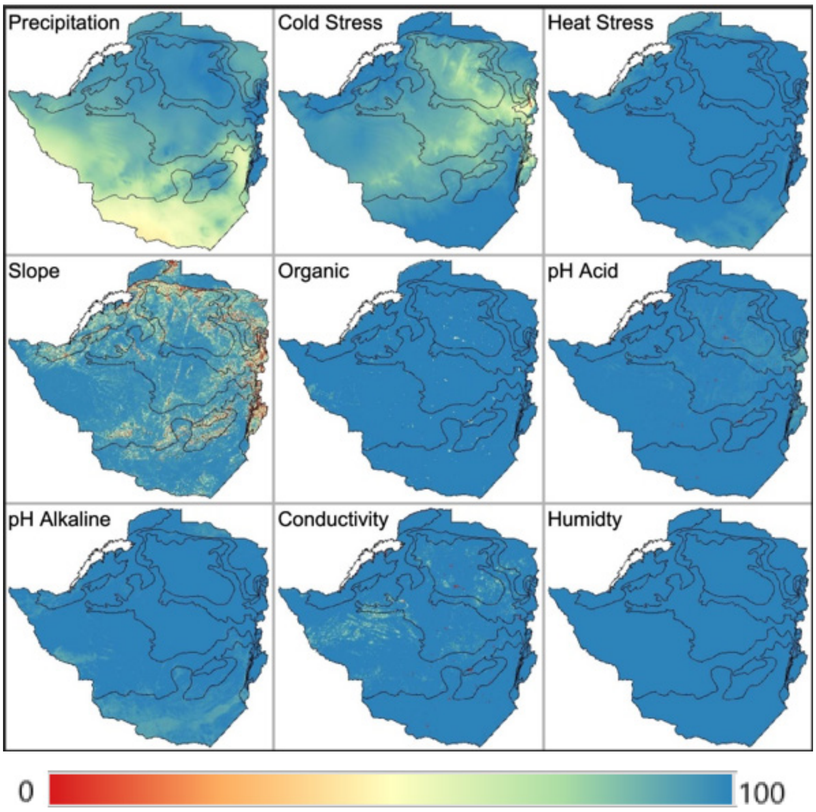


Figure F7. Map of Sorghum Suitability Change for a Hotter and Drier Future Climate

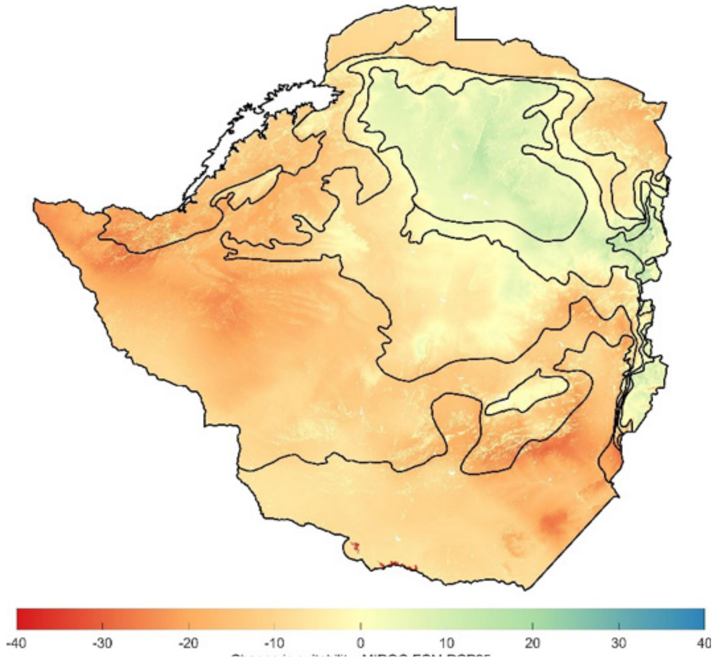


Table F8. Change in Sorghum Suitability for a Hotter and Drier Future Climate (values in change in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	-10%	20%	-10%
Region II	0%	-32%	32%	0%
Region III	0%	-24%	12%	12%
Region IV	0%	-13%	-51%	63%
Region V	0%	-9%	-27%	36%
Total	0%	-17%	-19%	36%

Model Results - Cotton

Table F9. Cotton Suitability in Zimbabwe across Indices (values in percent of total area)

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	2%	51%	0%	46%
Cold stress	36%	57%	4%	3%
Heat stress	100%	0%	0%	0%
Slope	82%	14%	0%	4%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	99%	1%	0%	0%
Soil pH - Alkaline	100%	0%	0%	0%
Soil conductivity	99%	1%	0%	0%
Suitability	0%	7%	40%	53%

Table F10. Cotton Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	3%	35%	62%
Region II	0%	1%	79%	20%
Region III	0%	4%	81%	14%
Region IV	0%	9%	24%	67%
Region V	0%	11%	8%	81%
Total	0%	7%	40%	53%

Figure F8. Map of Cotton Suitability in Zimbabwe

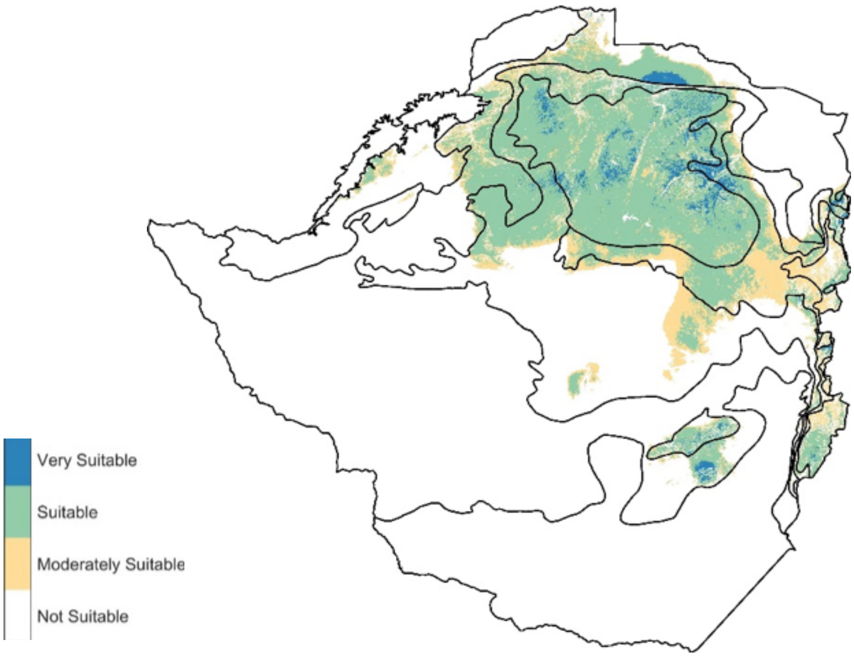


Figure F9. Map of Cotton Suitability Indices

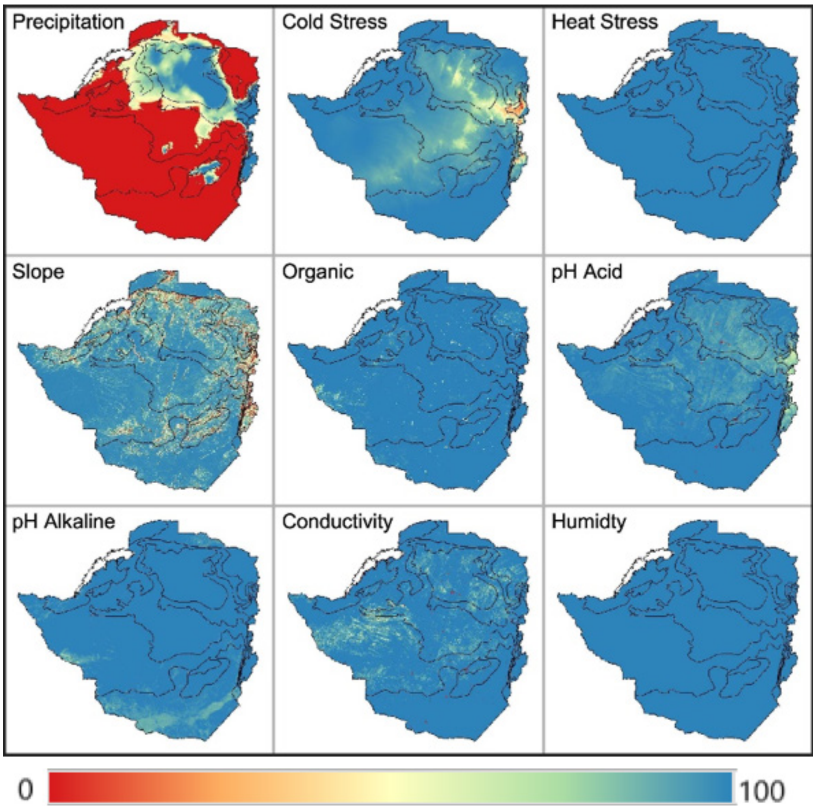


Figure F10. Map of Cotton Suitability Change for a Hotter and Drier Future Climate

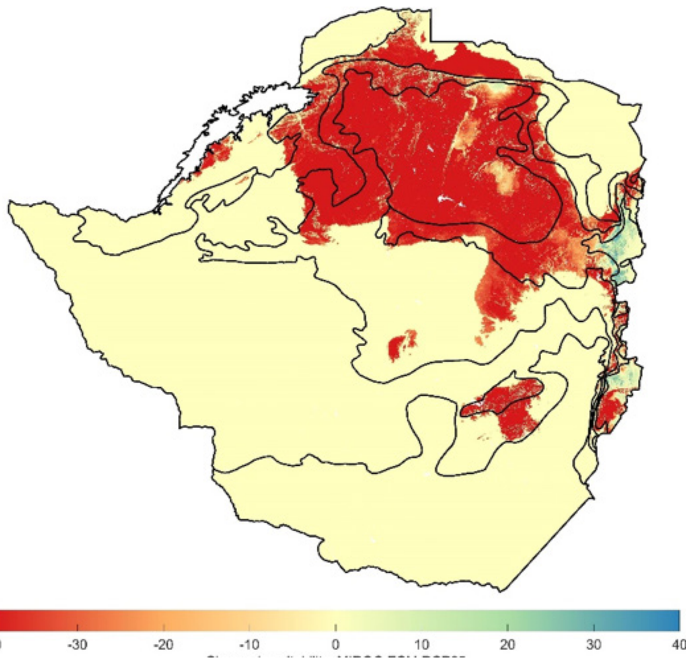


Table F11. Change in Cotton Suitability for a Hotter and Drier Future Climate (values in change in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	-10%	20%	-10%
Region II	0%	-32%	32%	0%
Region III	0%	-24%	12%	12%
Region IV	0%	-13%	-51%	63%
Region V	0%	-9%	-27%	36%
Total	0%	-17%	-19%	36%

Model Results - Groundnuts

Table F12. Groundnut Suitability in Zimbabwe across Indices (values in percent of total area

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	60%	39%	0%	1%
Cold stress	100%	0%	0%	0%
Heat stress	100%	0%	0%	0%
Slope	82%	14%	0%	4%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	99%	1%	0%	0%
Soil pH - Alkaline	100%	0%	0%	0%
Soil conductivity	99%	0%	0%	0%
Suitability	10%	80%	5%	4%

Table F13. Soyabean Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	42%	31%	26%
Region II	10%	82%	4%	5%
Region III	11%	82%	3%	4%
Region IV	11%	83%	3%	3%
Region V	8%	76%	11%	5%
Total	10%	80%	5%	4%

Figure F11. Map of Groundnut Suitability in Zimbabwe

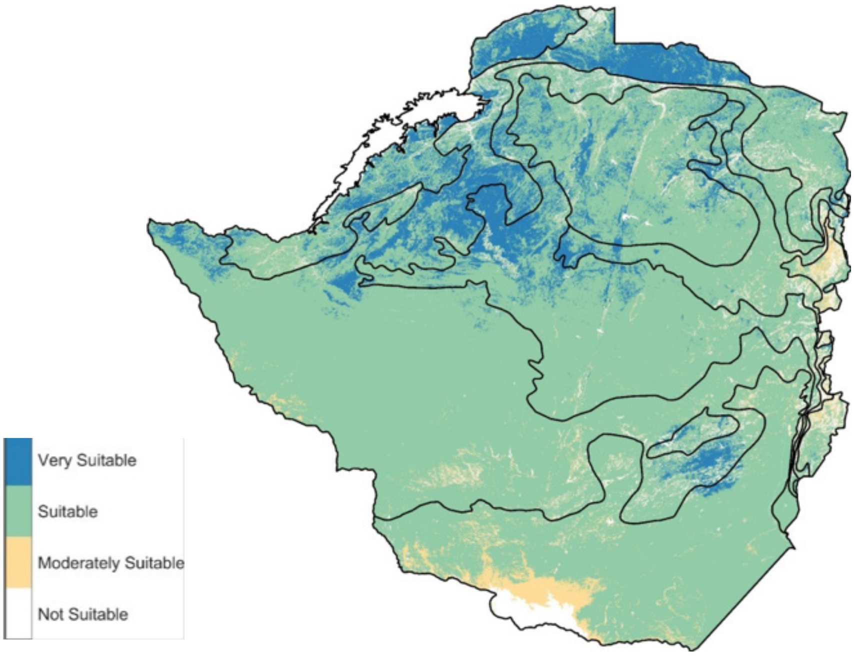
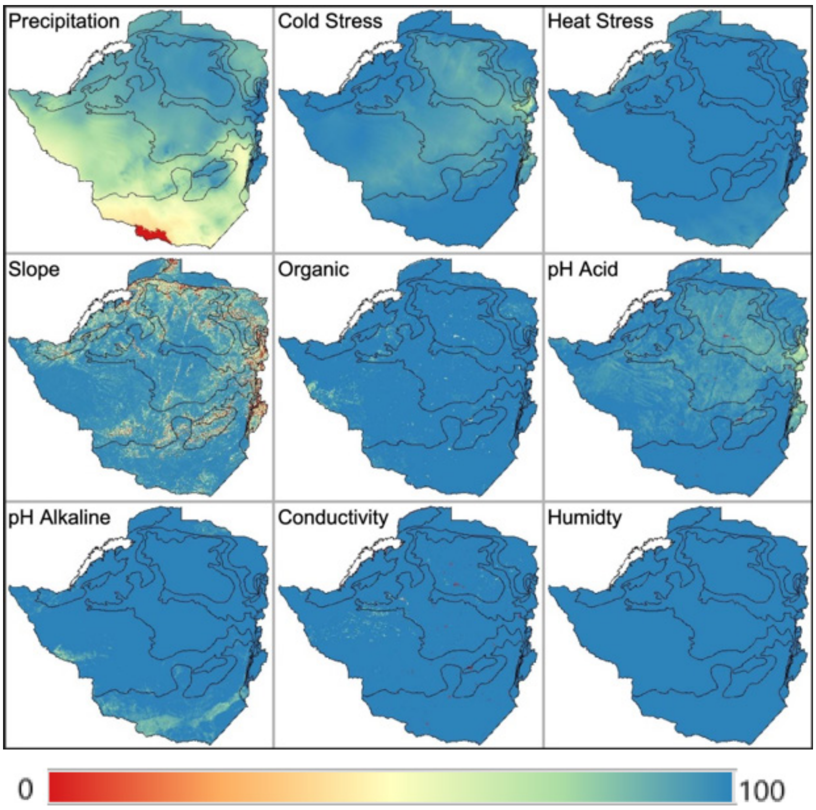


Figure F12. Map of Groundnut Suitability Indices



Model Results - Soyabeans

Table F14. Soyabean Suitability in Zimbabwe across Indices (values in percent of total area)

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	95%	5%	0%	0%
Cold stress	97%	2%	0%	0%
Heat stress	100%	0%	0%	0%
Slope	82%	14%	0%	4%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	100%	0%	0%	0%
Soil pH - Alkaline	100%	0%	0%	0%
Soil conductivity	99%	1%	0%	1%
Suitability	45%	49%	2%	4%

Table F15. Soyabean Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	3%	40%	31%	27%
Region II	35%	57%	3%	5%
Region III	51%	43%	1%	5%
Region IV	60%	36%	1%	3%
Region V	23%	73%	2%	2%
Total	45%	49%	2%	4%

Figure F13. Map of Soybean Suitability in Zimbabwe

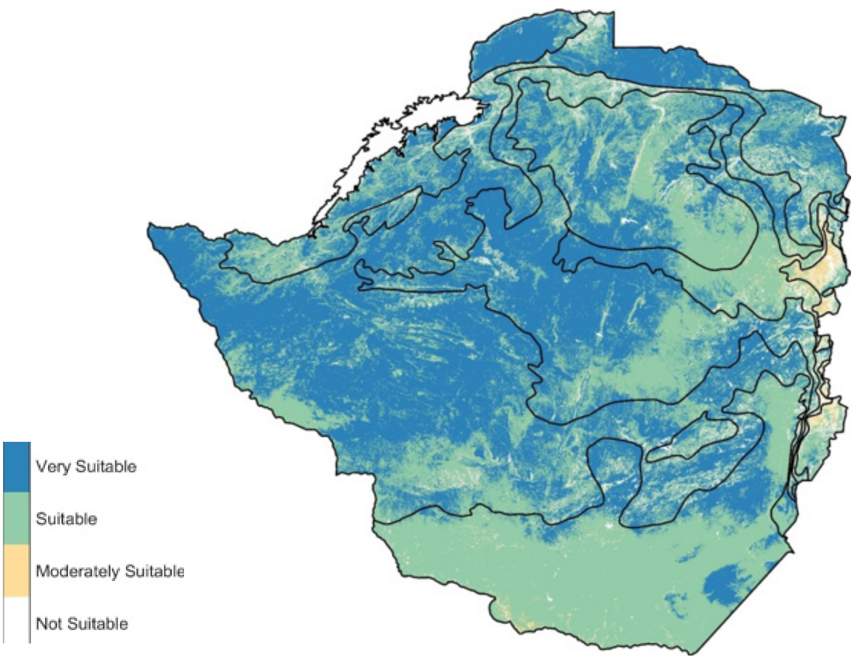
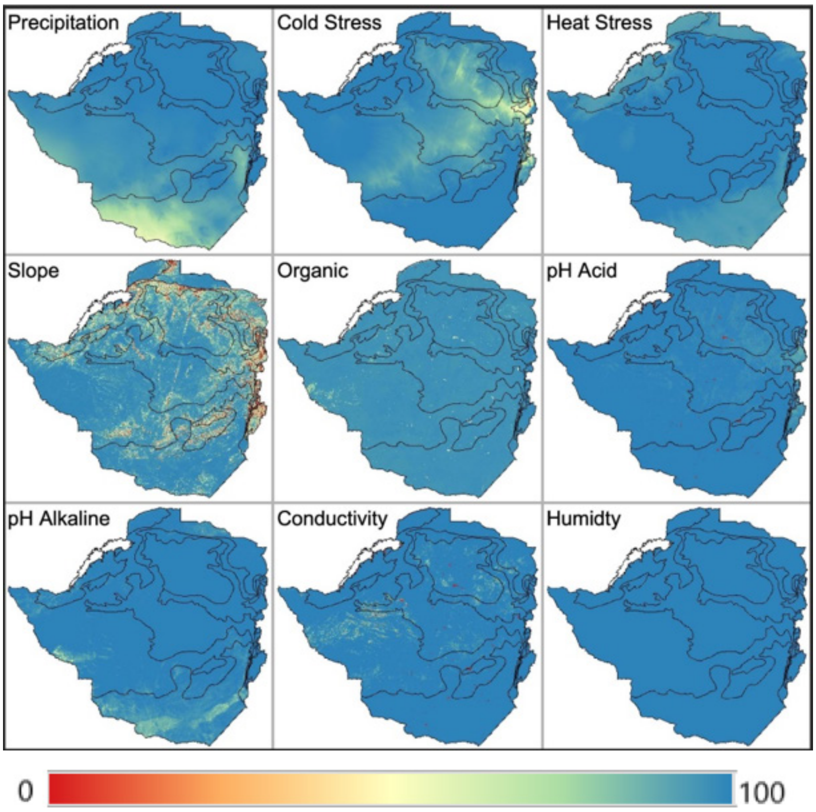


Figure F14. Map of Soyabean Suitability Indices



Model Results - Tobacco

Table F16. Tobacco Suitability in Zimbabwe across Indices (values in percent of total area)

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	17%	63%	12%	7%
Cold stress	70%	30%	0%	0%
Heat stress	100%	0%	0%	0%
Slope	82%	14%	0%	3%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	100%	0%	0%	0%
Soil pH - Alkaline	100%	0%	0%	0%
Soil conductivity	99%	1%	0%	1%
Suitability	0%	49%	39%	11%

Table F17. Tobacco Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	**40-80**	**10-40**	**0-10**
Region I	1%	25%	49%	25%
Region II	0%	78%	17%	4%
Region III	0%	66%	29%	4%
Region IV	0%	45%	52%	3%
Region V	0%	26%	40%	34%
Total	0%	49%	39%	11%

Figure F15. Map of Tobacco Suitability in Zimbabwe

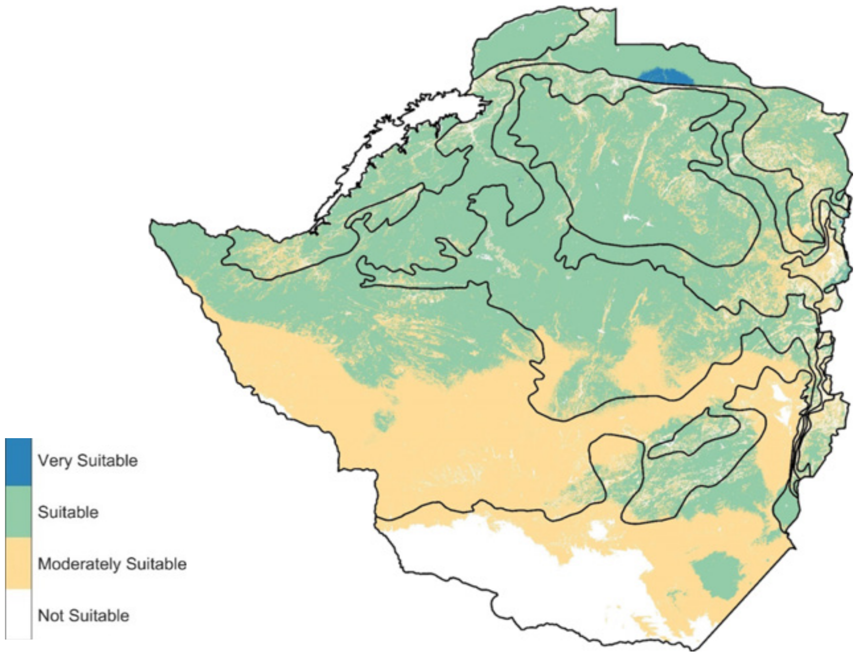
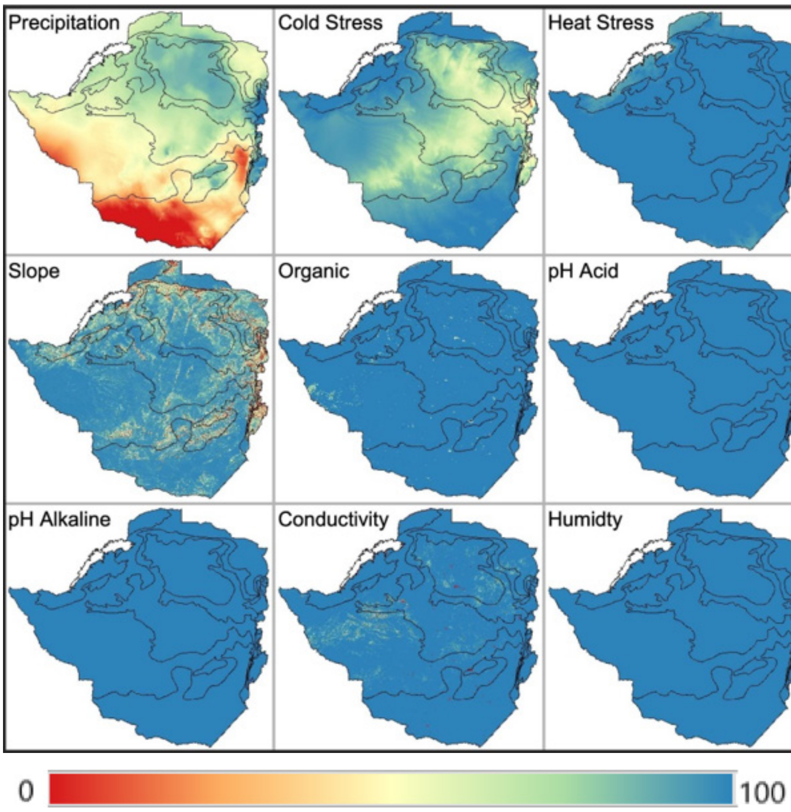


Figure F16. Map of Tobacco Suitability Indices



Model Results - Tomato

Table F18. Tomato Suitability in Zimbabwe across Indices (values in percent of total area)

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	2%	87%	0%	10%
Cold stress	99%	1%	0%	0%
Heat stress	100%	0%	0%	0%
Slope	82%	14%	0%	4%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	99%	0%	0%	0%
Soil pH - Alkaline	100%	0%	0%	0%
Soil conductivity	99%	1%	0%	1%
Suitability	0%	68%	18%	14%

Table F19. Tomato Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	1%	31%	42%	26%
Region II	0%	84%	11%	5%
Region III	0%	84%	11%	5%
Region IV	0%	76%	19%	6%
Region V	0%	32%	27%	41%
Total	0%	68%	18%	14%

Figure F17. Map of Tomato Suitability in Zimbabwe

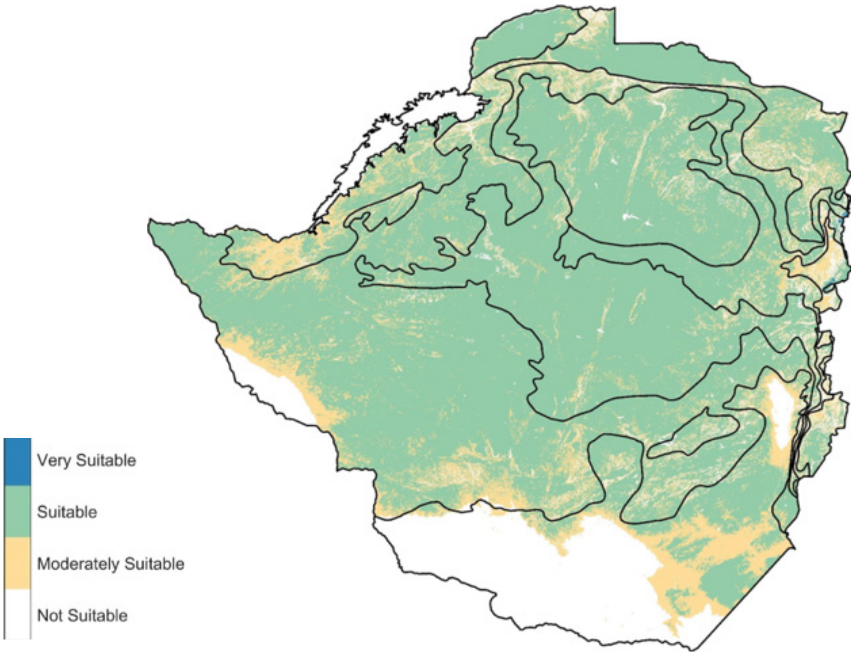
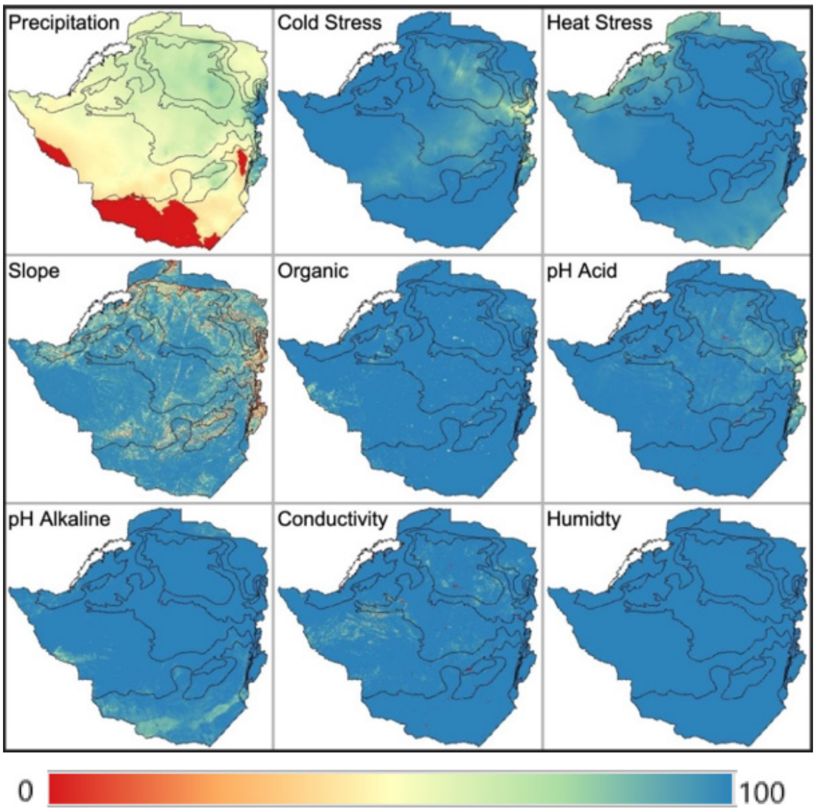


Figure F18. Map of Tobacco Suitability Indices



Model Results - Cowpea

Cowpea is a drought-resistant pulse or legume. While currently not a major crop in Zimbabwe, it may prove to be a more climate-resilient alternative than some existing crops.

Table F20. Cowpea Suitability in Zimbabwe across Indices (values in percent of total area)

Index	Very Suitable	Suitable	Marginally Suitable	Not Suitable
Rating Scale	80-100	40-80	10-40	0-10
Precipitation	94%	6%	0%	0%
Cold stress	97%	2%	0%	0%
Heat stress	100%	0%	0%	0%
Slope	73%	20%	0%	7%
Soil depth	100%	0%	0%	0%
Organic carbon	100%	0%	0%	0%
Soil pH - Acid	100%	0%	0%	0%
Soil pH - Alkaline	85%	14%	0%	0%
Soil conductivity	100%	0%	0%	0%
Suitability	99%	0%	0%	0%

Table F21. Cowpea Suitability in Zimbabwe across Agro-ecological Regions (values in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	11%	39%	50%
Region II	4%	75%	12%	9%
Region III	18%	69%	5%	9%
Region IV	38%	55%	2%	6%
Region V	27%	64%	5%	4%
Total	26%	62%	5%	7%

Figure F19. Map of Cowpea Suitability in Zimbabwe

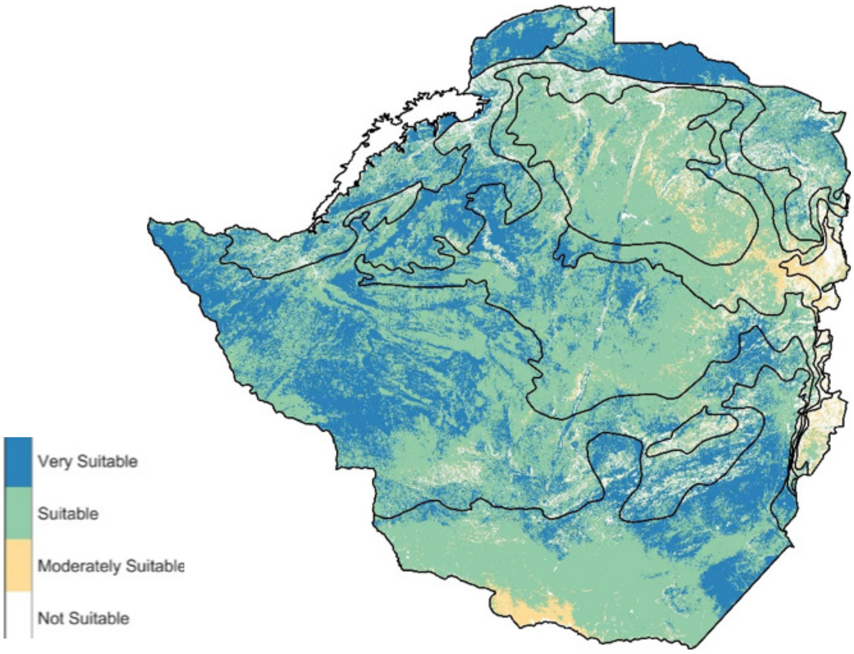


Figure F20. Map of Cowpea Suitability Indices

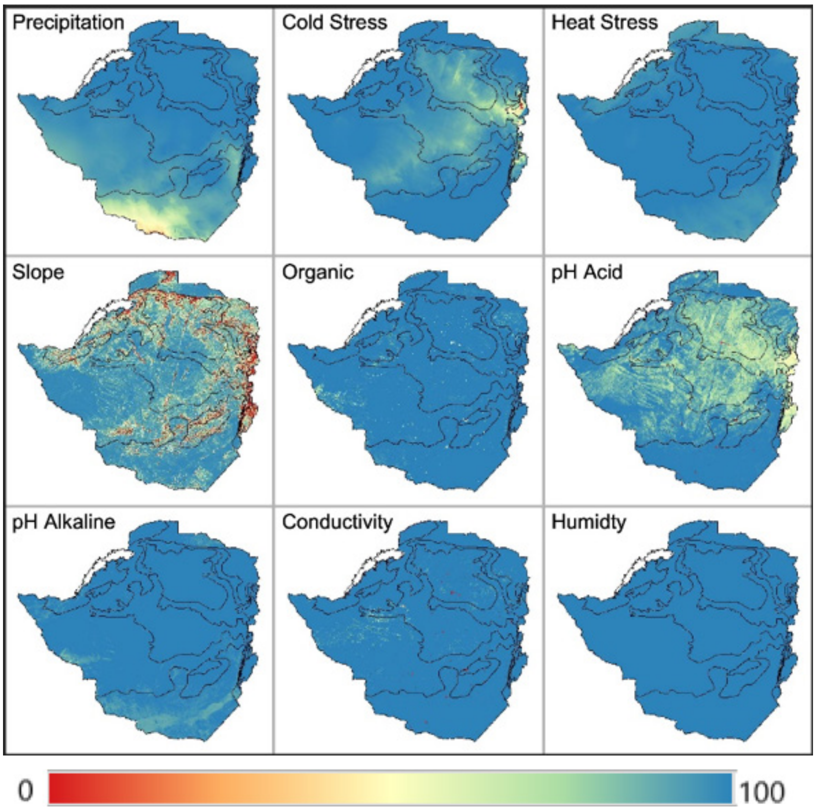


Figure F21. Map of Cowpea Suitability Change for a Hotter and Drier Future Climate

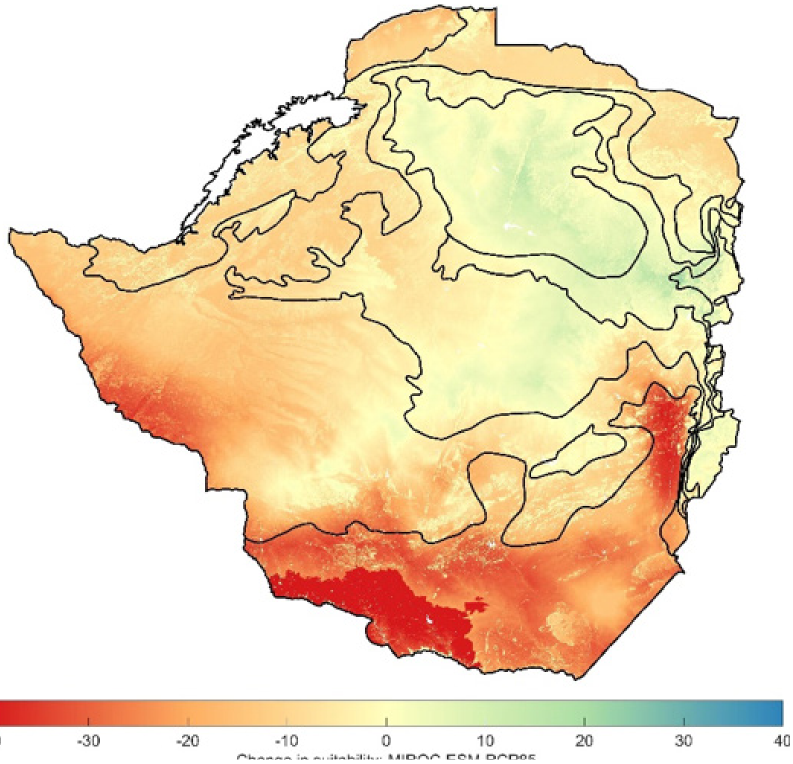


Table F22. Change in Cowpea Suitability for a Hotter and Drier Future Climate (values in change in percent of total area)

	Very Suitable	Suitable	Marginally Suitable	Not Suitable
	80-100	40-80	10-40	0-10
Region I	0%	4%	-2%	-2%
Region II	2%	2%	-4%	0%
Region III	-8%	7%	1%	0%
Region IV	-34%	31%	3%	0%
Region V	-27%	1%	13%	13%
Total	-21%	15%	4%	3%

Model Results - Summary

Table F23. Mean Suitability across Zimbabwe by Crop for Current Climate; and changes in Suitability under a Hot and Dry Future Climate Scenario

Main National Objective(s) for this Group of Crops	Crops		Current (out of 100)	Change By 2050*
Food security and nutrition and foreign currency savings (wheat)	Cereals	Maize	27	-55%
		Wheat**	79	-10%
		Sorghum	63	-13%
Foreign currency savings through import substitution and value addition/ industrialisation resulting in employment creation	Oilseeds	Cotton	13	-92%
		Groundnuts	62	-24%
		Soyabeans	72	-11%
		Sunflower	82	-27%
Foreign currency earnings and employment creation	Export	Sugarcane**	52	40%
		Tobacco	38	-45%
		Tea**	16	1%
Nutrition and foreign currency earnings	Horticultural	Tomato	40	-59%
Food security and nutrition	Pulses	Cowpea	64	-15%

* Changes based on a hot and dry climate future

** Irrigated (stress from insufficient precipitation is ignored)

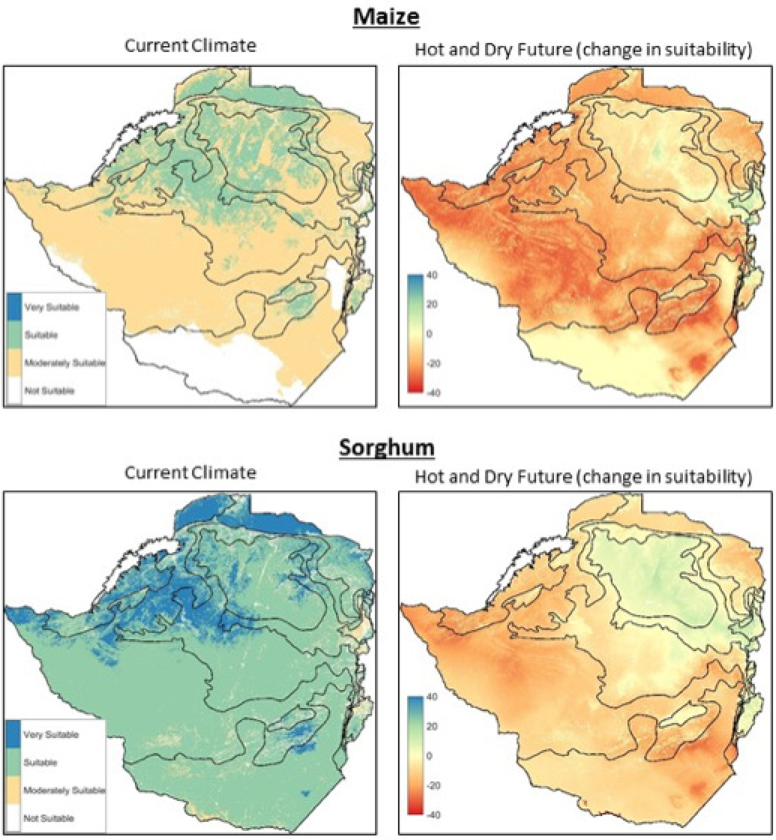
Table F-23 shows the results for each of the 12 crops analyzed, indicating both the mean suitability for each crop, as well as the change in the mean suitability under a hotter and drier future climate scenario. Among the 12 crops examined, only wheat, sugarcane, and tea are irrigated, meaning that precipitation stress is ignored for these crops. However, under dry conditions these crops may require more water than is available, which is not taken into account here.

Ten of the 12 crops examined show decreases in suitability under a hotter and drier future, with sugarcane and tea (only slightly) the exceptions. Under present conditions, sugarcane shows relatively low suitability, primarily due to cold stress; hence, the suitability of sugarcane increases under a hotter and drier future climate. However, sugarcane requires a substantial amount of irrigation during the dry season so it is likely that additional irrigation infrastructure (or rehabilitation of existing infrastructure) and water harvesting would be required to take advantage of this potentially higher suitability in the future.

Of the oilseeds, sunflowers show the highest suitability across Zimbabwe with an average suitability score of 82. However, under hot and dry future conditions, soyabeans indicate a lower reduction in suitability, making this crop more climate resilient (in fact the most climate resilient of all the rainfed crops examined). Maize, tomatoes, and tobacco are the least resilient to a hot and dry future because these are more reliant on precipitation during the growing season.

From a food security perspective, the analysis then looked in more detail at the results for two of the crops evaluated (maize and sorghum). It was found that under current climate conditions, maize is moderately suitable in Regions I, II, and III but is less suitable in the drier regions (Regions IV and V), as shown in top left chart of Figure F-22. The main driver for the observed spatial differences in suitability across Zimbabwe is precipitation, followed by slope and cold stress. Sorghum, on the other hand, shows higher suitability across the country under present climate conditions, as it requires less precipitation than maize.

Figure F22. Suitability of Maize and Sorghum under Current Climate and the Changes in Suitability under a Hot and Dry Climate Future



Next, these same two crops were evaluated for their resilience under poor climatic conditions by calculating the effects of a hot and dry future climate. For maize, suitability reduces significantly, especially in Regions III and IV. Regions I and II show less reduction in suitability as a result of a hotter and drier future climate. While precipitation is projected to decrease in Regions I and II, maize prefers warmer temperatures, with only a small resultant change to suitability. Sorghum shows a similar response to the hot and dry climate in terms of the pattern across the landscape but shows a noticeably higher resilience than maize to the hotter and drier future conditions. Thus, switching away from maize toward smaller grains such as sorghum is shown to be favorable from the perspective of crop suitability under an altered future climate. However, other aspects of the value chain (such as processing, demand, or subsidies) may need to change before it would be profitable to switch away from maize.

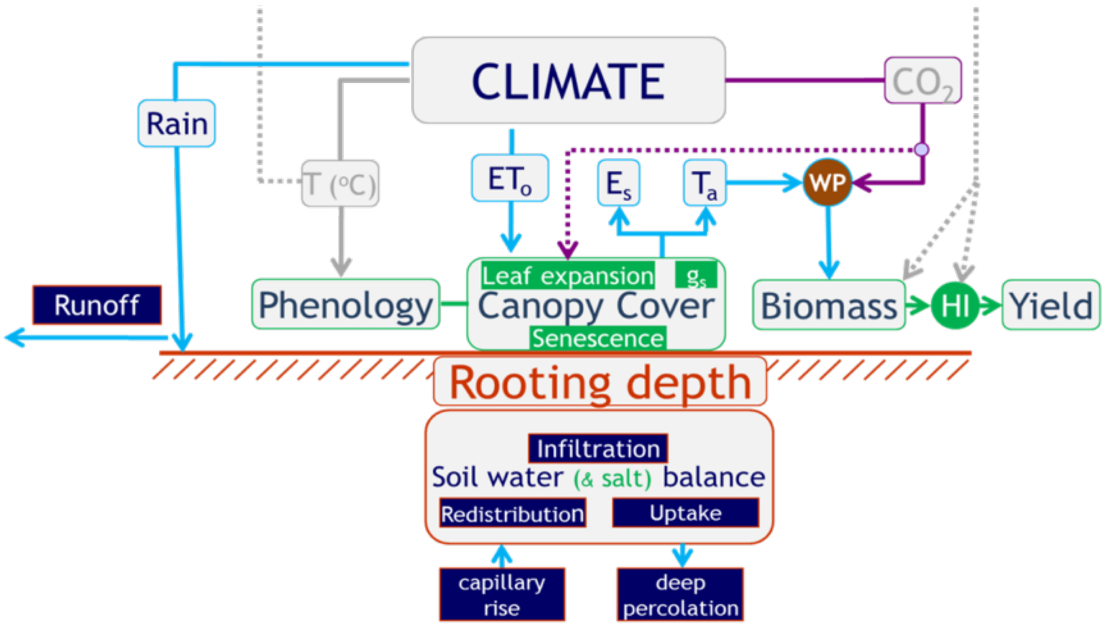
F.2 Crop Modeling (AquaCrop)

This portion of the analysis relied on the AquaCrop model to evaluate the impacts of climate change and adaptation measures on crop yields across Zimbabwe. AquaCrop is a "water-driven" crop model developed by the Food and Agriculture Organization of the United Nations. AquaCrop has previously been compared to both field measurements (Heng et al. 2009; Steduto 2011; Abedinpour et al. 2012; Stricevic et al. 2011) and to other crop models (Todorovic et al. 2009). Despite the simple structure and limited input requirements, AquaCrop performs well within the margin of error of other, often more complex, crop models. In addition, AquaCrop is ideally suited for assessing climate-induced changes—specifically, precipitation, and temperature changes—as opposed to changes in soil, pests etc.

Model Details

In AquaCrop, the above-ground biomass of a crop is based on the product of a water productivity parameter and the sum of daily transpiration. Water productivity is a calibrated parameter and is crop dependent. Transpiration is determined using a "green canopy cover" index (as opposed to a leaf area index) and is impacted by a number of "stressors" including soil fertility, temperature stress, and water-related stress, among others. These stressors vary by crop life stage so that stress during important stages (e.g. germination or fertilization) in a crop's life impact the biomass more than stresses in less important stages. Above-ground biomass is used to produce a yield based on a Harvest Index, which represents the portion of the crop that is a harvestable product. Harvest Index is also adjusted based on stressors that impact the harvestable product only. Figure F-23 shows the configuration of AquaCrop.

Figure F23. Structure of Aquacrop Model (Source: AquaCrop Model Documentation, FAO)



In this context, the irrigation water requirement is defined as the ideal amount of water used for irrigation by the farmer(s) given field-level infrastructure, crop parameters, soil characteristics, and field management. This value does not take into consideration the availability of water in the system, either from surface water or groundwater. This limitation is usually handled through a water systems model. Besides the various decisions made by the people involved in the irrigation scheme, climate impacts the irrigation water requirements through changes in precipitation (that which infiltrates through the soil) and dryness conditions (primarily driven by temperature and precipitation).

Model Implementation

The inputs required for AquaCrop are climate parameters, soil parameters, crop parameters, field management (including irrigation infrastructure), and irrigated area (used in post-processing). Since AquaCrop runs on a daily time-step, and the time-dependent parameters are required to be at the daily scale. Reference evapotranspiration (ET0), a required parameter that is estimated based on primary climate parameters, is estimated using the Modified Hargreaves method adjusted for a daily timestep as described in Farmer et al. (2011). This estimation requires mean daily temperature, daily temperature range, and daily precipitation.

A calibration procedure for the AquaCrop model has been developed. This uses the suggestions provided in the AquaCrop manual for "calibration" but packages these suggestions within an automated calibration module. This allows the use of observed yields to modify the crop parameters and soil conditions until the simulated yields closely matched the observed yields. Losses from irrigation infrastructure and conveyance can be modeled with efficiency factors. These efficiency factors are used in post-processing of irrigation demands estimated by AquaCrop. The losses in the soil column are modeled directly in AquaCrop using information on irrigation scheduling, if available. However, using a fixed irrigation schedule assumes the farmers do not adjust to changing climate conditions. Another option is to estimate scheduling using soil moisture conditions, i.e. once the soil reaches a dryness threshold, the farmer irrigates until the soil is sufficiently wet. This approach assumes the farmer will adjust irrigation practices as climate changes. For example, if the climate conditions are dryer, the farmer will irrigate more based on observable soil wetness conditions. This can be seen as a "smart farmer" assumption. For this study, it is assumed that the farmer adjusts the irrigation schedule and application in response to changing soil conditions.

The AquaCrop tool was calibrated to local yields obtained from the ZimStat survey to each major farm type and within each Agro-ecological Region to observe changes in yields across ownership/income categories. The analysis was conducted at the Agro-ecological Region resolution for a representative set of crops drawn from Benitez et al. (2018). Analyses were conducted for the full span of years in the project horizon (i.e. 2017 to 2030), crops, farm types, grid cells, and for a set of CSA options (e.g. irrigation technology, enhanced use of inputs). Model output is in the form of impacts of climate change on crop yields and irrigation water requirements, as well as the improvements under each adaptation intervention type. All results are scaled up from the grid cell to the Agro-ecological Region level, using crop production data from ZimStat for weighting.

Soil conditions and spatial distribution of crops were taken from Ramankutty et al. (2008; at the grid resolution) and ZimStat (at the Agro-ecological Region level), and crop yield data were drawn from ZimStat (2014 and 2016). Irrigation coverage and spatial distribution were based on a range of sources, one of which was the Food and Agricultural Organization's Global Map of Irrigation Areas.[17]

[17] See http://www.fao.org/NR/WATER/aquastat/irrigationmap/index10.stm

Model Results

The following expands on the results shown in Chapter 4 of the main report, showing yield factor improvements from the CSA options for all crops and all climate scenarios.

Table F24. Yield Factors for Drought-tolerant Varieties for Historical Climate and the Three Future Climate Scenarios

Crop	Historical	Wettest	Medium	Hot & Dry
Maize	1.06	1.05	1.11	1.13
Tobacco	1.12	1.05	1.16	1.19
Soybean	1.03	1.01	1.03	1.03
Potato	1.07	1.03	1.06	1.07
Cotton	1.05	1.03	1.10	1.09
DryBean	1.12	1.04	1.09	1.11
Sunflower	1.03	1.02	1.04	1.05
SweetPotato	1.05	1.02	1.07	1.10
Groundnut	1.08	1.07	1.13	1.10
Sorghum	1.13	1.04	1.11	1.16

Table F25. Yield Factors for Irrigation for Historical Climate and the Three Future Climate Scenarios

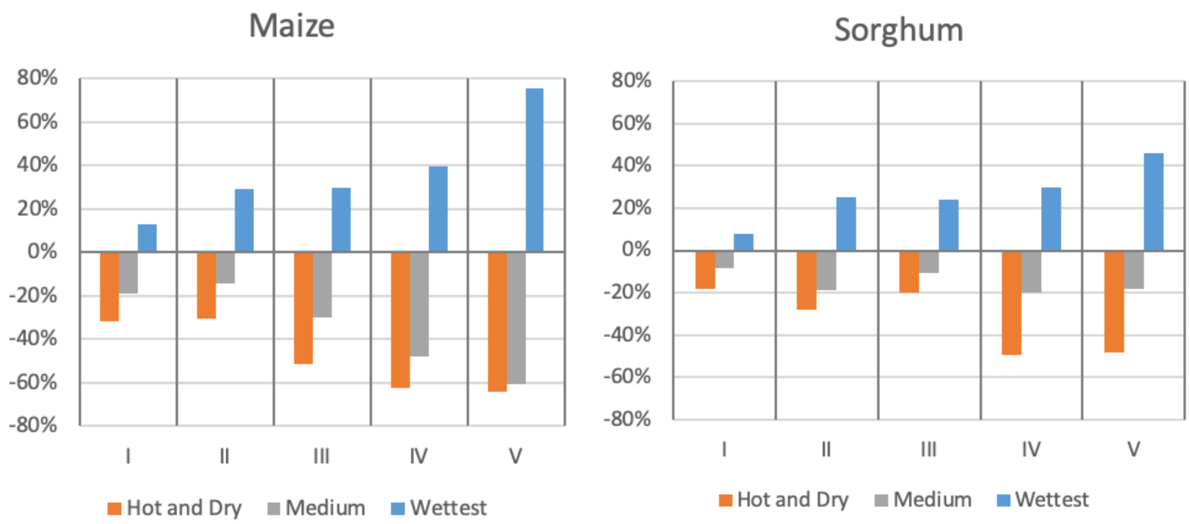
Crop	Historical	Wettest	Medium	Hot & Dry
Maize	1.98	1.46	2.96	3.88
Tobacco	1.52	1.16	1.86	2.19
Soybean	1.63	1.40	2.05	2.61
Potato	1.45	1.25	1.71	2.11
Cotton	2.37	1.93	3.69	4.65
DryBean	1.98	1.21	1.88	2.12
Sunflower	1.44	1.17	1.86	2.28
SweetPotato	1.49	1.26	1.90	2.34
Groundnut	2.00	1.54	3.05	3.54
Sorghum	1.70	1.24	2.09	3.16

Table F26. Yield Factors for Irrigation for Historical Climate and the Three Future Climate Scenarios

Crop	Historical	Wettest	Medium	Hot & Dry
Maize	2.87	2.12	4.30	5.62
Tobacco	2.00	1.52	2.44	2.87
Soybean	1.95	1.67	2.45	3.12
Potato	1.74	1.51	2.05	2.53
Cotton	3.13	2.55	4.87	6.14
DryBean	2.89	1.76	2.74	3.09
Sunflower	2.12	1.72	2.75	3.36
SweetPotato	2.08	1.75	2.65	3.27
Groundnut	2.70	2.08	4.11	4.77
Sorghum	2.45	1.79	3.00	4.55

Next, Figure F-24 looks in more detail at two crops, maize and sorghum, indicating the impact of climate change on yields in Zimbabwe, across the five Agro-ecological Regions by the 2030s. The focus on maize and sorghum is important: maize is the staple food crop, while sorghum is widely considered to be a replacement crop for maize under a drier climate. Under a climate future that is substantially wetter than the present, the drier regions show the greatest benefit from additional rainfall. Exploring a climate future that is substantially hotter and drier than the present, yields are expected to decline substantially, with the greatest impacts in the drier Regions IV and V. Under a future where only moderate changes to the climate are realized, maize and sorghum yields still decline. For maize these reductions with the medium climate scenario are large in Regions IV and V, close in magnitude to the impacts of the hot & dry scenario. Since most farms in these regions are communal farms, sharp declines in yield may be devastating to a large number of mainly subsistence farmers- as many as 7 million people. Generally, the changes in sorghum yields are not as extreme as for maize, with the largest difference between crops in the medium climate for Regions IV and V where sorghum yield changes are moderate.

Figure F24. Impact of Climate Change on Maize (left) and Sorghum (right) yields: Change from Baseline to the 2030s (percentage change in yield)



Three quantifiable crop-focused CSA options are evaluated here. The focus is on smallholder farmers, which are a combination of A1, communal, small-scale commercial, and old resettlement farmers, excluding large scale and A2 farmers. Smallholder farms represent the majority of harvested area for most crops and have the highest potential for increases in production given the low production from smallholder farms in the past.

Table F-27 shows the benefits of three adaptation options: drought and heat tolerant varieties, irrigation, and the combination of irrigation with fertilizer. Drought and heat tolerant varieties represent a relatively inexpensive option for farmers without the need for infrastructure or access to water for irrigation. However, this strategy tends to be less effective than the other, more expensive options. Irrigation requires high initial capital cost and likely implementation of water harvesting infrastructure to ensure water is available in the dry season. Once these are in place, irrigation provides higher, more reliable yields. Full commercialization (irrigation + fertilizer) is the highest cost strategy but provides the best production for all crops. These two options were combined because in many cases, using fertilizer without enough water can be counter-productive as a larger crop requires more water.

Tobacco, dry bean, and sorghum benefit the most from drought and heat tolerant varieties, increasing yields by 12%, 12%, and 13%, respectively. With irrigation, these yields basically double for half of the crops evaluated, with cotton and groundnut benefiting the most and tobacco and sunflower benefiting the least. Adding fertilizer to the irrigated crop doubles or triples production. Maize, cotton, and dry bean benefit the most from the addition of fertilizer. This observation is of critical importance to smallholder farmers who either do not apply or under-apply fertilizers because of a lack of capital to purchase fertilizers or because of long distances from suppliers. Low or poor fertilizer application largely explains the low crop yields in smallholder irrigation.

Table F27. Benefits of Adaptation Options for Smallholder Farms ordered from Most Harvested Area to Least, under the Current Climate

CROP	SHARE OF SMALLHOLDER FARMS BY AREA	BENEFIT OF CSA OPTIONS (MULTIPLIER ON CURRENT YIELD)		
		DROUGHT & HEAT TOLERANT VARIETY	IRRIGATION	IRRIGATION & FERTILIZER
Maize	92%	1.06	1.98	2.87
Cotton	97%	1.05	2.37	3.13
Groundnut	97%	1.08	2.00	2.70
Sorghum	99%	1.13	1.70	2.45
Tobacco	67%	1.12	1.52	2.00
Soybean	41%	1.03	1.63	1.95
Dry Bean	83%	1.12	1.98	2.89
Sunflower	94%	1.03	1.44	2.12

While these CSA options increase yields for all crops, understanding the risks from long-term climate change is important, especially for those options with high initial costs, such as irrigation infrastructure. In other words, having evaluated these CSA options for the current climate, how effective would they be given altered future climate conditions? As shown in Table F-28, a dry future climate will have mostly negative impacts on crop production for smallholder farms, given current practices. Dry bean is the least impacted by these hotter and drier conditions (actually benefits from the warmer temperatures), with maize and cotton the most impacted. Also shown in Table F-28 are the improvement factors for the CSA options as compared to the current practices given the medium climate. Although drought and heat tolerant varieties are more effective under these climatic conditions than with past climate, it will not bring yields back to historical conditions (aside from dry beans). These crops do benefit greatly from irrigation, although the benefit for some crops is less under these conditions than for historical climate (dry beans and soybean). Maize, cotton, and dry bean see the highest benefit from the addition of fertilizer under these future climatic conditions, returning yields to close to historical climate yields, although for the future conditions, this commercialization option is significantly more effective.

Table F28. Benefits of Adaptation Options for Small-holder Farms ordered from Most Harvested area to Least, for the Hot & Dry Climate Scenario

CROP	IMPACTS UNDER CURRENT PRACTICES	IMPROVEMENT FACTOR WITH CSA OPTION		
		DROUGHT & HEAT TOLERANT VARIETY	IRRIGATION	IRRIGATION & FERTILIZER
Maize	-33%	1.11	2.96	4.30
Cotton	-36%	1.10	3.69	4.87
Groundnut	-34%	1.13	3.05	4.11
Sorghum	-18%	1.11	2.09	3.00
Tobacco	-18%	1.16	1.86	2.44
Soybean	-21%	1.03	2.05	2.45
Dry Bean	5%	1.09	1.88	2.74
Sunflower	-23%	1.04	1.86	2.75

F.3 Livestock Modeling (GLEAM)

The Global Livestock Environmental Assessment Model (GLEAM) built by the Food and Agricultural Organization (FAO) was developed as a modeling tool to improve our understanding of the global environmental impact of livestock supply chains for six livestock species: cattle, buffalo, sheep, goats, chickens, and pigs. The model has been used in many contexts (Mottet et al 2017, Jose et al. 2016, among others) and is ideal for analysis in developing countries. The main data sources for GLEAM are Gridded Livestock of the World (FAO, 2007), National Inventory Reports of Annex I countries (UNFCCC, 2009), International Food Policy Research Institute, Life Cycle Inventory data from the Swedish Institute for Food and Biotechnology, CGIAR (formerly the Consultative Group for International Agricultural Research) and statistics from FAO.

Model Details

GLEAM consists of five distinct modules:

1. **Herd Module:** keeps track of the number of animals per species by location and management practices
2. **Manure Module:** evaluates manure production and emissions across the herds
3. **Feed Module:** calculates feed components, nutrient content, and emissions per kg of feed
4. **System Module:** estimates energy requirements per animal, incorporates feed and estimates production of livestock commodities
5. **Allocation Module:** calculates the total greenhouse gas emissions

Although GLEAM was originally designed to evaluate environmental impacts of livestock, the model also provides the production of livestock commodities such as meat, milk, and eggs. The current version of GLEAM (2.0) provides as output (source: http://www.fao.org/gleam)

- Production of manure and its management;
- Feed intake and animal feed rations composition and quality;
- Land use associated with feed intake;
- Production of livestock commodities;
- Greenhouse gas emissions arising from each stage of production;
- Nitrogen used at each stage of production.

Model Implementation

Since the geographic information system version of GLEAM is not publicly available, the "interactive" version of GLEAM, called "GLEAM-i," was used, which is excel-based. The calculations are identical but the model is not spatially resolved. However, the tool is able to provide national-level impacts of various CSA options. The focus of the analysis is on the CSA options shown in Table F-29.

Table F29. CSA Options Considered in the GLEAM Modeling

No.	CSA Options	Description
32	Commercialization of livestock *productivity benefits*	Intensive livestock production systems incorporating less dependence on rangelands; Alternative viable systems including pastures and other sources of feed with more intensification of high value livestock production systems.
34	Improve communal livestock conditions *sustainability, productivity, and mitigation benefits*	Find alternative feedstuffs and systems with Increased fodder production and fodder storage at the farm level; Develop and promote seed of improved and new grasses; Develop farmer's capacities in fodder storage to stretch feed availability for livestock during the lean period; Match densities of livestock numbers to carrying capacity of rangelands; In light of climate change; Invest more into increased research to find ways of improving rangeland management (e.g. more resilient grasses).
36	Increased small livestock production *mitigation and sustainability benefits*	Undertake research and encourage farmers to produce more small stock, as opposed to large animals that need more feed and water e.g., raising goats which are more resilient to drought.

These are modeled as independent options within GLEAM as well as in the form of a baseline run representing current conditions. These model runs are then compared to understand the resulting changes based on the chosen indicators. These indicators revolve around three goals: production, mitigation, and sustainability. For each of these categories, the indicators from the model are:

- **Production:** meat, milk, and eggs
- **Mitigation:** greenhouse gases released
- **Sustainability:** land use associated with feed intake

The GLEAM model categorizes cattle herds into "Dairy" and "Beef" cattle, and within each of these categories, into "Grassland based[18]" and "Mixed farming[19]" production systems. Due to the inter-annual rainfall variability, crop by-products are a large portion of cattle feed during the dry season for all farm systems. Here, the focus was on meat production, and thus, all model runs focusing on cattle fall into the categories of "Beef" and "Mixed farming," with all other model herd and production system combinations set to zero. As in the crop analyses, the six farm types have been broadly categorized into "Communal" and "Commercial," with old settlement and communal farms defined as "Communal," and A1, A2, small-scale and large-scale commercial farming falling under "Commercial."

Herd module inputs and assumptions are provided in Table F-30. Feed module inputs are broadly categorized into roughages, grains, and agro-industrial by-products. It is assumed that communal cattle are fed solely roughages, while commercial cattle feed on a mix of all three feed types, consistent with default FAO values. Feed module inputs for each specific feed type are based on FAO default ratios within each feed type category, and are adjusted based on the assumed category-level feed inputs presented in Table F-31.

[18] From the FAO Gleam-i¬ Ver. 2.0 Rev. 7 January 2019: "Systems in which more than 10% of animal feed is produced in the farm and the average stocking rate is less than 10 livestock units (LSU) per hectare of agricultural land.
[19] From the FAO Gleam-i¬ Ver. 2.0 Rev. 7 January 2019: "Systems in which more than 10% of animal feed comes from crop by-products or more than 10% of the production value is of non-livestock activities."

Communal cattle herd information is kept consistent across the scenarios considered. The GLEAM model does not include the possibility of underfeeding of livestock; underfeeding is represented by allocating 25% of fodder for communal cattle to general grazing on leaves from natural vegetation (see Table F-32). Improving feed with velvet beans shifts this 25% of fodder from leaves to hay and silage from grass and legumes (see table F-33). Commercial cattle feed is detailed in Table F-34 while the feed inputs for goats are shown in Tables F-35 and F-36.

Table F30. Cattle Herd Module Inputs

	Communal		Commercial
Adult reproductive females	Ratio from ZimStat preserved	480,368	ZimStat (2014pop)
(A1, A2, SSCF, LSCF)	Ratio from ZimStat preserved	3.69	4.87
Adult reproductive males	Ratio from ZimStat preserved	68,051	Same as above
Age at first calving (months)	Average age at first calving for communal cattle*	48	GEAM default
Fertility of adult females (%)	Manzungu	90	Manzungu
Mortality of young females (%)	Average calf mortality*	7	GLEAM default
Mortality of young males (%)	Average calf mortality*	7	Gleam default
Mortality of adult animals (%)	Homann andvan Rooyen (2007) and Masikati (2010) cite communal herd mortality as high as 18%	5	Gleam default
Adult females replacement (%)	Manzungu	25	Manzungu
Weight at birth (kg)	Manzungu	50	Manzungu
Weight of adult females	Average weight of indigenous breeds*	525	1.5x weight of indigenous breeds
Weight of adult males	Average weight of indigenous breeds*	862.5	1.5 weight of indigenous breeds
Weight of fattening females	Ratio (fattening females : adult females) kept equal to GLEAM default	525	Ratio (fattening females : adult females) kept equal to GLEAM default
Weight of fattening males	Ratio (fattening males : fattening females) kept equal to GLEAM default	525	Ratio (fattening males : fattening females) kept equal to GLEAM default

* Source: Tavirimirawa et al. 2013

Table F31. Cattle Feed Module Categorical Inputs

Communal				
Feed Type Consumption	Adult Females	Adult males and replacement animals	Fattening animals	Assumed no agro-industrial by-products or grains are found in communal herd diets. Adjusted default GLEAM ratio accordingly.
Roughages	100%	100%	100%	
Grains	0%	0%	0%	
Agro-industrial by-products	0%	0%	0%	
Commercial				
Feed Type Consumption	Adult Females	Adult males and replacement animals	Fattening animals	Default GLEAM ratios.
Roughages	91.5%	96.5%	91.5%	
Grains	3.5%	0%	3.5%	
Agro-industrial by-products	5.0%	3.5%	5.0%	

Table F32. Communal Cattle Herd Underfed Feed Type Inputs

	Feed Type Consumption (%)	Adult Females	Adult Males and Replacement Animals	Fattening Animals
Roughages	Fresh grass	2.88	2.88	2.88
	Hay or silage from grass	8.63	8.63	8.63
	Fresh mixture of grass and legumes	0	0	0.
	Hay or silage from grass and legumes	0	0	0
	Hay or silage from alfalfa (lucerne)	0	0	0
	Silage from whole grain plants	4.11	4.12	4.11
	Silage from whole maize plant	7.97	7.93	7.97
	Crop residues from wheat	7.56	7.54	7.56
	Crop residues from maize	2.55	2.56	2.55
	Crop residues from millet	0.82	0.85	0.82
	Crop residues from sorghum	3.12	3.11	3.12
	Crop residues from rice	6.74	6.76	6.74
	Crop residues from other grains	11.2	11.2	11.2
	Crop residues from sugarcane	12.2	12.1	12.2
	Fodder beet	7.31	7.31	7.31
	Leaves from natural vegetation	25.0	25.0	25.0

Table F33. Communal Cattle Herd Velvet Beans Supplement Feed Type Inputs

	Feed Type Consumption (%)	Adult Females	Adult Males and Replacement Animals	Fattening Animals
Roughages	Fresh grass	2.88	2.88	2.88
	Hay or silage from grass	8.63	8.63	8.63
	Fresh mixture of grass and legumes	0	0	0.
	Hay or silage from grass and legumes	25.0	25.0	25.0
	Hay or silage from alfalfa (lucerne)	0	0	0
	Silage from whole grain plants	4.11	4.12	4.11
	Silage from whole maize plant	7.97	7.93	7.97
	Crop residues from wheat	7.56	7.54	7.56
	Crop residues from maize	2.55	2.56	2.55
	Crop residues from millet	0.82	0.85	0.82
	Crop residues from sorghum	3.12	3.11	3.12
	Crop residues from rice	6.74	6.76	6.74
	Crop residues from other grains	11.2	11.2	11.2
	Crop residues from sugarcane	12.2	12.1	12.2
	Fodder beet	7.31	7.31	7.31
	Leaves from natural vegetation	0	0	0

Table F34. Commercial Cattle Feed Type Inputs

	Feed Type Consumption (%)	Adult Females	Adult Males and Replacement Animals	Fattening Animals
Roughages	Fresh grass	3.5	3.7	3.5
	Hay or silage from grass	10.5	11.1	10.5
	Fresh mixture of grass and legumes	0	0	0
	Hay or silage from grass and legumes	0	0	0
	Hay or silage from alfalfa (lucerne)	0	0	0
	Silage from whole grain plants	5.0	5.3	5.0
	Silage from whole maize plant	9.7	10.2	9.7
	Crop residues from wheat	9.2	9.7	9.2
	Crop residues from maize	3.1	3.3	3.1
	Crop residues from millet	1.0	1.1	1.0
	Crop residues from sorghum	3.8	4	3.8
	Crop residues from rice	8.2	8.7	8.2
	Crop residues from other grains	13.6	14.4	13.6
	Crop residues from sugarcane	14.8	15.6	14.8
	Fodder beet	8.9	9.4	8.9
	Leaves from natural vegetation			
Grains	maize	1.0	0	1.0
	grains	2.5	0	2.5
Agro-industrial by-products	by-products from soy	0.6	0.1	0.6
	by-products from rape (canola)	0.1	0.1	0.1
	by-products from cottonseed	0.1	0.1	0.1
	by-products from sugar beet	0	0	0
	oil palm kernel expeller	0.9	0.9	0.9
	molasses	2.2	2.2	2.2
	maize gluten meal	0.3	0	0.3
	maize gluten feed	0	0	0
	Dry by-product from grain industries	0.8	0.1	0.8
	Wet by-product from grain industries	0	0	0

Default ratios from GLEAM preserved

Table F35. Goat Herd Module Inputs

Herd Inputs	Goats	
Adult reproductive females	664116	GLEAM default values
Adult reproductive males	21916	
Age at first kidding (months)	23	
Fertility of adult females (%)	95	
Parturition interval	384	
Litter size	1.5	
Mortality of young animals	23.3	
Mortality of adult animals	10.0	
Adult females replacement	18.1	
Weight at birth	2.0	
Weight of adult females	44	
Weight of adult males	54	
Weight of fattening females	29	
Weight of fattening males	29	

Table F36. Goat Herd Feed Type Inputs

	Feed Type Consumption (%)	Adult Females	Adult Males and Replacement Animals	Fattening Animals
Roughages	Fresh grass	7.7	7.7	7.7
	Hay or silage from grass	7.7	7.7	7.7
	Fresh mixture of grass and legumes	0	0	0
	Hay or silage from grass and legumes	0	0	0
	Hay or silage from alfalfa (lucerne)	0	0	0
	Silage from whole grain plants	5.5	5.5	5.5
	Silage from whole maize plant	10.6	10.6	10.6
	Crop residues from wheat	10.1	10.1	10.1
	Crop residues from maize	3.4	3.4	3.4
	Crop residues from millet	1.1	1.1	1.1
	Crop residues from sorghum	4.1	4.1	4.1
	Crop residues from rice	9.0	9.0	9.0
	Crop residues from other grains	14.9	14.9	14.9
	Crop residues from sugarcane	16.2	16.2	16.2
	Fodder beet	9.8	9.8	9.8

Model Results

Use of high-quality fodder makes a significant difference for cattle production and emissions intensity. Commercial cattle have higher production and lower emissions intensity than communal cattle, but cost barriers may make such a switch difficult. However, goats have a lower entry barrier relative to cattle, and also have a lower emissions intensity than communal cattle. Goats have the added benefit of grazing on a wider variety of fodder types than cattle, reducing the likelihood of underfeeding during the dry season. Improving fodder for communal cattle by using velvet beans as supplemental fodder reduces the emissions intensity of production and has the added benefit of increasing nitrogen stocks of soil.

F.4 Engineering Cost Analysis

Model Details

This section presents the economic findings of the study from an "engineering cost" perspective, where impacts of climate change and benefits of adaptation are measured by simply multiplying changes in yields by the static 2030 forecast crop prices described in Appendix E. This analysis builds on work previously completed by Benitez et al. (2018).

Model Results

In terms of economic impacts, total average baseline agricultural revenues for the 13 crops considered in this study are estimated at approximately $1 billion annually, based on the production estimates from ZimStat. This estimate falls within the expected range (Benitez et al. 2018). Table F-37 shows the impacts of climate change on crop revenues, broken down across farm types and climate futures. The overall economic effects of climate change range from an annual loss of $186 million under a dry/hot climate future, to a gain of $129 million under the wettest climate future – this is between a 15% loss and 11% gain in total revenues. The communal farm types, which support by far the largest number of livelihoods, are projected to experience the largest reductions (or gains) in revenues. On the other hand, the large-scale commercial farm types experience almost no downside risk because of their relatively high dependence on irrigation – in the dry/hot climate future, any reduced rainfed yields are offset by beneficial temperature effects.[20]

Table F37. Impact of Climate Change on Average Annual Crop Revenues by Farm Type

Farm Type	Control Revenues	Climate Scenario		
		Dry/Hot	Medium	Wettest
LSCF	$427.1	($0.9)	$3.3	$26.5
A2	$233.2	($35.7)	($16.1)	$26.4
A1	$136.6	($36.6)	($16.8)	$19.5
Communal	$330.3	($89.7)	($39.7)	$44.4
SSC	$17.8	($4.6)	($2.4)	$2.4
Old Resettle	$77.3	($18.2)	($10.8)	$9.3
TOTAL	$1,222	($185.8)	($82.4)	$128.5
Change		-15%	-7%	11%

Table F-38 presents these effects across the different Agro-ecological Regions. Agro-ecological Region II is shown to have the highest impacts, both losses and gains. Agro-ecological Region V shows limited negative impacts because a large fraction of these revenues are from irrigated sugarcane, which are protected from water stress impacts by assumption. As noted above, water available for irrigation could certainly be limited under a dry climate change future.

[20] This is not to suggest that no LSCF farmers would be negatively affected by climate change, but rather that on average, the effects are generally positive.

Table F38. Impact of Climate Change on Average Annual Crop Revenues by Agro-Ecological Region

AER	Control Revenues	Climate Scenario		
		Dry/Hot	Medium	Wettest
I	$17.6	($4.0)	($2.8)	$0.8
II	$422.5	($90.3)	($51.2)	$49.4
III	$146.7	($47.0)	($19.7)	$22.2
IV	$144.8	($42.9)	($16.4)	$22.8
V	$490.6	($1.5)	$7.7	$33.4
TOTAL	$1,222	($185.8)	($82.4)	$128.5
Change		-15%	-7%	11%
Change		-15%	-7%	11%

F.5 Greenhouse Gas Mitigation Analysis

Mitigation is the third pillar of CSA, and the greenhouse gas mitigation benefits of a subset of the available CSA options (and thus scenarios) employed are quantified using simulation models (e.g. livestock) or based on information available in the literature.

F.6 Analytical Approaches Tailored to Specific CSA Options

Analysis of several of the CSA options required tailored approaches. These are described below.

Conservation Tillage

Conservation tillage involves disturbing the soil as little as possible during the planting process in order to reduce soil erosion and nutrient loss (CIAT World Bank, 2017). Conservation tillage ranges from zero tillage which leaves the soil undisturbed from harvest to planting, to mulch-ripping which involves some tillage but ensures that crop residues remain on the surface of the ground. In Zimbabwe's clayey and sandy soils, conservation tillage can help reduce the disturbance of soil organic matter and slow the release of soil carbon into the atmosphere. Conservation tillage has been shown to have widespread effectiveness across Zimbabwe, but different conservation tillage practices are more effective depending on the soil and climate conditions of the region (CTCN 2017).

Conservation Agriculture, including zero or minimum tillage, is a key part of the vision of the agricultural sector in Zimbabwe according to the ZAIP 2013-2017. The ZAIP allocates $1.5 million (USD 2013) to promoting Conservation Agriculture through extension services and advertising about the techniques (GoZ 2013). Zero and minimum tillage practices have largely been taken up in Agro-ecological Regions III, IV, and V by maize farmers, sorghum farmers, and groundnut and cotton producers largely due to the provision of training and free or subsidized inputs (CIAT World Bank, 2017). Table F-39 below summarizes the adoption rates of conservation tillage across crops and regions of Zimbabwe (adapted from CIAT World Bank, 2017).

Table F39. Approximate Adoption Rates of Conservation Tillage by Crop and Agro-ecological Region in Zimbabwe

Crop Types	Region I	Region II	Region III	Region IV	Region V
Maize	-	30-60%	-	<30%	<30%
Cotton	-	-	-	<30%	<30%
Groundnuts	-	-	<30%	30-60%	30-60%
Sorghum	-	-	30-60%	30-60%	30-60%

Source: CIAT World Bank (2017)

Production and Mitigation Benefits

Mitigation benefits from conservation tillage include carbon sequestration and reduced diesel emissions from tractor use. The costs of switching from conventional tillage to conservation tillage include government extension programs to train farmers in conservation tillage techniques, extension/NGO expenditures on training programs, and potentially greater expenditure on herbicides by farmers. On the other hand, the benefits of Conservation Agriculture include: a reduction in diesel fuel expenditures by farmers, lower labor costs, reduced machinery costs (reduced fuel and maintenance costs on tractors), increased soil carbon storage, and greater crop yields.

This analysis only considers the costs of government-sponsored conservation tillage extension programs, the avoided costs of reducing diesel fuel use and ceasing to use diesel tractors for tilling, and the avoided labor costs by switching to conservation tillage. Costs due to increase in herbicide use are not considered, as these costs are highly context-dependent for the given farm and region of Zimbabwe and are likely to be negligible or offset by reduced fertilizer use (Boyle, 2006). Studies disagree as to whether or not conservation tillage leads to increased yield in Zimbabwe (see for example Thierfelder et al. 2015 versus Giller et al. 2009), and hence yield benefits were not included. Finally, the cost of NGO training programs on conservation tillage are not calculated.

Adoption of Conservation Agriculture practices has had some success in Zimbabwe. According to Marongwe et al. (2011), the number of farmers adopting Conservation Agriculture from 2005 to 2010 increased by about 1.9% of total farmers each year. Assuming this rate continues over the period 2019-2030, adoption of conservation tillage would cover about 21% of all eligible hectares. As mentioned before, the ZAIP dedicates $1.5 million in 2013 into extension programs to ensure the adoption of Conservation Agriculture (GoZ 2013). However, since Conservation Agriculture is a suite of three different farming practices, only one-third of this yearly budget is considered to be spent directly on promoting conservation tillage.

The monetary benefits of switching to conservation tillage are found to outweigh the costs, resulting in a total net benefit of $1.30/ha. Farmers stand to gain, on average, $5.67/ha per year by switching.

In addition to the monetary benefits to the farmer, soil carbon sequestration from reduced tillage and the reduction of tractors use provide greenhouse gas mitigation benefits. For the latter, a study on climate change in Botswana was used, which details the carbon mitigation benefits of switching from conventional to no-till agriculture (EECG Consultants 1999).

Information from a long-term study conducted in Zambia (Thierfelder and Wall, 2010) was used to quantify the increase in soil carbon storage from switching to Conservation Agriculture. The number of hectares in Zimbabwe where conservation tillage is viable was then calculated, based on the current adoption rate of each region by crop type. Four crops are considered eligible: maize, cotton, groundnuts, and sorghum. In total, across the four crops and five regions, about 346,000 hectares are calculated to be eligible to convert from conventional to conservation tillage. The mitigation potential of increased soil carbon uptake from conservation tillage was estimated to be roughly 0.18 tCO_2e per hectare per year by applying IPCC soil carbon equations (IPCC, 2006).

Improved Livestock Feed for Communal Non-Dairy Cattle

Roughly 90% of all cattle in Zimbabwe are in communal smallholder farms. Before harvest, cattle are allowed to feed on crop residues, which are often unhealthy and result in higher methane emissions per unit energy gain. Legume hay can be an excellent source of protein for cattle health, but is often not available for communal cattle in Zimbabwe, especially during the dry season. A diet of roughly half legume hay is recommended (CTCN, 2018). Water is also a problem- communal livestock often walk long distances in the dry season for water and food (Tavirimirwa et al 2013).

Improved feeding management and reduction in stock size has had a low adoption rate in Zimbabwe to date (CIAT World Bank, 2017). Currently, feed either from home-grown fodder or purchased feed accounts for roughly 10% of the required diet for all communal cattle, with the majority of this feed provided to dairy producing cattle in the dry season (ZIMSTAT 2016). Improved feed for cattle has been shown to reduce methane emissions significantly and improve cattle health for better milk production, slaughter yield, and birth success rates (GoZ, 2016, Andeweg and Reisinger 2015, among others).

Velvet beans are ideal for providing leguminous hay because they are not labor-intensive, are native to tropical regions, are drought and heat tolerant, and have had success in the drier regions of Zimbabwe (CTCN 2018). For this reason, the costs, yield, and improved cattle weight are all based on planting velvet beans on-farm.

Production and Mitigation Benefits

With healthier cattle, higher slaughter weight and yield is expected. With legumes providing a healthy diet during the dry season, it was assumed that beef yields for communal cattle under this program will approach half the yields observed for commercial agriculture in Zimbabwe.

This program would intend to provide communal non-dairy cattle with enough legume feed from velvet beans for farmers to feed cattle a 50% legume diet for six months corresponding to the driest half of the year.

Other benefits are expected under this program but are not evaluated. These include:

- **Reduced herding labor.** This program would reduce the time spent herding cattle finding feed during the dry season. However, these tasks are often left to children and there is limited data on time spent specifically looking for feed. It is estimated that labor related to herding is roughly about 6 hours per day, on average (FAO 2000).
- **Food security**. Providing a drought-resistant source of food during the dry season provides food security during droughts. This avoided risk is not quantified here.
- **Improved calving rate.** Healthier cattle have more successful birth rates and provide calves more frequently. These impacts are not included due to lack of data on the impact of improved feed on communal cattle in Zimbabwe.

Mitigation potential for improved feed of communal non-dairy cattle is evaluated over two main mitigation levers: reduced enteric fermentation from cattle and increased carbon sequestration with new legume fields. Reduced methane from cattle is estimated as follows: since cattle are provided a half-legume diet for six months during the dry season, methane emissions are reduced by about 15%; half of the estimated 30% for cattle fed a legume diet for the entire year. Legume carbon capture is based on estimates of the mitigation benefit of planting legumes, about 0.7 tC/ha/year (Paustian et al, 2006), which equates to about 2.6 tCO_2e/ha/year. These together provide a total mitigation benefit of roughly 7 USD / tCO_2e, meaning that for every tonne of tCO_2e mitigated, there is a gain of 7 USD.

Reductions in Prescribed Savanna Burning

Prescribed savanna burning in Zimbabwe is often used in the late dry season to provide green grass (called the "green bite") for cattle when fresh grass is scarce and crop residues are unavailable. However, this green bite does not provide a substantial amount of food for cattle per hectare. While early dry season prescribed burns can be beneficial to African savannas, late dry season burns can cause significant harm to rangelands in the long-run by drying and hardening the soil, harming existing roots, reducing biodiversity, and causing erosion (Trollope 2004). Late dry season burns also burn hotter and produce significantly more emissions than early season burns. According to a recent study, late dry season burning accounts for roughly 83% of emissions from prescribed burns in Zimbabwe (Lipsett-Moore et al. 2018). Zimbabwe's Third National Communications includes reduction in savanna burning as one of the major recommendations for the agricultural sector (GoZ 2016).

Production and Mitigation Benefits

For reductions in prescribed burns during the late dry season to reduce, farmers with cattle will need an incentive. In Australia, farmers were incentivized using carbon credits, and emissions reductions reached 37.7% over a 10-year period (Lipsett-Moore et al. 2018). For Zimbabwe, an incentive structure was proposed involving purchased stock feed to provide roughly 5-10% of the annual diet of typical cattle using the same assumptions from the above analysis on improved feed. Assuming that the program is able to reduce late dry season burns by 1% / year (12% by 2030), this equates to approximately 64,700 tons of feed per year by 2030, or about 0.15 tons per head of cattle. Assuming this feed improves beef yield by about 5%, as stock feed is significantly healthier than the green bite provided by late season savanna burning, increased beef production results in a benefit of $0.634 million USD / year. Altogether, this equates to 2.5 million USD / year. These costs/benefits do not include

- Food security during the late dry season
- Reduced herding labor
- Facilitation of the program
- Improved quality of communal rangeland in the long-run from reduced burns, or
- The environmental benefits of greater biodiversity in savannas

According to the Third National Communications, emissions from prescribed savanna burning will double by 2020. Assuming that these emissions stabilize after 2020, this brings emissions to 3.72 Mt CO_2e/year. Applying the same portion of late dry season emissions of 83% of total emissions mentioned previously (Lipsett-Moore et al. 2018) brings the total potential reductions of the program to 3.07 $MtCO_2e$ / year. With a 12% adoption rate by 2030, emissions are reduced by 0.368 $MtCO_2e$ / year.

Appendix G: Further Details on Prioritized CSA Packages

This appendix is complementary to Chapter 5 in the main report, providing more comprehensive details on the context, focus, policy relevance, investment opportunities, and potential impact of each of the final five high priority packages.

G.1 Package A: Enhanced Agricultural Knowledge and Innovation System

This package strives to enhance the Agricultural Knowledge and Innovation System (AKIS) for the smallholder farming sector in Zimbabwe, by building the capacity of extension workers and training farmers on climate smart agronomic practices and technologies. The aim of this package is to improve the productivity and resilience of the smallholder farming sector, which in turn will contribute to improved food and nutrition, and income security. This package focuses on smallholder farmers in Agro-ecological Regions III-V, with an emphasis on Regions IV and V where most of these farmers are located. The focus is on maize, small grains, and horticultural crops.

G.1.1 Context and Problem Statement

Zimbabwe's agricultural sector has faced several decades of declining crop yields. Maize, the staple food crop, has consistently recorded average yields of less than 1 ton/ha since the early 2000's, down from peak yields of around 2.2 tons/ha in the mid-1980s (World Bank 2010). This represents a serious threat to food and nutrition security in the country, given that smallholder farmers account for 70% of maize production nationally, in addition to other major cash crops such as tobacco and cotton. The current long-term national average maize yield is estimated to be around 0.75 tons/ha (ZiLAN 2018), with the government targeting yields of 5 tons/ha or more (The Herald 2018). The observed decline in productivity is driven by a number of factors, including poor seed and fertilizer availability, frequent droughts and poor extension services (World Bank 2010). The food security situation is made worse by the limited area planted with small grains like sorghum, which are more suited to the dry climate prevalent in the smallholder farming sector.

Widespread food insecurity and poor nutrition at the household level for the majority of the country's rural population are two critical consequences of these declining yields. This is further exacerbated by the dominant maize-based monoculture, as well the occurrence of frequent floods and droughts (see Section 2.1 and Table 2-3 in the main report). According to the 2017 Global Hunger Index, the food security situation in Zimbabwe is categorized as "serious" with the country ranking 108th of 119 countries (IFPRI 2017). Furthermore, Zimbabwe's failure to meet its strategic grain reserve of 500,000 tons/year illustrates the depth of food insecurity in the country (GAIN 2019). For instance, Zimbabwe imported around 1.4 million tons of maize between May 2016 and April 2017, due to the impacts of drought. This amounted to almost three quarters of the estimated 1.9 million tons consumed in total by humans and livestock in the 2016/17 agricultural season (GAIN 2017).

Climate change and population growth are anticipated to further intensify these challenges. Yields on smallholder farms are projected to fall by as much as 36% by the 2030s. In fact, as previously shown in Table 4-2 of the main report, of the 10 different crops analyzed, only one (dry beans) shows any yield improvement under a hot and dry climate future. These projected yield declines are, however, not the same for all crops across Zimbabwe. The drier regions, such as Regions IV and V, show declines that are almost twice the national average. Such yield reductions will have a substantial impact on the livelihoods of smallholder farmers. Without action to increase resilience, climate change will likely leave Zimbabwean smallholder farmers facing further maize yield declines and food insecurity. Given projections that the population in Zimbabwe will increase by between 30-52% by 2040 (UN 2019), competing demands for available land and increasing demand for food could result in smallholder farmers cultivating marginal land, further exacerbating environmental degradation (see Package C).

A number of targeted initiatives are currently already underway to address the sector's productivity challenges. In 2013, the Government of Zimbabwe implemented a "Command Agriculture" program for commercial farmers, in an effort to stimulate maize production and reduce maize imports. The aim of the program was to support farmers in the production of two million tons of maize, enough to cover the country's annual requirements for both human consumption and livestock feed. Every farmer participating in the program received an input package that included seed, fertilizers, chemicals and fuel. After harvest, farmers were obliged to deliver a specified amount of maize to the Grain Marketing Board as repayment for the inputs provided at the start of the season. According to the Ministry of Agriculture, the response to the program was positive, with 168,666 hectares planted with maize, and 6,319 tons of seed, 10.1 million liters of fuel, and 81,615 tons of fertilizer distributed (GAIN 2017). Command Agriculture has since been expanded to other crops and the livestock sector.

A further initiative aimed at increasing maize production in the smallholder farming sector is the Presidential Input Scheme. Through this Scheme, the Government distributes free inputs to grow 0.4 hectares of maize each to 820,000 smallholder farmers (GAIN 2017). While Command Agriculture and the Presidential Input Scheme have generally been considered positive, a number of challenges have surfaced. First, only a small proportion of farmers have benefitted from the two schemes. Second, there are a number of sustainability issues, as the repayment rates in Command Agriculture are low, while the inputs provided by the Presidential Input scheme leave smallholder farmers trapped in the subsistence production mode. Third, the inputs tend to be delivered late in the farming season, are sometimes of inadequate quantity and of the wrong type for some Agro-ecological Regions. Fourth, the schemes have not taken on board CSA practices, in spite of the fact that some of these practices, such as Conservation Agriculture, have been actively promoted by the Government. There has also been a tendency to promote intensive maize production across the country, including in areas not favorable for maize cropping. Small grains are only going to be introduced in this coming growing season. Another important shortcoming is that the schemes are being promoted against a backdrop of serious gaps in extension service provision, as illustrated by extension workers operating without the requisite knowledge and material resources such as transport.

The building of farmer and extension officer capacity are a key step in achieving sustained improvements in agricultural productivity and resilience. A crucial insight derived from implementing the Command Agriculture initiative was "the centrality of capacitating extension workers with a number of tools particularly information to enable them to carry out their mandate to farmers" (The Herald 2018). There have been a few initiatives focusing on this: for example, the Zimbabwe Agricultural Society recently published a handbook titled *Commercial Maize Production Field Guide* and donated 5,000 copies to the Government for dissemination to extension officers and farmers. However, there remains much need for further investment in this area, including improvement of Zimbabwe's AKIS, supported by training and capacity building programs and practical demonstration projects. There is a clear need to provide information, particularly to smallholder farmers, to promote CSA practices and to build capacity among extension workers. To this end, this package strives to attain the benefits of an enhanced agricultural extension and innovation system in Zimbabwe, targeted at increasing and stabilizing smallholder crop productivity and resilience to enhance food and nutrition, and income security in the face of a variable and changing climate.

G.1.2 Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **National Agricultural Policy Framework:** Package addresses several pillars, most prominently Pillar 2: Agricultural Knowledge, Technology, and Innovation Systems.
- **Government of Zimbabwe CSA Framework:** Package addresses Objectives 1, 2, and 4 focused on access to information, application of CSA practices, and capacity for implementation.
- **Vision 2030 and Transitional Stabilization Program:** Package enhances farm productivity and incomes through Smart Agriculture.

These Government-identified priorities are unlikely to succeed if no measures are put in place to address the challenges facing the smallholder farming sector's AKIS. Zimbabwe's National Agricultural Policy Framework recognizes the smallholder farming sector's lack of access to relevant climate-smart knowledge, information and technology, as evidenced by

1. the lack of crop diversification, illustrated by continued maize monoculture, to the neglect of small grains such as sorghum;
2. the low uptake of CSA production practices; and
3. the low uptake of ICT in agriculture despite the presence of mobile service providers and high penetration of cell phones.

These challenges faced by the smallholder farming sector are a consequence of low investment in public extension services, which is necessary to equip extension workers with critical knowledge and skills. The existing public extension service is the primary source of information for the smallholder farming sector and its deterioration in recent years has been filled by a number of separate project-based NGO initiatives. However, these initiatives are not scaled up to the national level, and innovative private-sector initiatives tend to be profit-oriented and unproven.

For this reason, the National Agricultural Policy Framework proposes to increase investment in agricultural research and development, technology and extension systems, and adoption of climate- and business-smart technology and innovation. This package builds on this need by promoting farmer-based extension systems that incorporate public, private and civil society actors. Specifically, this package seeks to further the following strategic objectives of the National Agricultural Policy Framework as follows:

1. to develop and promote an efficient and inclusive agricultural knowledge, technology, innovation and communication (exchange and dissemination) system;
2. to increase public and private investment in agricultural research and development, technology and extension;
3. to improve delivery and coordination of public and private extension services adapted to farmers' current needs;
4. to improve early warning systems in crop production; and
5. to develop and promote deployment of information systems and mobile phone platforms.

Subsequently, a Strengths-Weaknesses-Opportunities-Threats (SWOT) Analysis was conducted for this package (shown in Table G-1), with the intention of summarizing which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

Table G1. SWOT Analysis for Package A

	Helpful	Harmful
Internal	**Strengths** • Climate resilient production systems and practices are generally known. • Many players (research institutes, universities, and civil society) are promoting climate smart crop production systems and practices. • The country has developed climate resilient policies, strategies and manuals. • Agriculture-ICT has been piloted.	**Weaknesses** • Farmers lack knowledge and information to adopt climate resilient production practices and systems. • Public extension service lacks capacity to spread appropriate message to farmers. • ICT systems are poorly developed and coordinated. • Innovation service providers are poorly coordinated.
External	**Opportunities** • Three strong cell phone providers exist. • Cellphone penetration is high and increasing. • Strong donor support directed at small-holder farmers exists. • There is public provision of crop inputs to vulnerable groups through the Presidential Input Scheme. • Other complementary initiatives include the Government's "Command Agriculture" program.	**Threats** • Poor supply and availability of crop inputs and markets. • Crops suffer moisture stress due to frequent and intense droughts. • Cellphone providers face high operational costs resulting in high data costs. • Small-holder farmers are poorly organised to receive knowledge and information. • Presidential Input Scheme is poorly structured to ensure maximum crop resilience.

Thus, summarizing the key take-aways of this SWOT analysis, the major policy challenges facing this package are:

- Poorly funded public extension services on which smallholders depend;
- Poor coordination of public, private and civil society components of existing extension services; and
- Poorly developed ICT-based extension services as well as low uptake.

To address these challenges the following policy actions are recommended:

- Strengthen public extensions services by building the capacity of extension workers through provision of training on climate resilient interventions, as well as material resources such as transport;
- Provide a coordinating platform for public, private and civil society actors to harmonise information to be provided to farmers; and
- Develop and strengthen ICT-based extension through provision of adequate and common ICT infrastructure to reduce data costs, and putting in place standards for ICT-based extension through public-private partnerships.

G.1.3 Investment Opportunities

This package includes a number of specific objectives and investment activities, as described below. For each of these investment opportunities, some thoughts on implementation are provided by illustrating how a similar investment was implemented in recent World Bank projects. A summary of all the past projects examined is presented in Appendix I.1.

- **Objective: invest in building capacity of public extension workers** in terms of 1) provision of knowledge of climate resilient crop production systems, practices and technologies, 2) expanding extension reach to farmers, and 3) practical demonstrations of CSA practices.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) conducting a capacity needs assessment of extension workers and farmers, ii) designing a training program for extension workers and farmers focusing on climate resilient crop production practices, and iii) identifying required financial and material resources in terms of amount and possible sources.

  Similar previous project from which to draw lessons learned: A recent World Bank project in Niger utilized Farmers Field Schools as the means by which to disseminate the technological developments of research institutions to farmers. The successful implementation of Farmers Field Schools depended on training state extension service workers, field visits, and the production of booklets and technical manuals.

- **Objective: Invest in innovation platforms based on strong public, private and civil society service partnerships** to facilitate farmers adopt climate resilient crop production practices incorporating: 1) drought- and heat tolerant varieties, 2) crop substitution and or diversification (e.g. replacing maize with small grains such as sorghum), and 3) efficient agronomic practices (e.g. by promoting appropriate sowing dates, plant populations, crop protection and fertilizer management).

  Specific activities: To achieve this objective, the following activities will be undertaken: i) building public-private and civil society coordinating platforms at provincial, district and ward level with a mandate to streamline extension messages, ii) establishing demonstration sites at the field level to showcase appropriate crops, crop varieties and agronomic practices, iii) public and private sector and civil society organisations jointly finding ways to promote effective harvesting, processing and value addition of small grains so to expand their market, and iv) demonstrating seed storage at the local level.

  Similar previous project from which to draw lessons learned: A recent World Bank project in Nigeria sought to increase access to improved agricultural inputs, including improved seeds, livestock, agro-chemicals, and farm machinery, with the aim of generating at least two transformational technologies to be adopted by project beneficiaries. Financing was made available through grants to farms smaller than two hectares.

- **Objective: Invest in ICT-enhanced information dissemination systems** incorporating 1) the bringing together of private mobile service providers, cell phone vendors, Meteorological Services Department, extension services and universities etc., 2) the designing of appropriate applications and information packages, and 3) the development of communication hubs that service farmers efficiently and effectively.

Specific activities: To achieve this objective, the following activities will be undertaken: i) Conduct an inventory of infrastructure (base stations) and information platforms to determine adequacy and deficits, and determine the level of investment, ii) hire services of a communications company to design and demonstrate appropriate ICT-messages, and iii) pilot and scale up effective ICT-extension platforms.

Similar previous project from which to draw lessons learned: In an effort to modernize irrigated agriculture in the Indian state of Tamil Nadu, a recent World Bank project designated funds for the launching of the Smart Agri-Marketing Hub. The Hub used wireless and mobile technologies that allowed farmers more efficient contact with regulated markets in selling their produce and reduced transaction costs.

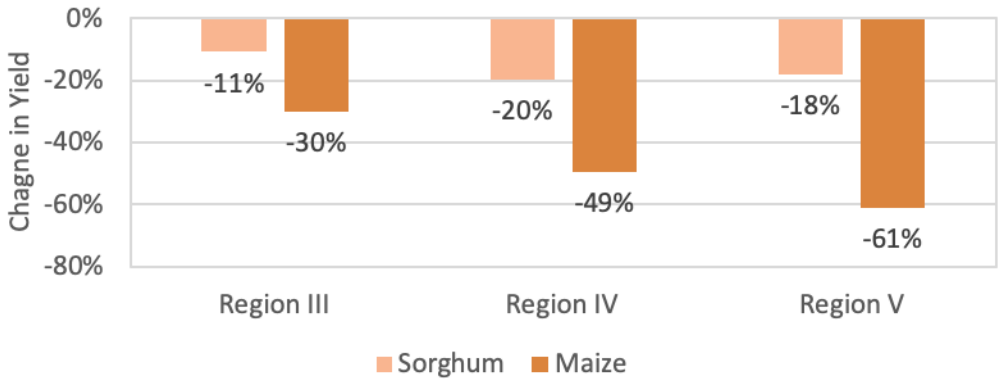
These proposed investments will be supported by recent actions to operationalize a national Agriculture Observatory which will access, synthesize, and deliver high resolution weather information to stakeholders of agricultural value chains. This will help facilitate climate-informed decision making at various levels.

G.1.4 Quantified Estimate of Impact

This package would enhance information dissemination in order to improve small holder farmer productivity and resilience in crop production. By doing so, the package is expected to increase farm incomes, food and nutrition security, and reduce poverty and vulnerability to extreme events and climate change. One of the key components of this package with readily quantifiable benefits would be dissemination of climate resilient agronomic practices, which may include switching crops to enhance crop suitability, employing improved crop varieties, or a number of other options. The potential benefits of three changes in agronomic practices aimed at enhancing productivity and resilience among farmers were estimated, namely:

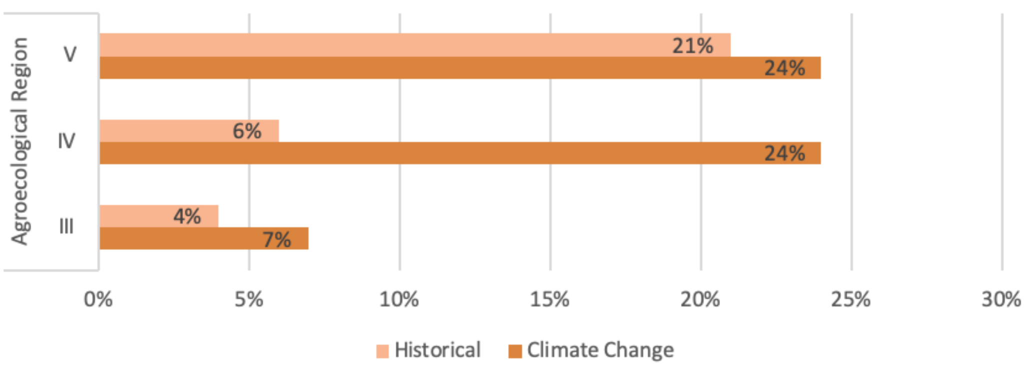
- **Switching to more suitable crops.** Sorghum requires less water than maize making it more resilient to drought or future climate change, which is especially important for smallholder farmers in Agro-ecological Regions III-V. Using a cropland suitability analysis (Sys et al. 1993), it was found that about 90% of the land in these regions is classified as suitable for sorghum while less than 20% of the land is suitable for maize (only 9% in Agro-ecological Region V), and most of the land is only marginally suitable. Under a hot and dry future climate, conditions worsen significantly for maize where reductions in precipitation leave about half of the marginally suitable land unsuitable. Sorghum is more resilient to drier conditions, with about 75-80% of the land maintaining a suitable classification (about 10-15% moves to marginally suitable land). Simulating the yield response to climate change, it was found that maize yields decline significantly for Agro-ecological Regions III-V as shown in Figure G-1, with yield reductions of 61% in Agro-ecological Region V. Again, Sorghum proves to be resilient to drier conditions with more moderate reductions, 11-20%. These results do not take into account market realities for the two different crops, nor possible cost implications for farmers.

Figure G1. Changes in Yield for Maize and Sorghum for the Median Climate Scenario in Agro-ecologcal Regions III-V



- **Drought- and heat-tolerant varieties provide a mechanism for farmers to increase yield and** climate resilience for crops. In Agro-ecological Regions III-V, drought and high temperatures regularly cause crop production shortages, which can be devastating for smallholder farmers. Switching to improved crop varieties does not require high up-front costs for infrastructure like other options such as installing drip irrigation systems. These varieties can increase yield by 6-21% in this area under historical conditions with greater benefits in the drier regions (Figure G-2). With drier future conditions, these benefits increase substantially to 24% in both Agro-ecological Region IV and V.

Figure G2. Yield Benefits from Drought- and Heat-tolerant Varieties of Maize for Historical and a Median Future Climate Scenario



- **Promoting crop diversification and moving away from monoculture not only increases productivity and climate resilience but can also increase soil carbon through soil sequestration.** A compilation of studies in Sub-Saharan Africa have shown that crop diversification can contribute to increasing soil carbon by about 0.5 tC/ha/yr (Powlson et al. 2015), which equates to over 1.8 tons CO_2e per hectare per year. If 10% of smallholder maize farmers in Agro-ecological Regions III to IV were to switch from monoculture to a diversified crop portfolio, national emissions would reduce by over 300,000 tCO_2e per year.

Summary of Impacts to CSA Pillars

- **Productivity:** Diversifying to smaller grains like sorghum is expected to increase **food security.** Drought- and heat-tolerant crop varieties not only maintain **more consistent productivity** from year to year, but are also expected **to increase crop yields by** roughly 7% across Agro-ecological Regions III-V.

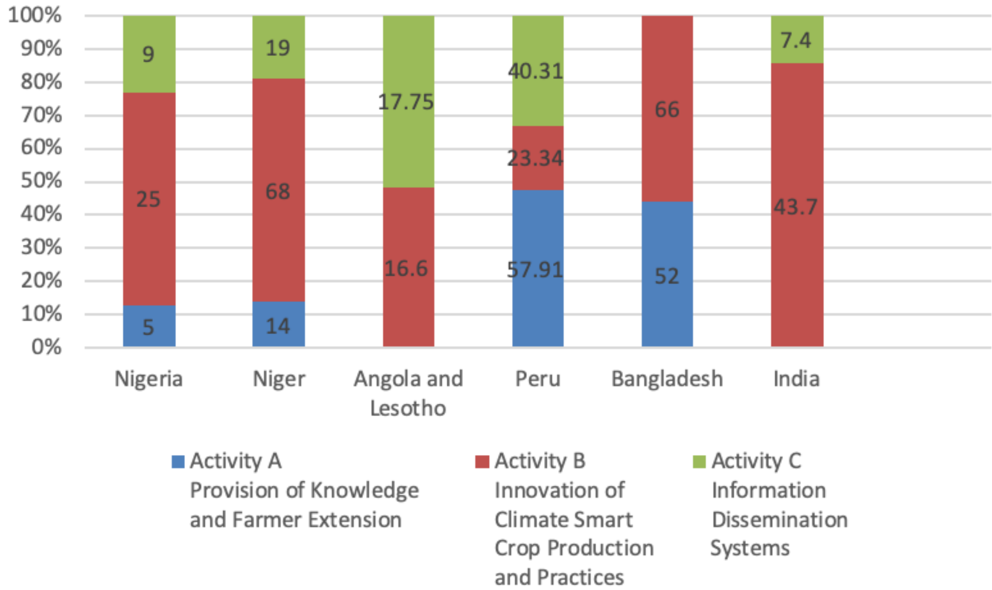
- **Climate Resilience:** Food security is a major concern for smallholder farmers in the drier regions of Zimbabwe, and as such, this package focusses primarily on achieving **improved climate resilience** through **advances in food security.** Sorghum is significantly more resilient to climate change than maize, with lesser yield reductions across Agro-ecological Regions III-V.

- **Mitigation:** Promoting **crop diversification** and moving away from monoculture not only increases productivity and climate resilience but can also **increase soil carbon through soil sequestration.** If 10% of smallholder maize farmers in Agro-ecological Regions III to IV were to switch from monoculture to more diversified crops, national emissions could be reduced by more than **300,000 tCO_2e** per year.

G.1.5 Cost Assessment

Projects focusing on capacity building and information dissemination have a significant range of costs. The components of past World Bank projects that are similar in their objectives to this package range from US$39 million to US$121.5 million. As shown in Appendix I, costs per beneficiary of these programs ranges widely, from $71 to $1000. As Figure G-3 reveals, generally, the production of innovative practices and systems is costlier than the dissemination of that knowledge.

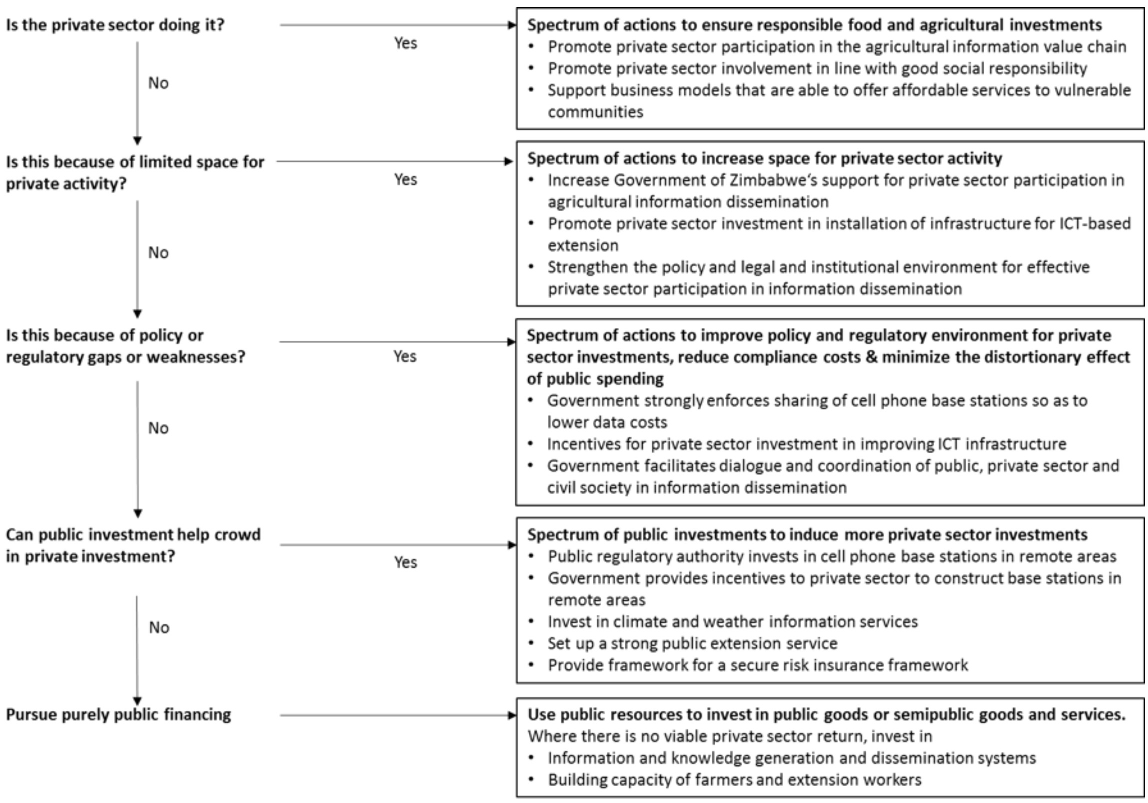
Figure G3. Component-Specific Costs of Work Bank Projects Similar to Package A



Based on these prior Project Appraisal Documents and the number of anticipated beneficiaries of this package, the initial estimated cost of Package A is US$50 million to US$75 million. The investment program would be scalable and focus on smallholder farmers in Agro-ecological Regions IV and V. The total number of potential beneficiaries from the extension services would be approximately 600,000 (ZIMSTAT 2016), which includes the smallholder maize, sorghum, and horticulture farmers located in Agro-ecological Regions IV-V. The World Bank projects in Nigeria, Niger, and Peru correspond closest to the activities proposed in this investment package. The higher costs of the project in Peru is likely due to its heavy focus on institutions as the main beneficiaries. Since the projects in Nigeria and Niger are aimed at farmers, their costs were taken as more representative for the proposed investment opportunities. The proposed package has a similar number of potential beneficiaries as the Niger project but is not looking to facilitate climate smart agronomic practices and technologies at the commune level. Therefore, the proposed cost of this package is between US$50 million to US$75 million. This translates to a cost of roughly $83 to $125 per beneficiary. Potential sources of financing to support this package are described in Appendix J.

G.1.6 Maximizing Finance for Development

The decision tree for maximizing finance for development for Package A is shown below. It indicates the various roles that the public and private sector could play in the implementation of this package of investments.



G.2 Package B: Sustainable Livelihoods through Diversified Livestock Systems

This package aims to secure the livelihoods of smallholder farmers through increased livestock productivity and diversified production systems. The focus is on smallholder livestock farmers in southern Zimbabwe, focusing on cattle, sheep, and goat production.

G.2.1 Context and Problem Statement

The cattle population in Zimbabwe is estimated to be between 4-5 million (Mashoko et al. 2007), with almost 90% of these animals located in the country's communal areas (Ndebele et al. 2007). The herd is predominantly found in the southern and western parts of the country, in regions that are semi-arid and characterized by poor grazing and limited access to water. Communal cattle are generally indigenous breeds or crossbreeds with mainly indigenous bloodlines. Indigenous breeds are considered less productive due to their smaller size (Francis and Sibanda 2001), which explains why the commercial sector has a greater proportion of exotic breeds and why a number of initiatives are underway that attempt to increase the proportion of exotic breeds in the smallholder sector. This perception is not necessarily supported by research, with numerous studies evidencing the advantages of indigenous breeds, including their hardiness (Khombe 2002), high fertility (Mpofu 2002), disease and heat tolerance (Assan 2012) as well as low feed requirements (Moyo 1995) in a semi-arid environment. Additionally, the production of goats and sheep occurs only at a small scale, despite the fact that small livestock are better suited to the semi-arid climate that prevails in the smallholder farming sector.

Cattle fulfil a variety of important roles in communal areas, including the provision of milk, meat, hides, manure and draught power, generating income through the sale of animals or their products. In addition, they serve as a status symbol, acting as an indication of a person's wealth, as well as being used as an investment. They are also culturally important for their role in bride price (lobola) payments. Goats are also culturally important as well as being a source of ready cash during times of need. The contribution of smallholder livestock production to the beef market is low, as indicated by low off-take from the sector. The same is true for commercial goat meat.

Attaining commercial production and productivity levels among smallholders in Zimbabwe continues to be a challenge. The causes for low productivity are varied and include reliance on low nutrient feed due to the limited availability of fodder on communal grazing lands, high prevalence of diseases and parasites, lack of access to extension services, low levels of livestock management including low vaccination rates, and inadequately developed breeding programs. Successfully increasing livestock productivity has the potential to greatly improve household coping capacity in the smallholder farming sector because, compared to crops, livestock can function as a calorie reservoir and can help communities cope with difficult times.

Current low communal livestock productivity levels are projected to be further negatively impacted by the impacts of climate change. As described in Section 2.2 of the main report, Zimbabwe is expected to face rising temperatures and changes in rainfall patterns. These are a threat to the sustainability of the livelihoods of smallholder farmers, with farm incomes from beef cattle projected to fall by nearly 15% due to heat stress by 2040. Sheep and chickens are expected to be impacted to an even greater degree, with income reductions around 15% and 20%, respectively. Goats on the other hand, are less impacted, with estimated income reductions of less than 10% (see Section 4.1 of the main report). Furthermore, future population growth and urbanization will put pressure on existing grazing areas. Communal grazing regimes currently contribute to land degradation, with these impacts expected to worsen as larger communal herds rely on more limited grazing resources.

A few initiatives are currently underway to address the livestock sector's productivity challenges. For instance, the Government of Zimbabwe, the European Union and FAO are engaged in a program to help smallholder farmers boost their productivity and engage in commercial agriculture. The $10 million livestock component of this program is focused on supporting 40, 000 rural farmers in the western part of Zimbabwe. The program rehabilitates shared livestock resources such as dip tanks, boreholes and sale pens and trains participants in livestock production and health. It also emphasizes reducing livestock mortality and morbidity, as well as training of field extension staff. Selected community members are trained to identify and manage common livestock diseases. Basic veterinary kits have been made available to farmers to ensure routine management activities are carried out effectively. This recommended package is complementary to such existing initiatives, proposing to invest in alternative feedstuffs, disease and pest prevention and treatment, and enhanced extension services. Extension training would target appropriate livestock breeding strategies, and encourage farmers to switch from cattle to more heat resilient livestock like goats and sheep.

G.2.2 Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **National Agricultural Policy Framework:** Package addresses several pillars, and most prominently Pillar 8: Resilient and Sustainable Agriculture
- **Government of Zimbabwe CSA Framework:** Package addresses Objectives 1, 2, and 4 focused on access to information, application of CSA practices, and capacity for implementation.
- **Vision 2030 and Transitional Stabilization Program:** Package enhances farm productivity and incomes.

The potential of livestock to contribute to sustainable agriculture-dependent livelihoods and increase the market share of red meat present an opportunity, not just to rural livelihoods, but the economy as a whole. The National Agricultural Policy Framework recognizes that sustainability of agriculture and food systems is only possible when livestock production adapts to climate shocks. While the policy environment points to the need for climate resilient agricultural practices in general and climate smart livestock production in particular, this is not supported by any practical programs. This explains why the National Agricultural Policy Framework proposes the following strategic objectives:

1. to enhance the resilience of agriculture production systems to climate change, pest and disease attacks;
2. to mainstream climate change impacts in all programs and subsectors and mobilise funds for climate change adaptation and mitigation programs;
3. to enhance local capacity to generate, disseminate and understand climate information and best practices;
4. to mainstream resource use efficiency and sustainable natural resource management in agricultural production systems through capacity building of extension services and farmers and payment for ecosystem service; and
5. to promote widespread uptake of sustainable agricultural intensification approaches and technologies.

Subsequently, a SWOT Analysis was conducted for this package (shown in Table G-2), with the intention of summarizing which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

Table G2. SWOT Analysis for Package B

	Helpful	Harmful
Internal	**Strengths** • There is a significant cattle herd owned by small-holder farmers. • Indigenous livestock breeds are generally more climate resilient than exotic breeds. • Farmers have experience in raising small livestock (mainly goats), indicating good potential for diversification away from cattle. • Government has a strong restocking livestock program. • Many actors are promoting livestock production in the small-holder farming sector.	**Weaknesses** • Poor quality feed and low water availability result in poor cattle performance. • Common livestock breeds are not resilient to climate change. • Poor extension services for sustainable and resilient livestock production. • Low commercialization indicated by low productivity, poor markets and low commercial offtake.
External	**Opportunities** • Current low meat consumption in the country represents a growing market opportunity. • High demand for leather as a raw material. • There is donor interest in the small-holder livestock farming sub-sector.	**Threats** • Lack of available finance for strengthening public extension services. • Limited funding for small-holder livestock production and poorly structured Command Livestock Programme. • Low purchasing power due to current macroeconomic conditions. • Private sector is poorly linked to the small-holder livestock farming sector. • Poor and deteriorating rural infrastructure.

Thus, summarizing the key take-aways of this SWOT analysis, the major policy challenges facing this package are:

- Poor financial and information support for appropriate breeding, feed and health services;
- Poorly developed markets which hinder commercialization of the sub-sector; and
- Over-reliance on cattle by the smallholder sector, with cattle being less climate resilient than other livestock.

To address these policy challenges the following policy actions are recommended:

- Developing a special investment facility to promote appropriate breeds through traditional breeding and artificial insemination, as well as alternative feed especially in the dry season, and disease control;
- Promoting livestock diversification to small livestock, such as goats, which are more climate resilient, by developing multi-purpose breeds; and
- Developing local and external markets for livestock products.

G.2.3 Investment Opportunities

This package includes a number of specific objectives and investment activities, as described below. For each of these investment opportunities, some thoughts on implementation are provided by illustrating how a similar investment was implemented in recent World Bank projects. A summary of all the past projects examined is presented in Appendix I.2.

- **Objective: Invest in improved/alternative feeding systems** incorporating production and transportation of grass, fodder, hay, crop residues and supplements in the dry season.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) conduct a needs assessment in terms of the number and type of livestock affected, type and quantity of feed, ii) development of public, private sector and civil society platforms for making feed available where it is most needed, as coordinated by the Ministry of Agriculture, and iii) monitoring of efficiency and effectiveness of the various feeding systems in use.

  Similar previous project from which to draw lessons learned: A component of a recent World Bank project in Cameroon assisted the country's Ministry of Livestock, Fishery, and Animal Industries by providing financial assistance to seed centers and by enabling sustainable feed production at the farm level. Providing access to improved fodder was a specific aim of the project.

- **Objective: Invest in climate resilient livestock breeding program and extension services** incorporating (1) the adoption of indigenous and small breeds, (2) screening of future diseases and pests because of climate change, (3) switching to small ruminants (goats and sheep), and breeds of goats that provide both meat and milk, and (4) improved animal husbandry & health, climate resilient fodder production and processing.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) assessment of the current situation across the four sub-objectives listed above, ii) development of a research program to provide climate resilient interventions, as coordinated by the Ministry of Agriculture, and iii) introduction of improved breeds (through traditional methods and artificial insemination), by Government, through the extension, veterinary departments and the private sector.

  S**imilar previous project from which to draw lessons learned:** In an effort to alleviate the burden of animal diseases on smallholder farmers, a project in Burkina Faso funded a wide variety of activities in animal health services. These activities included reports on the frequency and occurrence of certain diseases, the distribution of over 30 million doses of vaccines for diseases affecting cattle, poultry, and small ruminants, and the development of a Vaccine Overhauling Unit to efficiently vaccinate throughout the country.

- **Objective: Invest in commercialization of livestock in the smallholder farming sector** which is home to the bulk of the country's cattle herd through i) improved livestock management, and 2) access to markets and value addition by resuscitating the leather industry.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) Government will revive cattle markets and will establish goat markets at the local level, with the cooperation of the private sector, ii) Government facilitates, with cooperation of the private sector, diversification of benefits by promoting a small scale leather industry, and iii) Government promotes livestock insurance in the smallholder farming sector.

Similar previous project from which to draw lessons learned: A recent project in Mali provided market access to livestock value chains for cattle, poultry, and fish farming by overseeing the creation of inter-professional organizations and professional partnerships. It also strategically introduced infrastructure by way of cattle and fish markets, as well as milk collection and conservation centers.

G.2.4 Quantified Estimate of Impact

This package would enhance livestock farmers' productivity, resilience, and income security while reducing emissions. The potential benefits in this package of improved feed and switching from cattle to smaller livestock were quantified:

- **Improved feed for cattle has been shown to reduce methane emissions significantly and improve cattle health for better milk production, slaughter yield, and birth success rates** (GoZ 2016, Andeweg and Reisinger 2015, among others). Homegrown fodder also reduces herding time and labor, especially in the dry season, and cattle eat and drink less water from the reduction in roaming distance. Velvet beans are ideal for providing leguminous hay because they are not labor-intensive, are native to tropical regions, are drought- and heat-tolerant, and have had success in the drier regions of Zimbabwe (CTCN 2017). By providing velvet bean fodder during the dry season, total food intake reduces by 63% and methane emissions from cows reduces by 56% (Table G-3). A program like this would increase profits for non-dairy cattle farmers with a benefit-to-cost ratio of about 1.5 to 1.9.

- **Switching from cattle to smaller livestock increases protein production, provides a more climate resilient food source, and significantly reduces greenhouse gas emissions.** For example, goats can survive with less water and can forage on lower quality grasses than cattle without reductions in productivity. Goats are also more efficient protein producers, generating almost four times as much protein per unit of food intake than communal cattle. Switching to small livestock can also significantly reduce emissions. For example, the modeling indicates that goats produce 74% less emissions per unit of protein produced than communal cattle in Zimbabwe (see Table G-3). In addition, goats are less susceptible to heat impacts, which are expected to worsen, especially in southern Zimbabwe. The analysis shows that while climate change drives reductions in the income from beef cattle by 11-13% by 2040, income from goats only decreases by 7-9% (see Figure 4-1 in the main report).

Table G3. Change in Feed Intake, Protein per Unit of Feed, and Emissions Intensity for the CSA Options of Improved Feed and Switching to Goats, as compared to Communal Cattle

INDICATOR	IMPROVE FEED	SWITCH TO GOATS
Feed Intake	-63%	-96%
Protein Per Unit of Feed	174%	284%
Emission Intensity of Meat	-56%	-74%

Summary of Impacts to CSA Pillars

- **Productivity:** Healthier cows produce more milk and meat. Improving cattle diet can greatly increase profits and reduce mortality. Switching to goats for meat production can also increase productivity and lower costs since goats have a significantly higher intake to protein ratio than cattle. Improved livestock productivity in turn positively impacts **poverty and food security** among farmers.

- **Climate Resilience:** Access to alternative feed for livestock is expected to greatly reduce livestock losses in drought years and/or during extended dry seasons. In addition, **diversification** of livestock, such as switching from cattle to goats, which are more drought resistant and therefore have lower mortality in dry conditions, further improves **food security** by providing a more climate resilient source of meat.

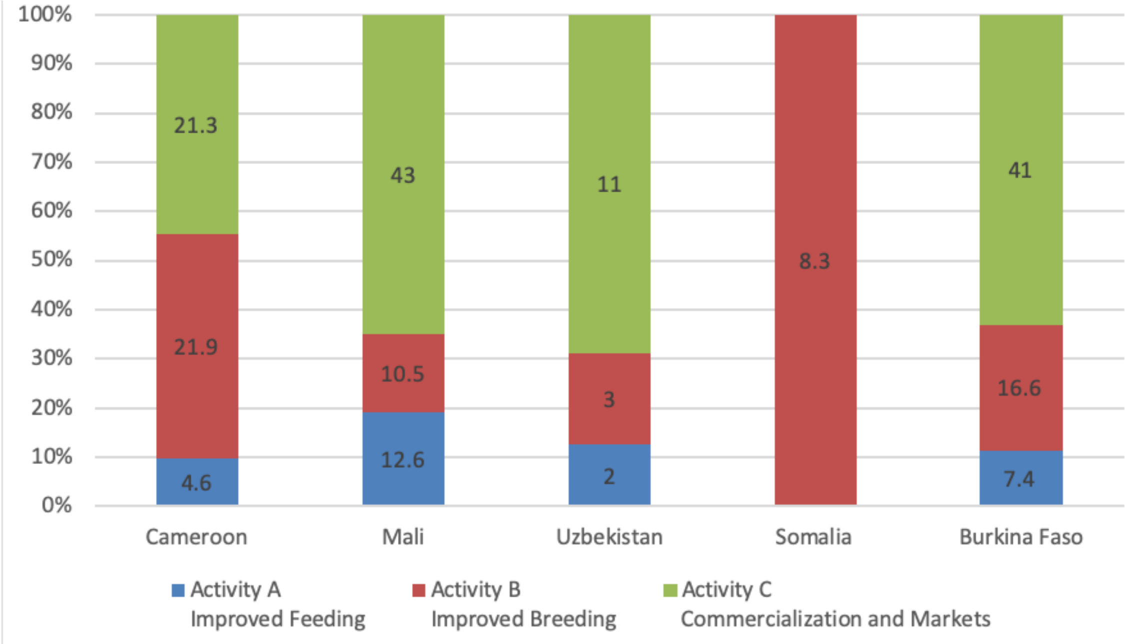
- **Mitigation:** Improved feed for cattle reduces the emissions per unit protein produced, as lower quality feed sources are less efficiently metabolized and are associated higher methane production per unit. **Diversification** of livestock to smaller species also reduces emissions – for example, goats produce only 26% of the emissions associated with cattle. Furthermore, access to alternative feed may reduce savannah burning as there is less need for the "green bite" when grass and crop residues are scarce in the late dry season.

G.2.5 Cost Assessment

Projects focusing on the diversification of livestock systems have a significant range of costs. The components of past World Bank projects that are similar in their objectives to this package range from US$8 million to US$66 million. Associated costs per beneficiary range from $90 to $6800 for the overall investment programs that include these subcomponents (see Appendix I).

Despite the range of costs, as Figure G-4 demonstrates, typically around 35-50% of the total cost of the components of each package is dedicated to enhancing animal health services through activities such as breeding practices to address disease and climate-related issues as well as the enhancement of and dissemination of knowledge about livestock feeding. In general, the money allocated to investing in alternative feedstuffs is generally lower than health services. There are important exceptions to this trend, as in the case of Mali's Livestock Sector Development Support Project, in which over half the costs of animal health services in that project were dedicated to feed improvement. Unlike other projects that focus on access to high quality inputs, the project in Mali also specifically designated funds for the construction of requisite buildings and necessary equipment for feed improvements along with the creation and dissemination of medicine studies and technical and economic guidelines concerning feeding practices. Much of the cost depends on the status of the existing physical and knowledge infrastructures for livestock diversification. Figure G-4 also shows that, in addition to the technology and infrastructure, more than half of the costs for components similar to the objectives of Package B generally stem from the commercialization and marketing of the benefits derived from new technologies and improved practices.

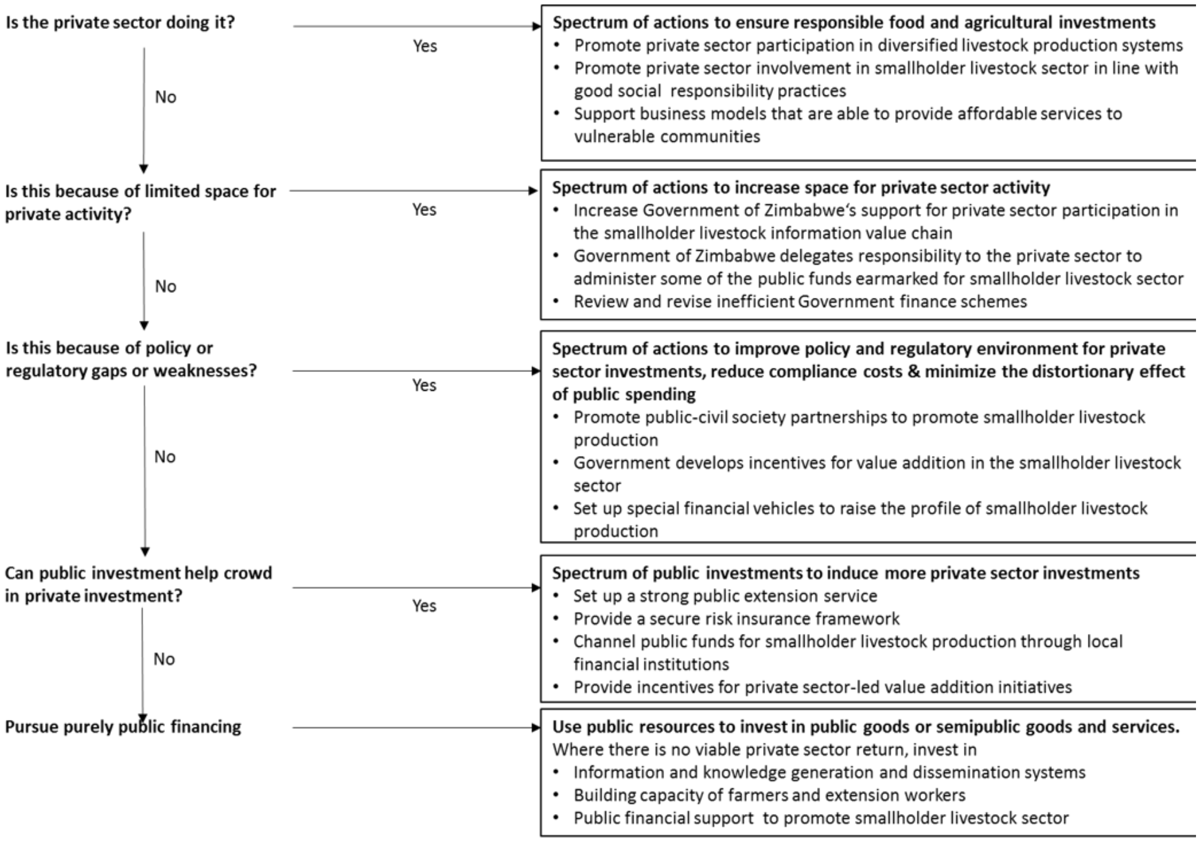
Figure G4. Component-Specific Costs of Work Bank Projects Similar to Package B



Based on these prior Project Appraisal Documents and the number of anticipated beneficiaries of this package, the estimated initial cost of Package B is US$30 million to US$60 million. The investment program would focus on smallholder farmers in Southern Zimbabwe. Beneficiaries of the package—through extension, enhanced feed, and other components—would potentially include the 300,000 smallholder livestock farmers in the southern part of the country (ZIMSTAT 2016). The World Bank projects in Cameroon, Mali, and Burkina Faso are generally representative of the proposed investment opportunities in this package, and this package assumes that the costs for feed inputs and health services are similar in the Zimbabwean context. However, lower overall costs are anticipated because those projects are heavily focused on access to financing and investment as well as value chain development. For that reason, the proposed cost of this package is between US$30 million and US$60 million. The package would thus cost between an estimated $100 to $200 per beneficiary. Potential sources of financing to support this package are described in Appendix J.

G.2.6 Maximizing Finance for Development

The decision tree for maximizing finance for development for Package B is shown below. It indicates the various roles that the public and private sector could play in the implementation of this package of investments.



G.3 Package C: Water Harvesting for Resilient Crop and Livestock Production

This package promotes water harvesting to enhance resilient crop and livestock production; sustainable soil and water conservation through in situ water harvesting; Conservation Agriculture; and multi-purpose small-scale infrastructure for domestic use, livestock watering and small scale irrigation. Investments in this package focus on smallholder farmers in Agro-ecological Regions III-V, characterized by low and erratic rainfall.

G.3.1 Context and Problem Statement

Practically all farmers in Zimbabwe (89%) are smallholders that are mostly reliant on rain-fed agriculture (CIAT World Bank 2017). Yet only 37% of Zimbabwe's land area receives sufficient rainfall to be considered adequate for rain-fed crop production (FAO 2000). Thus, many farmers face a high risk of crop failure each year due to droughts or delayed onset of seasonal rains. Access to some form of irrigation scheme would reduce this vulnerability, securing water not just for domestic purposes, but also for livestock and crop production.

Irrigation plays a significant role in successful crop production, contributing 20% of the value of agricultural crops in Zimbabwe (Aquastat 2016; Manzungu et al. 2018a). However, only half of the land suitable for irrigated agriculture is equipped for irrigation (CIAT World Bank 2017), with an estimated 60% of existing irrigation schemes either not functional or only partly functional (FAO 2016). This is in spite of the fact that there is enough water available in existing reservoirs to irrigate an additional 6,000 hectares of land (GoZ 2013). However, formal, large-scale irrigation schemes require substantial up-front investment. Investments in conventional smallholder irrigation schemes are as high as USD10,000/hectare, much higher than in farmer-led informal small scale irrigation.

Water harvesting, incorporating in situ water harvesting at field scale, small scale infrastructure and Conservation Agriculture, can improve productivity and resilience of smallholder farmers at a fraction of the capital cost required for formal irrigation infrastructure. In addition to providing water for small scale irrigation and rain-fed crop production at the field level, water harvesting has a variety of additional benefits. It can help control high soil erosion rates on croplands and grazing areas. In addition to this catchment protection, water harvesting also contributes to increased groundwater recharge. Groundwater is a source of water for domestic needs and vegetable production in many rural areas of Zimbabwe.

Improved water availability is key for increasing crop and livestock productivity. As discussed in detail in Section 4.2 of the main report, irrigation has the potential to dramatically improve crop yields in Zimbabwe. This is also true in livestock production. Water makes up approximately 60-70% of the body weight of livestock species and it is key for improved physiological functions of the body, which include digestion, reproduction, maintenance of body temperature and weight gain. Poor water intake leads to poor feed intake and consequently, a poor growth rate. Withholding water or supplying water of poor quality will have an overall negative impact on the profitability of a farm, as the growth rate, milk production and general health status of the herd decreases. Since many cattle die from inadequate grazing and limited water in the semi-arid areas of Zimbabwe, it is important to promote integrated water and soil systems operating within a watershed framework that simultaneously support both crop and livestock production, as well as natural resource systems. Improved crop and livestock productivity in turn have a positive impact on household food, water and income security in the face of a variable and changing climate.

G.3.2 Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **National Agriculture Policy Framework:** Package addresses Pillars 1, 2, 3 and 8, which includes Resilient and Sustainable Agriculture and Development of Agricultural Infrastructure.
- **Government of Zimbabwe CSA Framework:** Package addresses Objectives 1, 2, and 4 focused on access to information, application of CSA practices, and capacity for implementation.
- **Vision 2030 and Transitional Stabilization Program:** Package enhances farm productivity and incomes.

While the provision of water for sustainable crop and livestock production in the smallholder farming sector is critical, steps taken to address this challenge has been limited to date. Successive administrations, stretching back to the colonial era, have invested in a multitude of expensive formal smallholder irrigation systems, which have been characterized by poor governance, inadequate operation and maintenance, and agricultural productivity challenges. As a result, these existing irrigation schemes are not the source of food security, agricultural growth and socio-economic development they were originally conceived. Many of the schemes cannot operate without government or donor financial support, and they undergo endless rehabilitation. Despite their dominance in the agricultural discourse, less than 1% of smallholder farmers actually have access to formal irrigation schemes. These schemes are often poorly designed, as they do not provide water for livestock and domestic uses, which tend to be lacking in smallholder farming sector. Many of the existing schemes are also not water secure because of widespread catchment degradation.

It is clear that continuing on this trajectory will not improve the socio-economic status of many smallholder farmers as far as access to irrigation is concerned. Informal small scale irrigation, which is privately developed, managed and operated by farmers, does not currently receive government acknowledgement and support. This situation is a consequence of the lack of clear government policy with regards to ensuring water security for smallholder farmers. By focusing on water harvesting for small scale irrigation, and water for domestic and livestock needs, coupled with soil and water conservation, this package aims to ensure sustainable utilization of existing water resources, an important dimension of agriculture in a changing climate. The draft Agricultural Mechanization and Irrigation Development Policy and Strategy recognizes the importance of the interventions described in this package.

A SWOT Analysis was conducted for this package (shown in Table G-4), with the intention of identifying which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

Table G4. SWOT Analysis for Package C

	Helpful	Harmful
Internal	**Strengths** • In situ water harvesting technologies and techniques are well known and have been tried in the country. • Small scale water infrastructure exists in the country. • Conservation Agriculture is being widely promoted in the country.	**Weaknesses** • Low adoption of in situ water harvesting and small scale water infrastructure by farmers. • Conservation Agriculture is too manual. • Poor farming methods and poor soil and water conservation, resulting in poor catchment management. • Extension services do not include a strong soil and water conservation and water use efficiency component.
External	**Opportunities** • A number of projects that include elements of soil and water conservation are being implemented in the country. • Environmental Management and Water Acts promote sustainable catchment protection. • Environment Fund and Water Fund can support sustainable soil and water conservation.	**Threats** • Limited public financing for soil and water conservation extension services and adoption. • Limited financing for adoption of water-efficient technologies. • Poor appreciation of the benefits of environmental services. • Unsustainable groundwater exploitation. • Lack of integrated natural resource management.

Thus, summarizing the key take-aways of this SWOT analysis, the major policy challenges facing this package are:

- Poor catchment protection due to poor enforcement of existing legal frameworks and inadequate coordination between the different agencies involved;
- Inadequate investment in infrastructure and low utilization of existing water resources; and

- Lack of institutional mechanisms for the operation and maintenance of small scale infrastructure.

To address these policy challenges the following policy actions are recommended:

- Strengthen the implementation of existing legal and institutional frameworks for catchment protection, including soil and water conservation;
- Create a special facility for the development, operation and maintenance of small infrastructure as a way to climate-proof production in spite of frequent droughts; and
- Promote sustainable and integrated use of existing water resources, including surface and groundwater.

G.3.3 Investment Opportunities

This package includes a number of specific objectives and investment activities, as described below. For each of these investment opportunities, some thoughts on implementation are provided by illustrating how a similar investment was implemented in recent World Bank projects. A summary of all the past projects examined is presented in Appendix I.3.

- **Objective: Invest in soil and water conservation techniques as part of integrated catchment management** that incorporates water, land and environment sectors. The first step in this process will be a holistic study of the catchment to evaluate current land use and agronomic practices in order to tailor the interventions to the catchment context. This is essential in order to avoid investing in measures that fail or are not adopted. For example, constructing a community pond may need to be accompanied by soil conservation techniques in order to avoid rapid sedimentation of the reservoir.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) conduct an inventory of soil and water conservation, agronomic practices and other measures, and ii) practical demonstrations of mechanisms/measures that are effective in specified contexts.

  Similar previous project from which to draw lessons learned: In Timor Leste, a World Bank project assisted in the development of a Watershed Agricultural Development Plan, which focused on increasing the production of crops and livestock as well as identifying small-scale infrastructure and equipment that contributed to sustainable land management. Specific funds were reserved for proposals focusing on water harvesting technologies as well erosion control and watershed protection works, such as shelterbelt plantations.

- **Objective: Invest in situ water harvesting** (e.g. enhanced soil water retention) that improves and complements Conservation Agriculture practices. These practices may include mulching, limited or zero till agriculture, crop rotations, agro-forestry approaches, or other practices that enhance water retention in the soil.

  Specific activities: This objective will be achieved by: i) practical demonstrations of relevant techniques, and ii) monitoring water retention at the field scale as well as groundwater recharge.

  Similar previous project from which to draw lessons learned: Conservation Agriculture and integrated soil fertility management were critical aspects in developing smallholder agriculture in a recent project in Lesotho. The project study identified crop rotation, mulching, contour ploughing, and intercropping as technologies that all contributed to productivity, resilience, and mitigation.

- **Objective: Invest in small scale water infrastructure** for supplementary irrigation, livestock watering and domestic water. This could include rain barrels or small scale water harvesting such as community-level ponds. The aim would not be to develop large scale irrigation infrastructure, but instead focus on providing water for supplemental irrigation to cost-effectively improve incomes.

  Specific activities: To achieve this objective, the following will be undertaken: i) Government, through the Zimbabwe National Water Authority and Department of Irrigation, promotes multi-purpose water use schemes, ii) Government adopts best practices to guide small scale water infrastructure, and iii) practical demonstrations of the interventions.

  Similar previous project from which to draw lessons learned: In an effort to augment drought-resilience and preparedness in Malawi, a recent World Bank study addressed critical infrastructure that was in disrepair but also focused on the rehabilitation of small earth dams and the construction of nearly 30 excavated tanks.

- **Objective: Invest in building the capacity of extension workers and farmers** in sustainable water harvesting. This training will focus on soil and water conservation techniques, operation & maintenance of new infrastructure, and Conservation Agriculture practices.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) conduct a needs assessment for building capacity of extension workers and farmers, ii) design and implement a training program for extension workers and farmers, and iii) monitor the effectiveness of training.

  Similar previous project from which to draw lessons learned: A recent World Bank project in the Commonwealth of Dominica highlighted the importance of training and technical assistance to farmers in technologies such as contour farming, conservation buffers, reduced tillage, and intercropping. This assistance was provided to farmers through the Ministry of Agriculture and Fisheries' extension services as well as in practical demonstrations through Farmer Field School.

G.3.4 Quantified Estimate of Impact

This package would enhance water availability for crops and livestock, thus allowing for increased income through several possible channels: increasing yields of existing cropping or livestock, adding a second crop, or moving toward commercial production. The potential benefits of agro-forestry approaches, water harvesting, and conservation tillage were quantified:

- **Trees provide leaves for mulching and efficiently reduce water losses from soil evaporation, especially in hot and dry conditions.** The key to reducing evaporation is to reduce exposure of wet soil to the atmosphere. The amount of wet soil surface exposed can be reduced with mulching and shading from tree crops planted around row crops like maize and sorghum. Siriri et al. (2012) find that trees planted with maize or beans can reduce soil evaporation after rainfall by 15-24% and increase soil wetness by 9-18% compared to single crop methods. Drier regions like Agro-ecological Region V could benefit greatly from effective tree-crop combinations, effectively making rainwater more efficient when water is scarce.

- **A variety of water harvesting systems can significantly enhance yields and provide assurance in hot and dry years.** While full irrigation systems may be too expensive for smallholder farmers, in situ rainwater harvesting can provide supplemental irrigation, which can reduce the volatility of crop yields and food prices—especially an issue in the drier regions of Zimbabwe, namely Agro-ecological Regions IV and V. Collection of water during the wet season can also help to extend the growing season, providing additional income. Hagblade and Tembo (2003) and Conservation Farming Unit (2009) reported that farmers in Zambia lost about 1.5% of their potential maize yield for each day that maize was planted later near the start of the wet season. Table G-5 shows the benefits of irrigation in Agro-ecological Region V. These are considerably higher than the nation-wide benefits. For example, benefits of irrigation for maize is almost two times but for Agro-ecological Region V it is 4.5 times higher. Although water requirements will be higher under climate change, irrigation will be more beneficial (given irrigation water is available), with yield factors of 11.6 for maize and 9.3 for groundnut. Even supplemental irrigation can greatly increase yields if irrigation timing is optimized. This analysis shows that irrigating as little as 4.5 mm/week (i.e. 30% of the growing season rainfall) throughout the growing season has the potential to double maize yields under conditions consistent with the historical climate, and quadruple yields under climate change.

Table G5. Benefits of Irrigation for Agro-ecological Region V (Yield Factor is 1 for historical rainfed yield)

	Historical	Climate Change
Maize	4.52	11.62
Tobacco	2.94	4.28
Soybean	3.22	6.20
Cotton	3.45	6.76
Dry Bean	1.64	3.41
Sunflower	1.48	2.14
Sweet Potato	2.10	2.91
Groundnut	3.47	9.31
Sorghum	1.95	2.38

- **Conservation tillage helps to reduce erosion, improve soil fertility, and reduce emissions**. It has been shown to be effective in Zimbabwe for maize, sorghum, cotton and groundnuts (CIAT World Bank 2017). This analysis shows that farmers stand to gain, on average, $5.67/ha per year by switching to conservation tillage practices nation-wide. Mitigation benefits from conservation tillage include carbon sequestration and reduced diesel emissions from tractor use. While decreased tractor use may not apply to many farmers, increased soil carbon uptake from conservation tillage reduces emissions by about 0.18 tCO_2e per hectare per year. If conservation tillage were adopted in Agro-ecological Region V, soil carbon sequestration alone would decrease emissions by 6,400 tCO_2e / year.

Summary of Impacts to CSA Pillars

- **Productivity:** Access to irrigation options would greatly enhance productivity in Agro-ecological Region V. While full irrigation would increase yields by as much as 4.5 times for maize, some irrigation through in situ rainwater harvesting could still double maize yields. Also, conservation tillage can save farmers time and money due to reduced labor, among other factors.

- **Climate Resilience:** Planting trees for mulching and shade reduces soil evaporation, especially in dry years. As conditions are expected to be drier under climate change, both trees and supplemental irrigation would be even more effective in the future, greatly enhancing future **food** and nutrition security compared to current practices. The same 4.5 mm/week of supplemental irrigation that would double yields under historical conditions would quadruple yields under climate change.

- **Mitigation:** Conservation tillage has the potential to decrease national emissions by about 6,400 tCO_2e per year in Agro-ecological V due to soil sequestration, as compared to current practices. If this is combined with other CSA options that increase yields, these emissions reductions are expected to further increase.

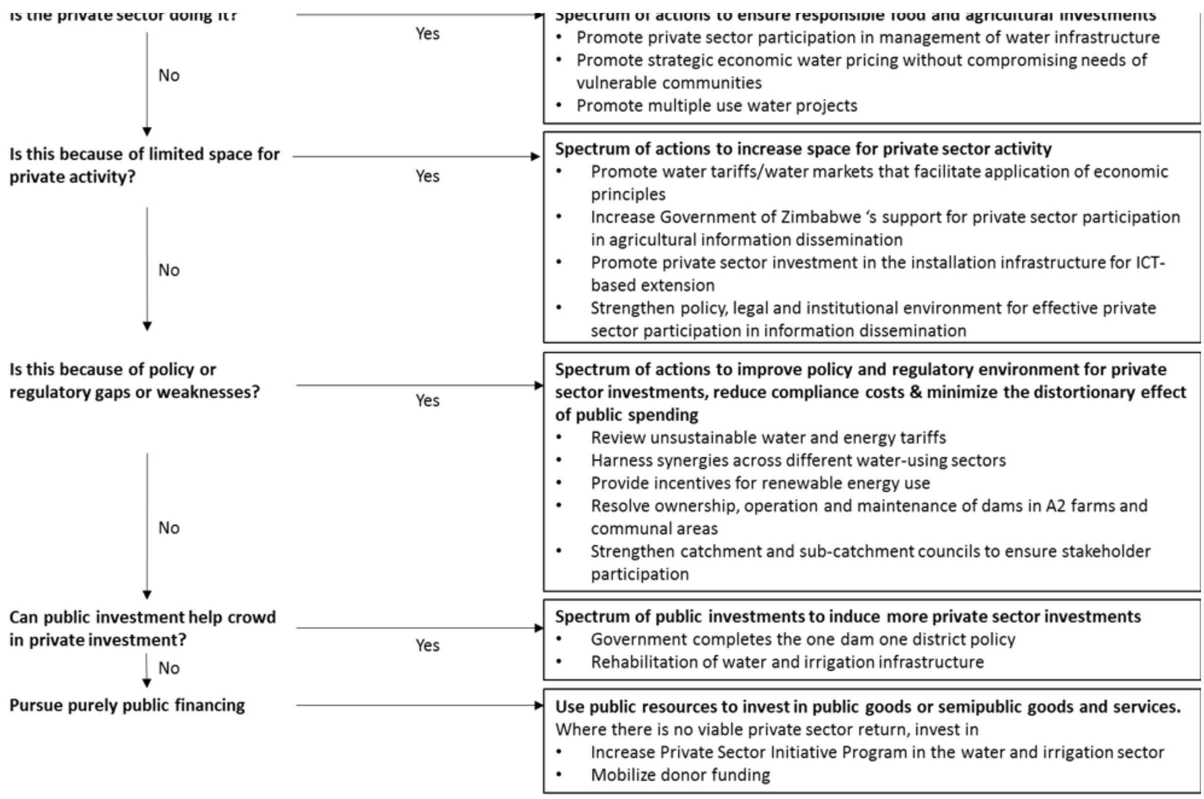
G.3.5 Cost Assessment

Projects incorporating water and soil conservation measures have a modest range of costs. The components of past World Bank projects that include similar objectives, including Conservation Agriculture, in-situ rainwater harvesting, soil conservation, and extension services, to those in this package range from US$3.1 million to US$12 million. More expensive World Bank projects that include similar objectives are primarily focused on the major extension or reworking of irrigation infrastructure, such as the US$68 million Disaster Vulnerability Reduction Project in Saint Lucia or the USD$187 million Sindh Irrigated Agriculture Productivity Enhancement Project in Pakistan. Further, the package investment opportunities are generally presented within the same component or subcomponent of comparable World Bank projects, making specific cost comparisons challenging. One discernable trend, however, is that, unlike Packages A and B, the primary cost of these investment opportunities is not in providing agricultural inputs or generating knowledge but rather in the dissemination of and support for climate-smart soil and water practices to farmers. As shown in Appendix I, the cost per beneficiary of these projects ranges from $49 to over $6000.

Based on these prior Project Appraisal Documents and the number of anticipated beneficiaries of this package, the initial estimated cost of Package C is US$75 million to US$100 million. The investment program would be highly scalable and focus on smallholder farmers in Agro-ecological Regions IV and V where water is most scarce. There would be 800,000 potential beneficiaries of this package (ZIMSTAT 2016), which includes the smallholder farmers in Region IV and V. The components of the World Bank project in Lesotho most closely align with the proposed investments to increase water availability. The projects differ in that the proposed investments focus more on the development and implementation of water and soil conservation techniques, whereas the Lesotho project incorporated improved nutrition. While there is a comparable number of potential beneficiaries, the main determinant of cost is the size of the country and the corresponding scope of irrigation rehabilitation. Lesotho is less than 10% the area of Zimbabwe, and the recent World Bank project focused on rehabilitating or installing new irrigation infrastructure on less than 3,000 hectares. Because this package envisions a much greater scope, the estimated cost is between US$75 million and US$100 million. Per beneficiary costs would range from $94 to $125. A general description of the financing landscape in Zimbabwe is provided in Appendix J.

G.3.6 Maximizing Finance for Development

The decision tree for maximizing finance for development for Package C is shown below. It indicates the various roles that the public and private sector could play in the implementation of this package of investments.



G.4 Package D: Woman- and Youth-focused Value Chain Development

This package aims to increase the productivity and resilience of women- and youth-run smallholder farms in peri-urban areas by developing all aspects of crop and livestock value chains. The focus is on women and youth-owned farms in peri-urban areas. Agricultural product focus would primarily include poultry, vegetables, and potentially goats or other small livestock.

G.4.1 Context and Problem Statement

Women and youth are two particularly vulnerable groups active in Zimbabwe's agricultural sector. Female participation in the Zimbabwean labor market is 78.5% compared to 89.1% for men (World Bank, 2019) and around 50% of rural households are headed by women. At the same time, the 62% of Zimbabwe's population that is under 25 years old (UNFPA 2019) faces high rates of unemployment due to the economic challenges of the past decade, which have driven many to seek jobs in the agricultural sector.

Women and youth face a particular set of issues compared to other sectors of the population active in agriculture. They face diverse institutional, legal, economic and social barriers to increasing their agricultural productivity (World Bank 2016). Women, for instance, face lower access to productive inputs such as land, labor, fertilizer, improved seeds, and agricultural information. They subsequently also experience lower returns to these inputs due to cultural and social norms (e.g. women tend to carry the greater burden of domestic chores, impeding their ability to supervise or conduct farming activities), institutional constraints, and market failures. Additionally, there are challenges across every step of the agriculture value chain, including access to financing, knowledge of appropriate agronomic practices, and access to markets. These issues have been especially concentrated in urban and peri-urban areas, where women- and youth-owned farms supply poultry, vegetables, and other products to urban residents.

Women, youth and other vulnerable populations are particularly affected by climate variability and extreme events. Women in poverty are heavily reliant on natural resources for their livelihoods and generally have fewer available resources to cope with shocks such as droughts, floods and food shortages. Additionally, poor people's adaptive capacity is often undermined by lower education levels, limited access to resources and alternative livelihood options, discriminatory social norms that affect their access to labor markets and decent work, and a lack of long-term institutional planning, policy, and programmatic support for resilience strengthening activities. Often this leads to negative coping strategies, such as mothers reducing their own food intake, which has subsequent impacts on health and nutrition; withdrawing children from school or marrying off daughters to reduce the number of mouths to feed (or bring new assets into the household), which may jeopardize the well-being of children with inter-generational consequences. Thus, an effective response to climate change in Zimbabwe will need to consider not just resilience and the building of adaptive capacity among vulnerable populations such as women and youth, but also the social cohesion of these populations.

Furthermore, globally, women are more vulnerable to disasters than men, experiencing higher mortality rates, stemming from cultural constraints on women's mobility and gender norms, among other factors. For example, Cyclone Idai which hit Southern Africa in March 2019, affected 270,000 people in Zimbabwe alone, half of whom are children (UNICEF 2019). A recent report by the UN estimates that in the aftermath of Idai, more than 15,000 displaced women and girls in Zimbabwe are at risk of gender-based violence due to disruptions caused by the storm (USAID 2019), for instance, when walking to aid distribution locations or sleeping in long queues.

The anticipated impacts of climate change and urbanization will further intensify the pressure on these already-vulnerable populations, as they tend to have lower adaptive capacity than the general population. As previously discussed in Section 4.1 and shown on Figure 4-1 in the main report, under climate change, incomes on poultry farms stand to fall by as much as 20% by 2040 as a result of heat stress. Women and youth typically have less voice and agency to institute change and may also be less able to select adaptation options in agriculture, including CSA (FAO 2011). Their lower levels of participation in all levels of decision making significantly limit their potential to contribute to climate resilience and adaptation efforts, despite their perspectives and knowledge being unique and vital in climate-related decision making. Furthermore, climate change increases women and girl's workloads. For example, increasing resource scarcity and population growth will impact the distance they must travel to collect water and wood for cooking.

Against this backdrop, this investment package focuses on improving the value chain for women and youth-run farms, with the aim of increasing both their productivity and income, as well as their resilience to climate and other shocks. A number of complementary initiatives are already underway in Zimbabwe, including activities of the Youth Wing of the Zimbabwe Famer's Union. Their Youth Development Program acknowledges the importance of youth in agriculture and attempts to promote their participation throughout the agriculture value chain. The program focuses on capacity building (e.g. financial literacy training, emphasizing participation of at least 65% women), use of ICTs (e.g. through the so-called Innovation Lab project) and strengthening young farmers club structures (e.g. by providing micro grants to Young Farmers Clubs), among other initiatives (ZFU 2017). While emphasizing the participation of vulnerable populations such as women is a key first step, their participation alone does not necessarily translate to their improved productivity and income. Much additional work is needed to remove existing barriers so as to ensure vulnerable groups are afforded the same opportunities as the rest of the population.

G.4.2 Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **National Agriculture Policy Framework:** Package addresses pillars on resilience and knowledge systems, and most centrally the Guiding Principal on Mainstreaming Gender, Youth, and Other Vulnerable Groups.
- **Government of Zimbabwe CSA Framework:** Package addresses Objectives 1, 2, 3, and 4 focused on access to information, application of CSA practices, participation in markets, and capacity for implementation.
- **Vision 2030 and Transitional Stabilization Program:** Package enhances employment and opportunities for youth.

There is a recognition in the country that women and youth constitute an important demographic, but that women and youth are often economically disadvantaged as compared to other sub-groups of the population. This is evidenced by a number of recent Government initiatives, aimed at changing the situation across all economic sectors including agriculture. Despite efforts to promote and facilitate the mainstreaming of women and youth in agricultural production (e.g. through positive discrimination such as quotas), the situation has not changed significantly. Women and youth continue to lack access to agricultural land and the necessary support services. As a consequence, women and youth in urban areas are as poor as their rural counterparts. This calls for specific and specialized programs. Poultry and vegetable production is a low level entry point into agriculture for women and youth in terms of the resources that are required, as well as the skills.

In addition, poultry and vegetable production can cater to both the local and export market. Increased poultry production can contribute to improving the current low meat consumption levels. There is also a market for organic vegetable production which has yet to be exploited. The existence of an organization dedicated to organic vegetable production and the proximity of producers to vital infrastructure such as the airport, makes organic vegetable production a worthy investment to pursue.

A SWOT Analysis was conducted for this package (shown in Table G-6), with the intention of identifying which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

Table G6. SWOT Analysis for Package D

	Helpful	Harmful
Internal	**Strengths** • There is experience in organic vegetable production and poultry production. • Organisations exist that promote organic vegetable production (Zimbabwe Organic Producers Association) and poultry (Zimbabwe Poultry Association). • Government has put in place pro-gender and youth policies.	**Weaknesses** • Poor extension for climate resilient vegetable and poultry production. • Low awareness of the potential economic and environmental benefits of organic products. • Poorly developed markets for organic vegetables • Poor access to resources such as land and water. • Poor access to funding by women and youth.
External	**Opportunities** • Organic vegetable and poultry production do not require a lot of land and therefore women and youth can easily enter these sub-sectors. • Dedicated funding streams for women and youth exist e.g. Women's Bank. • Package can take advantage of NDC targets.	**Threats** • Lack of export incentives. • Lack of credit lines at the country level. • Inadequate research and development on organic and poultry production. • The Women's Bank is poorly capitalised.

Thus, summarizing the key take-aways of this SWOT analysis, the major policy challenges facing this package are:

- Limited access to agricultural land by women and youth;
- Poor financial and information support; and
- Over-reliance on traditional production practices.

To address these policy challenges the following policy actions are recommended:

- Establish a quota for women and youth to access land, taking advantage of the land audit which is underway;
- Strengthen extension support for climate resilient vegetable and poultry production, complemented by developing local and export markets; and
- Provide special financial support for women and youth to engage in climate resilient production.

G.4.3 Investment Opportunities

This package includes a number of specific objectives and investment activities, as described below. For each of these investment opportunities, some thoughts on implementation are provided by illustrating how a similar investment was implemented in recent World Bank projects. A summary of all the past projects examined is presented in Appendix I.4.

- **Objective: Invest in climate resilient organic vegetable and poultry/small livestock production** on women and youth-owned farms. Lower land and capital requirements make these products ideal for peri-urban farms.

Specific activities: To achieve this objective, the following activities will be undertaken: i) conduct a needs assessment in terms of access to land and water resources, finance, and information and knowledge, ii) assess the constraints that face implementation of the project, and iii) Government puts in place a secure land tenure system.

Similar previous project from which to draw lessons learned: In an effort to restore livestock and fisheries in the wake of Hurricane Maria, a World Bank project in the Commonwealth of Dominica supported 200 livestock producers, of which 40 were estimated to be women, to repair animal housing and other necessary equipment for the production of poultry, goats, sheep, rabbits, and pigs.

- **Objective: Invest in sustainable financial inclusion mechanisms** that cater to women and youth, targeting more widespread affordable access to financing for inputs.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) Government sets aside money for women and youth and puts in place operating rules, and ii) Government invites participation of the private sector in disbursement of a special vehicle financial facility.

  Similar previous project from which to draw lessons learned: In Liberia, improved integration of value chains required substantial investment in links between smallholder farmers and agribusiness. The aim was to provide farmers of rice and horticulture as well as oil palm with the necessary market inputs and supplies that would allow them to expand their supply base and increase their ability to process their produce for market. A subcomponent of this investment was the support of women who would grow vegetable gardens or other means of homestead food production.

- **Objective: Invest in marketing networks and capacity building.** Invest in women- and youth-oriented production and marketing networks, including gender- and youth-sensitive extension services, aimed at conveying climate smart agronomic practices.

  Specific activities: To achieve the objective, the following activities will be undertaken: i) Government facilitates development of platforms and networks for local and export markets, and ii) extension workers, women and youth are appropriately trained on the basis of a capacity needs assessment.

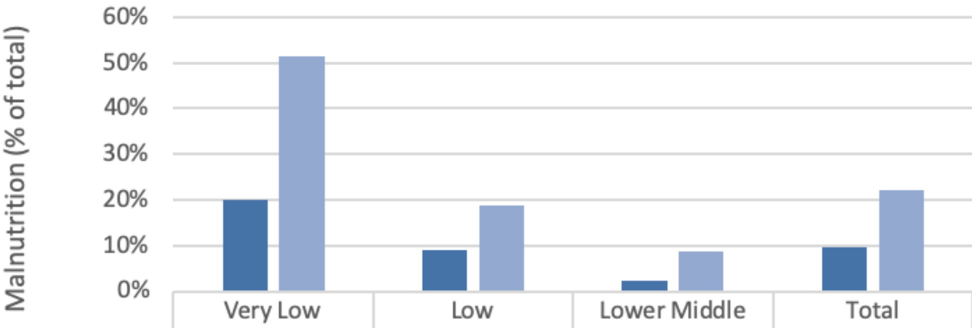
  Similar previous project from which to draw lessons learned: Around 10,000 women and youth were the targets of grant funding in an agro-processing improvement project in Nigeria. While the project included increased productivity and access to materials, it also designated considerable funds to linking beneficiaries to agro-business markets and technical assistance and capacity building functions.

G.4.4 Quantified Estimate of Impact

This package would enhance income and food security among women- and youth-owned farms. Urban farming helps to reduce food costs by consuming products that are home grown. For instance, families around urban areas in Zambia consume much of what is grown on their small (~0.5 ha) urban and peri-urban farms, and can use the rest for supplemental income (FAO 2012). Revenue from sales accounts for roughly 18% of the family income. The potential benefits of reduced malnutrition among mothers involved in urban farming, drought resilient poultry production, and reduced emissions from small livestock were quantified

- **Mothers involved in urban farming have more time for maternal care for their children and children are less likely to be malnourished.** Evaluation of survey data from Kampala, Uganda suggests that households involved in agriculture in urban areas are less likely to have malnourished children than non-farming households (Maxwell et al. 1998). This relationship holds true from very low to lower middle socioeconomic status, but is especially true for very low socioeconomic status where malnourishment reduces from 52% to 20% from non-farming to farming families (see Figure G-5). The study also finds that mothers who farm full time have about three additional hours each day to care for their child than mothers with other employment.

Figure G5. Malnourished Children in Urban Farming Families compared to Urban Non-farming Families by Socio-economic Class (Source: Data from Maxwell et al. 1998)



	Very Low	Low	Lower Middle	Total
Farming	20%	9%	2%	10%
Nonfarming	52%	19%	9%	22%

■ Farming ■ Nonfarming

- **While poultry production has steadily increased in Zimbabwe over the years, drops in broiler (chicken) meat production are often correlated with droughts and heat waves in Zimbabwe.** For example, production of day-old broiler chicks dropped from above 70 million to less than 40 million in response to a drought in 2015/16 (World Bank 2019). Broilers are very sensitive to temperature changes, and an increase in temperature is associated with high mortality, especially for high producing exotic breeds bred for cooler climates. Indigenous or cross-bred chickens that are accustomed to warmer climates have a better chance of survival, and a breeding program would help to increase productivity while maintaining heat and drought tolerant genes.

- **Consuming protein from small livestock instead of cattle can significantly reduce Zimbabwe's emissions in order to meet the NDC goals.** Analysis conducted as part of this study shows that chickens and pigs produce significantly fewer emissions (kg CO_2e) per kg of protein produced than cattle, around 18% and 27%, respectively. Protein from eggs produces even fewer emissions per unit protein, around 14% of the emissions from cattle.

Summary of Impacts to CSA Pillars

- **Productivity:** Enhancing peri-urban farming in Zimbabwe encourages small-scale food production with low upfront costs. Surplus food can be sold at markets, providing as much as 18% of a household's income and contributing to **poverty reduction**. This program would encourage women and youth to engage with the local economy.

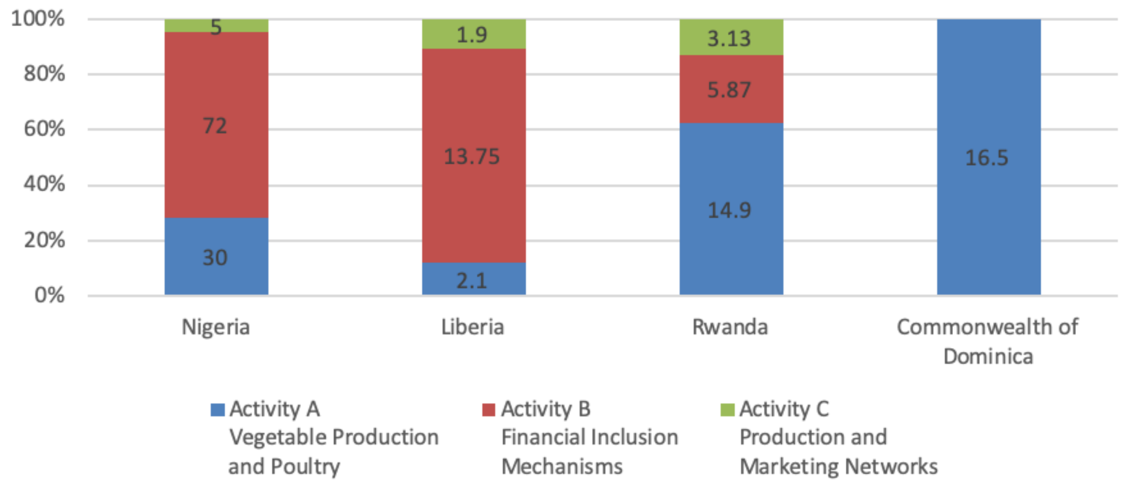
- **Climate Resilience:** Studies have shown that mothers engaged in farming practices are less likely to have malnourished children, enhancing **food security** for Zimbabwe, especially among those with the lowest income status. In addition, encouraging the adoption of indigenous breeds of poultry would enhance climate resilience, as exotic breeds are more sensitive to drought and heat.

- **Mitigation:** Consuming protein from small livestock instead of cattle can significantly reduce Zimbabwe's emissions, with protein from chickens and pigs producing fewer emissions per unit of protein than protein from cattle.

G.4.5 Cost Assessment

Projects focusing on value chain development that emphasize the inclusion of women and youth have a wide range of costs. The components of past World Bank projects that include similar objectives to those in this package range from US$17.75 million to US$107 million. The per beneficiary costs of these projects range from $200 to $1400, as shown in Appendix I. The project costs in Nigeria are certainly influenced by overall population, thus our project is more similar to those of Liberia and Rwanda. Regardless of the total cost, Figure G-6 demonstrates that the costliest component of value chain development tends to emerge in securing sustainable mechanisms for the financial inclusion of women and youth. However, as the Sustainable Agricultural Intensification and Food Security Project in Rwanda illustrates, investments and marketing is directly reliant upon the present state of infrastructure and tools. The Rwanda project focused on strengthening existing farming organizations and extension services as well as improving the irrigation capacity and efficiency. Because our package emphasizes agricultural activities with minimal land and capital requirements for women and youth, most of the costs are found in the creation and promotion of investment and marketing structures.

Figure G6. Component-Specific Costs of Work Bank Projects Similar to Package D

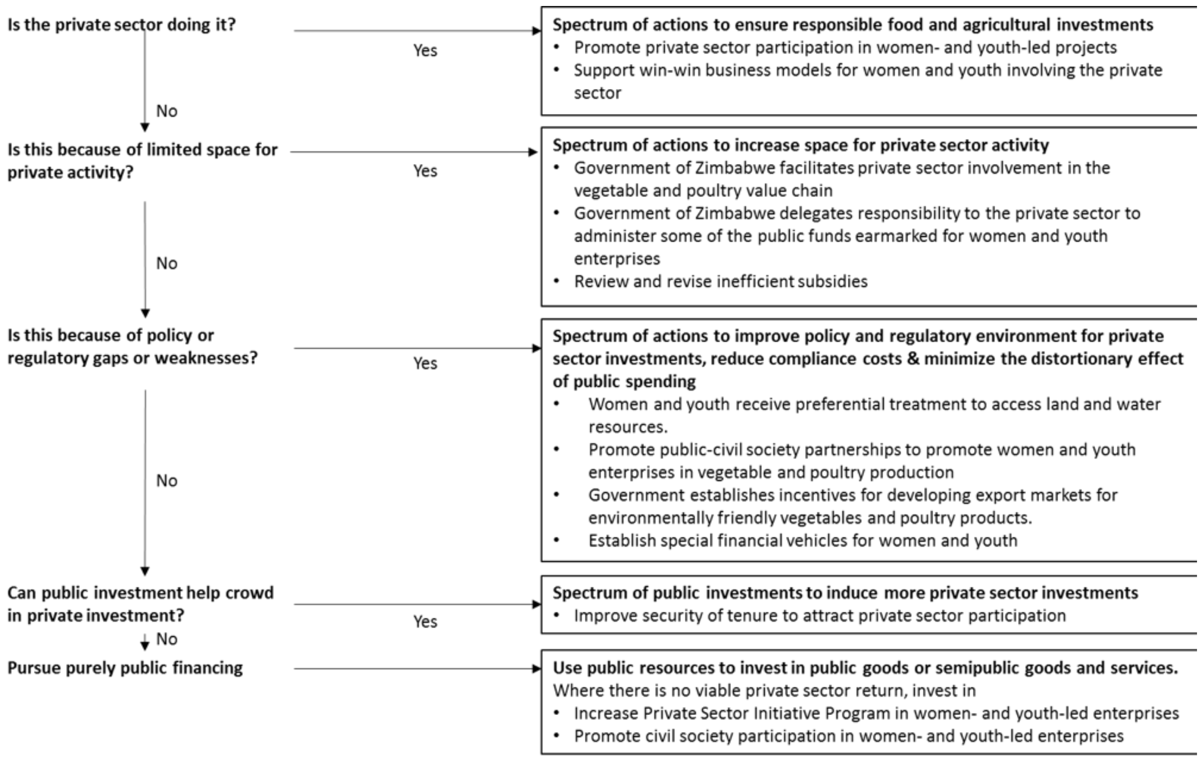


Based on these prior Project Appraisal Documents and the anticipated number of beneficiaries of this package, the initial estimated cost of Package D for Zimbabwe is US$20 million to US$40 million. The investment program would focus on women and youth-owned farms in the Harare region. Based on information from the Poverty Income Consumption and Expenditure Survey (2011/2012; ZIMSTAT 2013), approximately 7.7% of women in urban areas are actively engaged in agriculture. Based on Harare's population of 1.5 million, this translates to roughly 60,000 women engaged in agriculture. Developing an estimate of young farmers is more challenging. The World Bank projects in Nigeria and

Liberia correspond closest to the aim of greater participation of women and youth in the agricultural sector. Because the targeted potential beneficiaries for this investment package lies between the size of the two prior World Bank projects, the estimated cost of package is between US$20 million to US$40 million. Including only women-farmers yields a cost per beneficiary of $330 to $670. Information on financing is provided in Appendix J.

G.4.6 Maximizing Finance for Development

The decision tree for maximizing finance for development for Package D is shown below. It indicates the various roles that the public and private sector could play in the implementation of this package of investments.



G.5 Package E: Resilient Commercial Dairy Farming

This package aims to boost commercial dairy farming through alternative and improved feeds and nutrition products, breeding programs for more climate resilient cow breeds and climate smart production practices. It focuses on commercial A2 dairy farmers (20 to >120ha) in Manicaland and Midlands, in the eastern and central parts of the country respectively.

G.5.1 Context and Problem Statement

Over the course of the last two decades, Zimbabwe has lost its self-sufficiency in dairy production. It is estimated that around 180 million liters of milk are necessary for domestic consumption. Currently, the dairy herd is between 26,000 and 40,000 cows (excluding beef cattle and communal milking cows used for home consumption), producing between 50 and 65 million liters of milk per year (SNV 2012). This is a dramatic drop from peak production levels of more than 260 million liters per year in the early 1990s (GoZ 2012c).

This drop in production has resulted in significant increases in milk imports, as well as reduced local milk consumption, leading to food and nutrient, as well as income insecurity. Decreased production has been driven by a variety of factors, including the land reforms of recent decades which resulted in depletion of the dairy herd; low demand due to ongoing socio-economic challenges; and varying government support resulting in high costs of inputs as well as import competition. The impact of these causes has been further exacerbated by environmental factors such as the destruction of grazing pastures by veldt fires.

Improving milk production and productivity has to take into account the new realities of small dairy farm sizes. The dairy sector is currently made up of around 230 large producers and more than 1,700 smallholders, geographically clustered around 35 milk collection centers (SNV 2012). The majority of these largely A2 smallholdings used to be large scale commercial farms prior to the Fast Track Land Reform Program undertaken in the early 2000s. A2 farmers cannot easily expand their milk production because of smaller farm sizes, ranging from 40-120 ha. Smallholder dairy farmers typically have herds of between three and ten animals, and their contribution to national production remains insignificant, at only 2% of the national milk totals. Furthermore, estimates undertaken under the Dairy Development Program in 2012, suggest that smallholders produced enough milk to realize only US$2-3.00/day per farmer (SNV 2012).

A number of challenges faced by smallholder dairy farmers in Zimbabwe contribute to their low productivity. Issues include breed quality, a lack of affordable improved feed and insufficient access to medicines and veterinary services. Milk deliveries to collection centers peak during the rainy season when grazing is plentiful, indicating that productivity is constrained by water availability for irrigated pasture in the dry season. Consequently, smallholder farmers often find themselves trapped in a vicious cycle with low productivity preventing farmers from being able to afford the operation of local milk collection centers, which in turn prevents access to markets.

Additionally, smallholder and A2 dairy farmers in Zimbabwe face increasing vulnerability due to high temperatures and reduced rainfall as a result of climate change. Under climate change, milk production will be further threatened due to heat stress, limitations on water availability for cows, and increased risks of extreme weather events causing damage to on-farm as well as distribution network infrastructure. This package responds to these current and anticipated future challenges by proposing investments that will help boost dairy farmers' resilience to uncertainty, enhance farm incomes, and reduce Zimbabwe's dependence on milk imports.

G.5.2 Enabling Environment

This package builds directly on the following policy priorities identified by the Government:

- **National Agriculture Policy Framework:** Package addresses several pillars, and most prominently Pillar 5: Agricultural Marketing and Trade Development.
- **Government of Zimbabwe CSA Framework:** Package addresses Objectives 2 and 3 focused on application of CSA practices and improved participation in markets.
- **Vision 2030 and Transitional Stabilization Program:** Package reduces imports, increases exports, and thus improves the country's fiscal situation.

The dairy industry is both capital- and knowledge-intensive, as well as having a delicate value chain. In the context of climate change, the dairy industry is sensitive to both changes in rainfall and temperature. Its higher sensitivity to climate change as compared to the other livestock sub-sectors means that there is a need for more investment in infrastructure, technology, knowledge and innovation to safeguard production and ensure resilience of the industry. However, the necessary interventions are different for large and small scale dairy farmers. Thus, for maximum effectiveness, any investments must take into account the complex operating environment in which specific sub-sectors of the dairy industry finds themselves.

Since 2000, the dairy research and development context in Zimbabwe has regressed significantly. At present, dairy farmers are not served with new information, knowledge and innovations regarding the industry. This means that for almost two decades, the industry has faced stagnation in terms of both innovation and investment. This package provides a pathway to address this stagnation.

A SWOT Analysis was conducted for this package (shown in Table G-7), with the intention of identifying which elements of the enabling environment for this package are already in place and functioning well, and where further efforts are required:

Table G7. SWOT Analysis for Package E

	Helpful	Harmful
Internal	**Strengths** • A well-developed dairy industry exists in Zimbabwe. • Adequate knowledge and information about certain aspects of the dairy industry exists. • Zimbabwe Association of Dairy Farmers exists and looks after the interests of dairy farmers. • Value addition is strong.	**Weaknesses** • Available feed is often of low quality and limited in quantity. • High production costs. • Low dairy herd size. • Sectoral competition from milk imports. • Farm sizes are potentially too small for commercial dairy. • Breeding program is poorly developed. • Low use of animal waste to produce energy due to lack of institutionalisation of circular agriculture.
External	**Opportunities** • Low milk demand presents an opportunity for growth in the sector. • Government is implementing a Command Livestock Policy. • Dairy industry can take advantage of NDC targets.	**Threats** • Lack of suitable funding. • Lack of collateral due to the unacceptability of 99-year lease by financiers. • Low research and development budget. • Command Livestock program is poorly structured. • Lack of a coherent export/import policy to stimulate local production.

Thus, summarizing the key take-aways of this SWOT analysis, the major policy challenges facing this package are:

- Unviable farm sizes for dairy production;
- Poor land tenure that does not guarantee collateral for accessing financial resources; and
- Low investment in livestock breeds, infrastructure and information.

To address these policy challenges the following policy actions are recommended:

- Increase dairy farm sizes, taking advantage of the current land audit;
- Provide a more secure land tenure system that provides collateral for farmers to access loans;
- Establish a special investment facility that addresses livestock breeds and infrastructure; and
- Strengthen extension for dairy farming.

G.5.3 Investment Opportunities

This package includes a number of specific objectives and investment activities, as described below. For each of these investment opportunities, some thoughts on implementation are provided by illustrating how a similar investment was implemented in recent World Bank projects. A summary of all the past projects examined is presented in Appendix I.5.

- **Objective: Invest in programs that promote increased feed and fodder production** (including local level feed formulation), as well as nutrition systems and products. Feed is one of highest costs for a dairy enterprise, and the production of feed at the farm level will significantly reduce the cost of feed. This in turn will reduce emissions and also contribute to carbon sequestration.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) conduct an inventory identifying the number and type of livestock and quantity of feed, ii) Ministry of Agriculture coordinates development of public, private sector and civil society platforms for making feed available where it is most needed, and iii) monitoring of efficiency and effectiveness of these mechanisms.

  Similar previous project from which to draw lessons learned: In Mongolia, a World Bank project addressed the role of animal nutrition in overall livestock productivity and quality. Particular concern was given to the ability to manage herd feed requirements during winter. In addition to reserving certain areas for winter consumption, the project also explored investment opportunities from micro- to large-scale forage plots.

- **Objective: Invest in breeding programs that incorporate the adoption of smaller and climate resilient mixed breeds that are more disease and pest resistant.** Zimbabwe's cattle population declined from approximately 6.1 million in 2000 to 5 million in 2011, while dairy production dropped from over 100,000 cows in 2000 to approximately 22,000 cows in 2010 (Brown et al. 2012). More work needs is needed to close the local demand gap and meet export market demands.

  Specific activities: To achieve this objective, the following activities will be undertaken: i) Government sets up artificial insemination centers to reach as many farmers as possible, ii) practical demonstrations of artificial insemination, and iii) develop a viable financing mechanism for promoting relevant livestock breeds.

  Similar previous project from which to draw lessons learned: In an effort to revitalize the livestock sector in India, a World Bank project sought to increase productivity of dairy animals and to implement climate-resilient animal husbandry technologies. Through disease surveillance and breeding programs, the project expected to increase milk production by 25% and to add over 100,000 genetically improved dairy cattle to the herd.

- **Objective: Robust extension service provision,** including dairy cow management (dry and lactating cows), herd health and biosecurity. Milk hygiene is of paramount importance and farm level practices should ensure high milk quality.

Specific activities: To achieve this objective, the following activities will be undertaken: i) conduct a capacity needs assessment in relation to training, ii) develop and implement a training program, and iii) determine and put in place financial and material resources.

Similar previous project from which to draw lessons learned: A livestock sector development project in Nepal addressed animal health by way of disease and parasite control but also proposed a One Health strategy to address broader impacts on herd health during periods of drought. It also proposed the development of standard operating procedures in the breeding and production of dairy cattle.

- **Objective: Invest in climate smart production systems and practices** including efficient milk bulking and cold chain management systems, appropriate animal housing and circular agriculture (e.g. use of biogas from animal waste).

  Specific activities: To achieve this objective, the following activities will be undertaken: i) practical demonstrations of what is possible, ii) Government facilitates access to funding through public, private sector and civil society partnerships, and iii) Government develops best practices for climate smart production systems and practices.

  Similar previous project from which to draw lessons learned: In a dairy development project anticipated to benefit nearly 2,000,000 households of small and medium scale livestock producers in Bangladesh, the World Bank identified climate smart production practices as a necessary contributor to increased productivity. While many of the practices related to feeding and breeding, animal housing was listed as a key contributor to productivity. The supply of energy through biogas was also suggested as a way of enabling the use of cold chain systems.

G.5.4 Quantified Estimate of Impact

This package would enhance productivity among commercial A2 milk farmers, and thus both reduce Zimbabwe's milk imports and increase exports. This would increase incomes, as well as enhance food and nutrition security while lowering emissions. The potential benefits of several investments in this package were quantified, namely enhanced livestock farming practices, reduced malnourishment in children, and job creation based on higher productivity:

- **Improving on-farm conditions for dairy farmers can greatly increase production, reduce emissions, and instigate the need for breeding programs in Zimbabwe.** Currently milk production in communal areas is low per dairy cow compared to commercially focused farms. Gross output of milk production per cow for small scale commercial farmers is 7.8 times higher than in communal dairy farms (ZIMSTAT 2013). Large-Scale Commercial farms produce 12 times more and resettlement areas produce seven times more. There are many reasons for the disparity in production in communal farms but this is in large part due to the quality of feed, farming practices, and better breeds that would be associated with commercialization of dairy production. Also, as previously shown in Table 5-2 in the main report, improved feed can greatly reduce emissions from cows, which are a major greenhouse gas emitter in Zimbabwe.

- **Additionally, milk can significantly reduce malnourishment in children.** Many health problems associated with child undernutrition can be overcome with access to affordable milk products.

Milk provides iron to prevent anemia and is a good source of vitamin A, important for the immune system and vision. A daily glass of milk provides a 5-year old child with 21% of daily protein requirements, 8% of daily calories, and key micronutrients for overall health and growth (Dugdill 2008).

- **An increase in milk production would reduce milk imports and create jobs in Zimbabwe.** Milk is expensive to import and there are high energy costs associated with importing milk. To transport milk over long distances, it is usually first dried and then on arrival must be converted back into liquid form. Producing milk locally eliminates the need for processing on the front and back end, increasing efficiency and reducing emissions from the energy required. Milk production also creates jobs, both on-farm and off-farm. One off-farm job is created for every 10-20 liters of milk collected, processed, and marketed. In Kenya, 77 people are employed full time for every 1,000 liters of milk produced daily (FAO 2013).

Summary of Impacts to CSA Pillars

- **Productivity:** Moving toward commercialized dairy farming would provide from 7 to 12 times the milk production per cow than communal farming. Higher milk production in Zimbabwe would reduce milk imports and help to create jobs, contributing positively to both **food security** as well as **poverty reduction**.

- **Climate Resilience:** Access to milk can greatly increase **nutrition security**, especially in children, by providing necessary iron, vitamins, and protein. While dairy cows are sensitive to high temperature and drought, breeding programs can help to introduce **more heat resistant breeds** that are better suited to local climatic conditions.

- **Mitigation:** Improved feed for cattle reduces methane emissions by 56% as compared to less efficient, lower quality food sources.

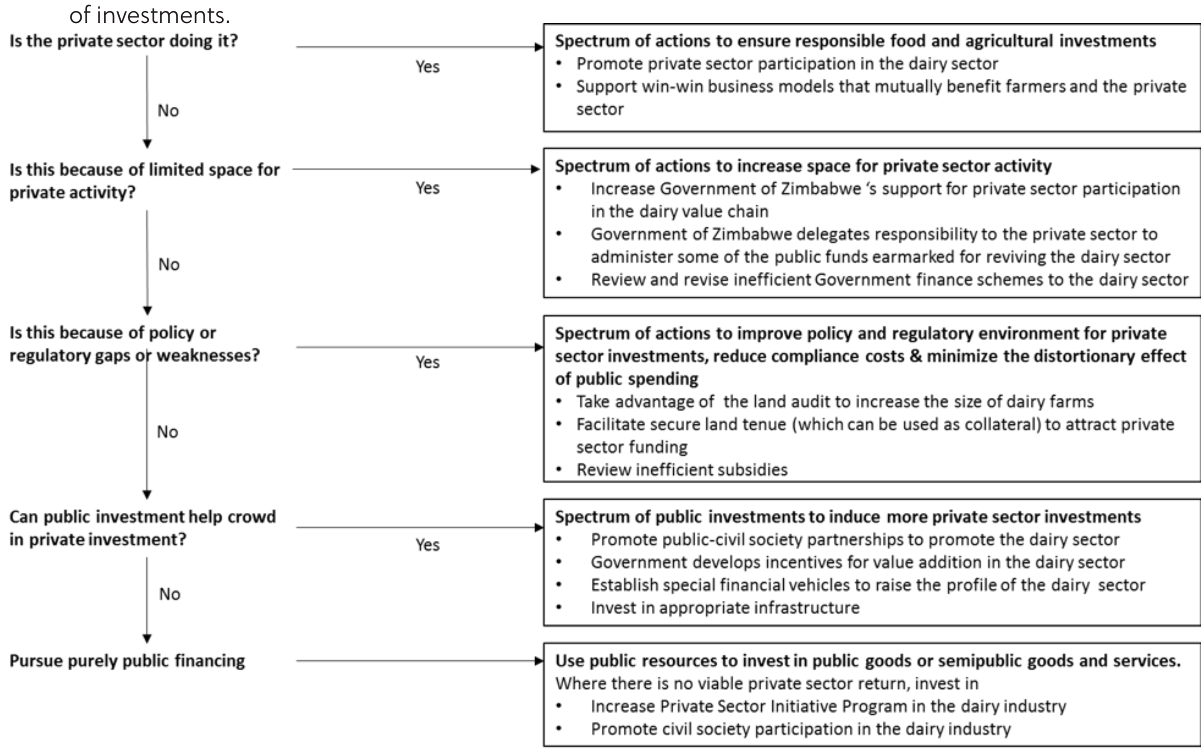
G.5.5 Cost Assessment

Projects focusing on fostering resiliency among commercial dairy farming have a large range of costs. The components of past World Bank projects that are similar in their objectives to this package range from US$40 million to US$258 million. As shown in Appendix I, these translate to $260 to $900 per beneficiary. Unlike the other packages, Package E specifically delimits the scale and type of farming, making a discrete breakdown of costs in other PADs difficult. There are World Bank projects for India (US$258 million) and Nepal (US$40 million) that have focused on improvements to feeding and breeding programs across all scales of dairy farming. A recent World Bank project in Bangladesh (US$142.5 million) incorporates all three components of our package, with specific mention of animal housing and manure management. However, the project is geared toward small- and medium-scale dairy farmers.

Based on these prior Project Appraisal Documents, the estimated cost of Package E for Zimbabwe is US$30 million to US$60 million. The investment program would focus on the roughly 1,000 A2 dairy farms in central and eastern Zimbabwe (ZIMSTAT 2016) where the bulk of dairy farming occurs (estimate includes A2 farms in Manicaland and Midlands). Prior World Bank projects with similar objectives have emphasized value chain development of the livestock sector. Because the scope of this investment package is limited to commercial A2 milk farms and focused primarily on farm management and increased productivity, the estimated cost is between US$30 million to US$60 million. By reducing the price of dairy products, the investment package would indirectly benefit a much larger population. Information on financing options is provided in Appendix J.

G.5.6 Maximizing Finance for Development

The decision tree for maximizing finance for development for Package E is shown below. It indicates the various roles that the public and private sector could play in the implementation of this package of investments.



Appendix H: Configuration, Evaluation and Prioritization of CSA Investment Packages

This appendix is complementary to Section 5.1, providing more detail on the process of configuring, evaluating and prioritizing packages of desirable CSA investments and providing intermediate results used to identify the final five high priority packages.

H.1 Configuring Individual CSA Options into Investment Packages

Having established that CSA is a robust short- and long-term strategy in Zimbabwe, the team worked with local and international experts to configure a set of high-impact, promising investment packages made up of combinations of individual CSA options. As shown in Table H-1, these packages are grouped into three thematic areas that address government priorities: (1) improving production and productivity, (2) increasing resilience, and (3) commercialization. The packages focus on both the crop and livestock sectors, and have a broad geographic focus.

Table H1. Descriptions of Nine Shortlisted CSA Investment Packages

CATEGORY	PACKAGE NAME	DESCRIPTION AND MOTIVATION	FOCUS	
			AER/ National	Crop/ Livestock
1. Improving Production and Productivity where the goal is to ensure crop and livestock production approaches their full potential	Increase crop production to improve food and nutrition security	Because of low staple crop yields, there is widespread food insecurity and poor nutrition at the household level for the majority of the population in rural areas, as well as failure to meet the strategic grain reserve of 500,000 tons/year.	AER II,III, IV and V	Maize, Wheat, Small grains
	Increase livestock production to meet protein intake	The smallholder sector accounts for 60% of the population and owns 90% of the national cattle herd. The livestock component of the smallholder sector is characterized by poor genetics, high disease prevalence and mortality rates, and poor market systems.	AER II,III, IV and V	Beef cattle; Sheep and goats
	Increase milk production	Milk production has suffered due to a reduction in the dairy herd from 100,000 in 2000 to 22,000 in 2010.	AER I, III and III	Dairy cows
2. Increasing Resilience of crop and livestock production considering climate change	Enhance crop resilience to climate change	Crop production is projected to decrease because of climate change impacts, and this will negatively impact food production and revenues.	National	All crops
	Enhance livestock resilience to climate change	Livestock production will be negatively affected by climate change because of limited fodder and water availability exacerbated by the direct effects of temperature and heat. Communal areas record the highest numbers of livestock deaths due to lack of feed or water during the dry periods and in the face of drought.	National	All livestock
	Increase water use efficiency	Water utilization for agricultural production in Zimbabwe is low and water is used inefficiently.	National	All agricultural commodities

3. Commercial-ization (value addition, import reduction and increasing exports)	Reduce agricultural imports	Agricultural production in Zimbabwe has deteriorated to the extent that the country imports an estimated one billion US dollars per annum worth of agricultural products.	National	All agricultural commodities
	Increase agricultural exports	Zimbabwe has lost its market share of agricultural exports because of low production.	National	All agricultural commodities
	Industrialize agricultural sector to increase value added	Zimbabwe mainly exports primary agricultural products.	National	All agricultural commodities

H.2 Evaluating the Performance of Investment Packages using Multi-Criteria Analysis

Table H-2 presents the average ratings across experts for each package according to the six **CSA Pillar** criteria, and three **Enabling Environment** criteria. As described in Chapter 3 of the main report, experts rated each package (from 1 to 10: 1 is poor and 10 is very high) based on analytical results, their own experience and insight, and input from stakeholders during workshops.

Table H2. Scores for Nine Shortlisted Investment Packages, Averaged Across Experts

CATEGORY	SHORTLISTED INVESTMENT PACKAGE	CRITERIA RATING (1-10)								
		CSA Pillar						Enabling Environment		
		Increases productivity	Increases food and nutrition security	Commercialization of the agricultural sector	Improves equity	Moves toward GoZ NDC targets	Builds resilience	In line with GoZ policy priorities	Expected high adoption rates	Leverages finance
1. Improving Production/ Productivity	Increased crop production to improve food and nutrition security	8.0	6.7	6.0	5.3	5.7	5.0	8.3	6.3	4.7
	Increased livestock production to meet protein intake.	7.3	5.7	5.7	5.7	6.0	5.0	8.0	5.7	5.3
	Increased milk production	6.7	4.7	6.0	5.3	5.3	5.3	7.7	5.7	5.0
2. Increasing Resilience	Enhance crop resilience to climate change	5.3	6.7	5.7	5.3	7.0	9.0	7.7	5.0	6.7
	Enhanced livestock resilience to climate change	5.3	6.7	5.7	5.3	6.3	9.0	7.7	5.0	7.0
	Increase water use efficiency	6.3	7.0	6.0	4.7	6.7	8.0	8.3	6.3	6.7
3. Commer-cialization	Reduced agricultural imports	6.0	5.0	5.7	3.7	4.3	5.7	8.7	4.3	5.0
	Increased agricultural exports	6.0	4.3	7.7	3.7	4.7	4.7	8.7	4.0	5.3
	Industrialize agricultural sector to increase value added	6.0	5.0	8.0	3.7	4.0	4.3	8.3	4.0	5.0

H.3 Prioritizing Packages of CSA Options

Next, the packages were plotted according to their aggregated CSA Pillar and Enabling Environment scores to evaluate the highest-priority packages (Figure H-1). Resilience packages (category 2 in Table H-2 above) tend to perform best, followed by the productivity packages (category 1).

This informed the development of five synthesized packages that integrate key characteristics from other packages, emphasizing those with higher scores (Table H-3). This synthesis ensured that the full set of government and stakeholder priorities were captured in the set of high priority packages ultimately recommended in the CSAIP. To illustrate this for one of the high priority packages:

- Package E, "Resilient Commercial Dairy Farming", draws on elements of all three categories in the table above, focusing on productivity gains, commercialization, and resilience, acknowledging the government's emphasis on enhancing productivity, reducing inputs, and increasing farmer incomes.

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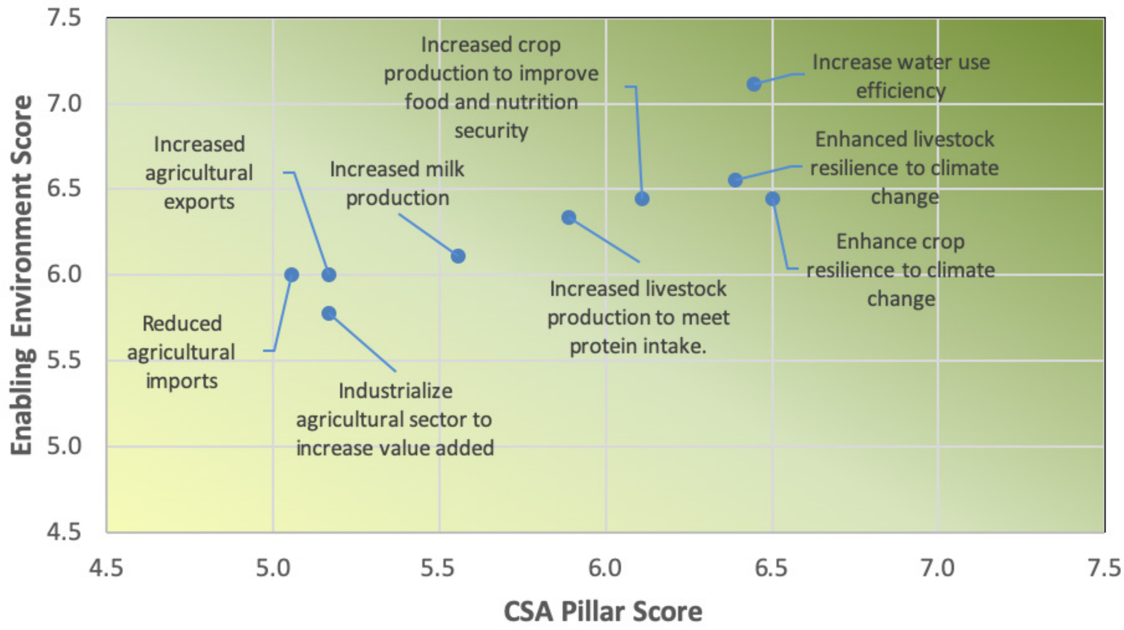


These proposed final packages are therefore synthesized from the initial set of nine packages, based on consideration of analytical results, government and CSA priorities, and expert judgment. The final five high-priority packages, which are inclusive of all subsectors and focus on key CSA goals, are discussed in detail in Chapter 5 of the main report and in Appendix G.

Table H3. Characteristics of Final Five High Priority Packages

PACKAGE	FOCUS			CSA VISION CATEGORIES					
	Sectoral	Farm Type	Region	Commercialization & Competitiveness	Crop and Livestock Productivity	Food and Nutrition Security	Crop and Livestock Diversification	Climate Resilience	Reduced Emissions
A. Enhanced Agricultural Knowledge and Innovation System	Maize, small grains, horticultural crops	Smallholders	Agro-ecological Regions III, IV, V		++	++	++	+++	
B. Sustainable Livelihoods through Diversified Livestock Systems	Cattle, sheep, and goats	Smallholders	Southern Zimbabwe	+	+++	++	++	++	++
C. Water Harvesting for Resilient Crop and Livestock Production	Crops and livestock	Smallholders	Agro-ecological Regions III, IV, V		+++	+++	+	++	+
D. Women- and Youth-Focused Value Chain Development	Poultry, vegetables, small livestock	Women- and youth-run	Urban and peri-urban areas	++	++	+		++	+
E. Resilient Commercial Dairy Farming	Dairy cows	Commercial A2 farms	Central and Eastern Zimbabwe	+++	+++	+	+	++	+

Appendix I: Summary of Project Appraisal Documents Consulted and Appraisals of Project Unit Costs

This appendix provides an overview of the Project Appraisal Documents consulted to support the development of the investment packages described in Appendix G and in Chapter 5 of the main report.

I.1 Package A: Enhanced Agricultural Knowledge and Innovation Systems

PAD Country	PAD Program	PAD #	Activity A	Activity B	Activity C	Relevant Components	Relevant Component Cost (million $)	Overall Cost (million $)	Relevant Component Cost		Cost per Beneficiary ($)
									Direct	Indirect	
Commonwealth of Dominica	Emergency Agricultural Livelihoods Resilience Project	2717	X	X		A.3	2.2				
Sri Lanka	Agriculture Sector Modernization Project	1790	X			2.1	6.2				
Brazil	Strategic Climate Fund--Forest Investment Program	1067	X	X		2	1.3				
Nigeria	Agro-Processing, Productivity Enhancement and Livelihood Improvement Support Project	1114	5	25	9	1	39	200	60,000	300,000	555.6
Niger	Climate-Smart Agriculture Support Project	1745	14	68	19	1.1, 2	101	117.8	500,000		235.6
Angola and Lesotho	Agricultural Productivity Program	2866	16.6		17.75	1, 2	34.35	50	50,000		1000.0
Sri Lanka	Climate Smart Irrigated Agriculture Project	P163742		42		1	42				
Peru	National Agricultural Innovation System Support Project	81708-PE	57.91	23.34	40.31	1,2,3	121.5	125	450,000		277.8
Pakistan	Sindh Irrigated Agriculture Productivity Enhancement	841		X		C3	2.4	187	2,000,000		93.5

Bangladesh	National Agricultural Technology Program	1146	52	66		1,2	118	214	3,000,000		71.3
India	Tamil Nadu Irrigated Agriculture Modernization Project	1947		43.7	7.4	B.1	65.9	455.8	500,000		911.6

Note: Activity A = Provision of knowledge and farmer extension

Activity B = Innovation of Climate Smart Crop Production and Practices

Activity C = Information Dissemination Systems

Of all these past projects examined, a few of those most directly relevant to the investment opportunities described in Appendix G are summarized below in order to provide an indication of how these investments could be realized in the context of Zimbabwe.

Demonstration and dissemination of CSA knowledge in Nigeria:

Crop production accounts for 90% of the livelihoods for the rural population of Nigeria. Despite the increasing importance of agriculture to the nation's GDP, overall productivity has remained low. This project supported demonstrations of climate-smart technologies and provided grants to farmers with less than 2 hectares of farmland, for improved agricultural inputs and machinery. In addition to physical materials, the project provided for the demonstration and dissemination of CSA knowledge. The project estimated that 60,000 individuals were direct beneficiaries and 300,000 farm household members were indirect beneficiaries of the suggested project components.

Capacity building on the implementation and management of CSA in Niger:

A recent World Bank project in Niger addressed issues arising from both climate change and low productivity in their agricultural sector. Over 80% of the country relies on agriculture as their primary source of income, and nearly all of Niger's agriculture is composed of rainfed crops, like millet, sorghum, and cowpeas. This project provided funds for activities and services that contributed to CSA, with a specific focus on supporting rainfed production systems. The project endeavored to train commune officials, technical staff, and others on the implementation and management of CSA. To promote the desired outcomes of CSA, namely productivity, resilience, and mitigation, the project promoted drought-tolerant seed production, compost production, water conservation for small-scale irrigation, and more. Research institutions and other agencies were tasked with the generation and dissemination of knowledge, such as crop choices, agronomic practices, and weather advisory, to farmers. The project was estimated to benefit 500,000 farmers and agro-pastoralists directly.

Enhancing Peru's National Agricultural Innovation System:

A pre-existing information system in Peru—the National Agricultural Innovation System —was the focus of this World Bank project to extend and enhance the reach of information within the agricultural sector. While the project addressed the augmentation of the existing information system, the project also funded innovation in projects focusing on adaptive research, extension services, and community seed improvement. In addition to public sector institutions, the project directly benefited Peruvian farmers, affecting up to 450,000 farmers.

I.2 Package B: Sustainable Livelihoods through Diversified Livestock Systems

PAD Country	PAD Program	PAD #	Activity A	Activity B	Activity C	Relevant Components	Relevant Component Cost	Overall Cost (million $)	Beneficiaries	Cost per Beneficiary ($)
Cameroon	Livestock Development Project	1664	X	X	X	1, 2.1, 2.2	48	134	644000	208.07
Mali	Livestock Sector Development Support Project	2472	X	X	X	1, 2	66.8	78.4	340,000	230.59
Uzbekistan	Livestock Development Project	841	X	X	X	1.2, 2.2	22.3	236.5	35,000	6757.14
Bangladesh	National Agricultural Technology Program	1146	X	X	X	4	47	214	1,000,000	214.00
Somalia	Emergency Drought Response and Recovery Project	2425		X		2.3	8.3	50	550,000	90.91
Burkina Faso	Livestock Sector Development Support Project	2313	X	X	X	1	65.9	78.9	300,000	263.00

Note:

Activity A = Improved feeding

Activity B = Improved breeding

Activity C = Commercialization and markets

Of all these past projects examined, a few of those most directly relevant to the investment opportunities described in Appendix G are summarized below in order to provide an indication of how these investments could be realized in the context of Zimbabwe.

Improved animal health services, production practices, and marketing strategies in Cameroon:

This World Bank project in Cameroon focused on livestock development. Overall, one-third of households in Cameroon participate in the livestock sector, predominately relying on poultry and goats, and sheep, pigs, and cattle to a lesser extent. The project pursued animal health services through vaccination programs, disease detection and response services, enabling improvements to breeding and feeding. It further addressed production practices, such as herd management, by increasing forage productivity and overall access to resources. Given healthier and more productive livestock, the project aimed to incorporate livestock farmers into local and regional markets through improved networks, marketing strategies, and economic information. The project was estimated to benefit roughly 120,000 livestock households and 20,000 small livestock operators and enterprises.

Improving livestock health in Mali:

The livestock sector in Mali serves as a means of income for roughly 30 percent of the population. A recent World Bank project offered improvements, from production to market, within select sectors: cattle and small ruminants, poultry, and fish farming. It addressed livestock health through vaccination and disease detection programs, and increased livestock productivity through genetic and feed improvements. The dissemination of knowledge, particularly in the form of Good Agricultural Practices such as management of manure, natural resources, and biosecurity, was strongly emphasized in the project. While it provided for fostering and strengthening networks among actors and access to markets, the project identified women and youth as recipients of preferential treatment, primarily through reduced financial requirements, for receiving both productive partnership and micro-project financing. The project directly benefited an estimated 340,000 livestock-producing people along with small-scale livestock operators and enterprises.

Expansion of existing livestock knowledge bases in Burkina Faso:

A recent World Bank project sought to address surpluses (beef and goat meat) and deficits (milk, chicken, and eggs) in Burkina Faso's livestock sector, which provides the primary income for 40% of the country's rural population. The project improved animal health services (including vaccinations and disease prevention), access to quality inputs (including improved feed, forage seeds, and genetic material), and the expansion of existing institutions and knowledge bases. Access to markets as well as grants to livestock investors were key components of addressing the needs of the livestock sector. The areas selected for the project resulted in direct benefits to at least 300,000 livestock producers.

I.3 Package C: Water Harvesting for Resilient Crop and Livestock Production

PAD Country	PAD Program	PAD #	Activity A	Activity B	Activity C	Activity D	Relevant Components	Relevant Component Cost (million $)	Overall Cost (million $)	Beneficiaries	Cost per Beneficiary ($)
Commonwealth of Dominica	Emergency Agricultural Livelihoods and Climate Resilience Project	2717	X		X	X	A.1	9.3	29.5	4900	6020.4
Cote D'Ivoire	Cashew Value-Chain Competitiveness	2121				X	2.2	34.1	285.25	225,000	1267.8
Malawi	Malawi Drought Recovery and Resilience	2090		X			2.2	8.8	104	2,100,000	49.5
Saint Lucia	Disaster Vulnerability Reduction		X			X		50.4	68	169000	402.4
Tajikistan	Rural Water Supply	3028		X				9.4	59	400000	147.5
Mozambique	Agriculture and Natural Resources	1497				X		6	40	88000	454.5
Timor Leste	Sustainable Agriculture Productivity Improvement Project	1472	X			X	3.2	3.1	21	85000	247.1
Lesotho	Smallholder Agriculture Development Project	3310		X	X	X	1.1, 1.2a	12	57	750000	76.0
Uzbekistan	Ferghana Valley Water Resources Management Project--Phase II	1054	X			X		5.7 (m euro)	225	180000	1250.0

Note:

Activity A = Conservation Agriculture/Mechanization (No tillage, crop rotation, groundcovers)

Activity B = In-situ Water Conservation (Rainwater harvesting, barrels, community ponds, etc.)

Activity C = Soil Conservation

Activity D = Extension and/or Capacity Building

Of all these past projects examined, a few of those most directly relevant to the investment opportunities described in Appendix G are summarized below in order to provide an indication of how these investments could be realized in the context of Zimbabwe.

Agricultural production and climate resilience after Hurricane Maria in the Commonwealth of Dominica:

This World Bank project for the Commonwealth of Dominica focused on the restoration of agricultural livelihoods and the incorporation of climate resilience in the wake of Hurricane Maria. The two primary domains for agricultural livelihoods were farming and livestock, and fisheries systems. A key aspect of the project was supplying small-, medium-, and commercial scale farmers with the necessary inputs, tools, and materials along with extension services to train and support CSA practices. Key practices included the improvement of on-farm soil fertility and micronutrient management; integrating different crops, pastures, and forests with soil protection measures; and the enhancement of water productivity and water-use efficiency. In total, the project was expected to impact about 4,600 farmers with roughly 2,470 hectares of cropping area. The cost of this component was $9.3 million.

Sustainable watershed management in Timor Leste:

An important objective of this Sustainable Agriculture Productivity Improvement Project was the development of integrated watershed and sub-watershed agricultural development plans. While much of the project was focused on the formulation and dispersion of plans to associations of farmers, a significant component also focused on specific on-farm investments, including harvesting and processing technologies. The project identified smallholder Conservation Agriculture, namely reduced tillage, no grazing, retention of organic matter, and no burning of crop residues, as the foundation for its Sustainable Land Management approach, particularly for rain-fed maize production. It further identified soil fertility (composting and mulch crops), rainwater harvesting (small check dams and interceptor channels feeding water into communal tanks), and the prevention of silting and soil erosion (upstream reservoirs used for domestic and small-scale irrigation) as critical aspects of sustainable watershed management. The projected estimated the reach of its impact at 16,500 rural farm households, or 85,000 direct beneficiaries. The sustainable watershed management component of this project cost $9.3 million.

Conservation agriculture and integrated soil fertility management in Lesotho:

This Smallholder Agricultural Development Project—II supported CSA technologies, enhanced commercialization, and improved dietary diversity. Along with improved seed varieties and agroforestry, much of the project's capacity building in CSA practices focused on Conservation Agriculture and integrated soil fertility management (minimum tillage, crop rotations, crop residue management, contour ploughing, and terracing) and irrigation (including water harvesting). While much of the irrigation component focused on rehabilitating and extending infrastructure for the supply of surface water and groundwater, the project also suggested rainwater harvesting systems in the way of runoff collection with household surface ponds and the prevention of soil erosion through low earth embankment dams. It further sought to generate information for soil conservation through a soil information system and laboratory for soil testing services. The project expected to impact 150,000 farm households, roughly 750,000 people, with women comprising about 50% of the beneficiaries and persons under 35 years old comprising about 35%. The relevant water management focused elements of this project cost approximately $10 million.

I.4 Package D: Woman- and Youth-focused Value Chain Development

PAD Country	PAD Program	PAD #	Activity A	Activity B	Activity C	Relevant Components	Relevant Component Cost	Relevant Component Cost (million $)	Overall Cost (million $)	Beneficiaries	Cost per Beneficiary ($)
Commonwealth of Dominica	Emergency Agricultural Livelihoods and Climate Resilience Project	2717	16.5			A.1	16.5	29.5			6020.4
Nigeria	Agro-Processing, Productivity Enhancement, and Livelihood Improvement Support Project	1114	30	72	5	1.2, 1.3, 2.1, 2.3	107	200	360,000	555.56	1267.8
Liberia	Smallholder Agriculture Transformation and Agribusiness Revitalization Project	P160945	2.1	13.75	1.9	1.1, 2.1, 3	17.75	25	17,500	1428.57	49.5
Nigeria	Nigeria for Women	2747	X		X	2.1	50	100	324000	308.64	402.4
Zambia	Girls' Education and Women's Empowerment and Livelihoods Project	1304		X		1	36	65	99,000	656.57	147.5
Rwanda	Sustainable Agricultural Intensification and Food Security Project	2824	14.9	5.87	3.13	1,2,3	22.2	32.97	163400	201.77	454.5

Note:

Activity A = Organic vegetable production (and other climate resilient practices) by women and youth

Activity B = Sustainable financial inclusion mechanisms

Activity C = Women- and youth-oriented production and marketing networks

Of all these past projects examined, a few of those most directly relevant to the investment opportunities described in Appendix G are summarized below in order to provide an indication of how these investments could be realized in the context of Zimbabwe.

Business planning, financing, and mentorship for women and youth-led businesses in Nigeria:

This Work Bank project in Nigeria focused on the improvement of small and medium scale farmer's agricultural productivity and on their successful integration from subsistence farming into value chains. While the projected dedicated considerable resources to the development of networks and alliances, it also made provisions for the demonstration and adoption of new farming technologies, such as climate-smart and nutrition-sensitive inputs, equipment, machinery, and more. The project focused on improving efficiency and access to resources during post-harvest, processing, and sale of goods. Over one-third of the project's total cost was directed toward business planning, financing, and mentorship for women and youth-led businesses. The direct beneficiaries of this project were roughly 60,000 individuals, with 300,000 farm household members as the indirect beneficiaries. The project assumed that approximately 35% of the direct beneficiaries were women.

Augmenting farmers' economic and entrepreneurial knowledge in Liberia:

This World Bank project addressed the agricultural productivity and commercialization of approximately 17,500 smallholder farmers in Liberia, at least 30% of which were women. This project focused on five Liberian counties with specific value chains identified for each county, including horticulture, oil palm, and rice. The capacity building component of the project not only provided farmers with knowledge about CSA but also augmented the farmers' economic and entrepreneurial knowledge about regional cooperatives, markets, and financing activities. Although the project was tailored in specific ways to the identified value chains, it generally sought to improve the quality and productivity of farming ventures and to link those outputs with relevant aspects of the agribusiness industry.

Enabling women and youth to shift from subsistence farming to commercial farming in Rwanda:

The Sustainable Agricultural Intensification and Food Security Project in Rwanda emphasized the role of horticulture-based value chains, specifically 1) vegetables and fruits, 2) maize, 3) potatoes, and 4) beans, for enabling women and youth to shift from subsistence farming to commercial farming. While it focused on strengthening the organization of farmer groups and CSA, it also stressed the importance of household-level nutrition through access to nutrient-rich foods, such as backyard poultry, as a consistent source of protein. The project identified the improvement and expansion of small-scale irrigation infrastructure as a crucial aspect of increased crop productivity and climate resiliency. The marketing and financing component of the project addressed the need for both post-harvest facilities and equipment and the pre-processing cleaning, sorting, and packaging to ensure quality for regional and international markets. The project expected to impact around 38,000 farming households, which were comprised of approximately 200,000 family members, with 88,000 women.

I.5 Package E: Resilient Commercial Dairy Farming

PAD Country	PAD Program	PAD #	Activity A	Activity B	Activity C	Relevant Components	Relevant Component Cost	Relevant Component Cost (million $)	Overall Cost (million $)	Beneficiaries	Cost per Beneficiary ($)
India	Tamil Nadu Irrigated Agriculture Modernization Project	1947	X			B.2	13 (incl. fisheries)	445.8	500,000	891.6	6020.4
India	National Dairy Support Project	P107648	94	164.3		A	258.3	453.9	1,700,000	267.0	1267.8
Mongolia	Livestock and Agricultural Marketing Project	P125964	2.5	1.5		2	4	11.49	28,385	404.8	49.5
Nepal	Livestock Sector Innovation Project	1605	40				B	40	115	200,000	402.4
Bangladesh	Livestock and Dairy Development Project	2500	112				9.4	A	142.5 million	578.6	147.5

Note:

Activity A = Alternative/improved animal feeding, nutrition systems and products

Activity B = Breeding programs

Activity C = Climate smart production systems and practices

Of all these past projects examined, a few of those most directly relevant to the investment opportunities described in Appendix G are summarized below in order to provide an indication of how these investments could be realized in the context of Zimbabwe.

Improving productivity and market access for dairy farmers in India:

In India, dairy farming produces around 112 million tons of milk annually and accounts for around 17% of agricultural GDP. This World Bank project sought to improve productivity and market access for dairy farming in approximately 40,000 villages in roughly half the states of India. The beneficiaries of the project were 1.7 million milk producing households, many of which were small-scale producers. The project aimed to achieve productivity enhancement through breed improvement, with emphases on selecting high genetic merit bulls and the use of artificial insemination, and animal nutrition, through feeding balanced rations and fodder development. Given the size of India and the role of dairy farming, the primary concern of the project was scaling up the production of milk to meet demand, instead of creating a climate-resilient dairy industry.

Developing livestock value chains in Bangladesh:

A recent World Bank project in Bangladesh addressed livestock development broadly, with a specific focus on the low productivity of dairy farming. In Bangladesh, 70-80% of milk production comes from small-scale farms, which make up 70% of all dairy farming. The project estimated 2,000,000 households, comprised of small- and medium-scale producers in cattle, goat, sheep, and poultry, as the direct beneficiaries of the project. Because of the scale of farming, a significant part of the project was incorporating livestock production into local and regional markets and general value chain development. However, the project suggested climate smart production practices as a key component of address low productivity. These practices included animal feeding, animal breeding, improved health services, animal housing, and manure management.

Improved animal health, breeding, training and extension services in Nepal:
A World Bank project addressing livestock development in Nepal focused on dairy and goat farming. For all livestock, the project sought to address productivity issues through the improvement of animal health and breeding services, training and extension services for farmers, and the development of vaccine production facilities. The project estimated that the number of dairy cattle would increase from 350,000 to 385,000 due to the project and that milk production would increase from 147,000 tons per year to 210,210 tons. The project claimed to benefit roughly 200,000 small-scale livestock producers, at least 45% of whom were female, in 271 municipalities across Nepal.

I.6 Unit Costs of a set of Investment Opportunities

This analysis develops cost estimates for the five investment packages using cost information from Project Appraisal Documents that have comparable investment components. Another way of developing costs for the packages would be to build the estimates from the ground up using data on labor costs, capital costs, programmatic costs, and other cost inputs. For reference, the table below provides a set of unit costs (i.e., per person, per hectare) for several of the investment opportunities considered in the packages. These and other cost data could be the building blocks for the ground up cost estimates. Note that unit cost information is only readily available for a subset of the investments included in the packages.

Investment Opportunity	Subcomponent	Topic (incl. Country/ Region)	Cost Data	Reference
Capacity of Public Extension Workers	Extension program costs	Based on government spending (not NGO or other aid groups); however, the effectiveness includes NGO or other aid	$1.5 million / year (ZAIP 2013) for 1.9% adoption rate / year (Marongwe et al. 2011)	Marongwe , Lungowe Sepo, Karsto Kwazira , Michael Jenrich , Christian Thierfelder , Amir Kassam & Theodor Friedrich (2011) An African success: the case of conservation agriculture in Zimbabwe, International Journal of Agricultural Sustainability, 9:1, 153-161, DOI: 10.3763/ijas.2010.0556
Climate Resilient Crop Production Practices	Drought- and Heat Tolerant Crop Varieties	Based on seed costs derived from economic CGE study	$60-$75/ha/ year	Benitez, Pablo, Brent Boehlert, Rob Davies, Dirk van Seventer (2018) Assessment of the Potential Impacts of Climate Variability and Shocks on Zimbabwe's Agricultural Sector. World Bank Report
In Situ Water Harvesting	Including Mulching, Limited/Zero Till, Crop Rotations, Agro-Forestry Approaches	No Tillage/Wheat Production (Pakistan)	Using zero tillage, Cost of Production is US$144 to US$174/ Hectare	www.wepa-db.net/pdf/0703forum/ paper16.pdf
	Crop Rotation	Based on NDC Report, lower end of approximated global costs (McKinsey & Company 2009)	Crop Rotation ($13.4/ha/ year)	McKinsey & Company, 2009. Pathways to a Low Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve.
	Limited / Zero Till	Zero/Minimum Till has a net reduction in labor, so costs are negative (benefit)	-$1.3 / ha, based on 2.15 hrs/ha/ year (Boyle 2006) and wage rates of $0.63/hour	ADDITIONAL LABOR -> Boyle, K. P. 2006. The economics of on-site conservation tillage, West National Technology Support Center Technical Note: Econ 101.01, USDA: Portland, OR, 2006. WAGE RATES -> Zimbabwe National Statistics Agency (ZIMSTAT) 2015, Agriculture and Livestock Survey 2015, Published: ZIMSTAT, Zimbabwe.

Investment Opportunity	Subcomponent	Topic (incl. Country/ Region)	Cost Data	Reference
Water Infrastructure	Rain Barrels, Community-Level Ponds	Unit Costs for Rural Water Supply Systems (Rainwater, includes others)	From $0.33 per m^3 to $0.77 per m^3 (assumptions about capital investment, recurrent costs, interest rates, and water demand)	https://www.who.int/water_sanitation_health/economic/chapter7.pdf
	Rain Barrels, Community-Level Ponds	Possible development of small-scale irrigation schemes in sub-Saharan Africa	From $600 to $5,000 per hectare to implement simple to complex small-scale infrastructure	http://www.eu-africa-infrastructure-tf.net/attachments/library/aicd-background-paper-9-irrig-invest-summary-en.pdf
	Irrigation Infrastructure	Based on new sprinkler system cost of $8500/ha and rehabilitated systems of $3000/ha	$3,000/ha - $8,500/ha	Dzingirai et al. (2014). Table 5, cited from FAO AquaStat Zimbabwe 2011. https://books.google.com/books?isbn=1779222025.
Capacity of Extension Workers and Farmers	Extension program costs (should cover conservation agriculture, which includes mulching, zero/no till, and crop rotation)	(Same as A.1b Extension Program Costs)	$1.5 million / year (ZAIP 2013) for 1.9% adoption rate / year (Marongwe et al. 2011)	ZAIP 2013; Marongwe et al. 2011
Increased Feed and Fodder Production	Home-grown Fodder	Calculated in NDCs using ZIMSTAT (2015) for wage rates, Suttie (2000) for hey making labor, Chakoma (2016) labor for growing feed labor, Chakoma (2016) seed requirement	$52.9 / ha / year	Chakoma, I., Manyawu, G., Gwiriri, L. C., Moyo, S., & Dube, S. (2016). The agronomy and use of Mucuna pruriens in smallholder farming systems in southern Africa, ILRI extension brief, International Livestock Research Institute, Nairobi, Kenya: ILRI. Suttie, J.M., 2000. 'Chapter II: Haymaking' in Hay and straw conservation: for small-scale farming and pastoral conditions (No. 29). Food & Agriculture Organization (FAO).
	Purchased Stock Feed	Based on weighted average expenses and quantities across farm types	30 USD / tonne	ZIMSTAT (2015)
Production Systems and Practices	Milk Bulking and Cold Chain Management Systems, Animal Housing, Circular Agriculture	Viability of smallholder dairy farming (Zambia)	Average cost of production (USD 0.18/liter); Returns (USD 0.25/liter)	http://www.lrrd.cipav.org.co/lrrd23/6/mumb23137.html

Appendix J: An Overview of Financing in Zimbabwe

This appendix describes the general financing landscape in Zimbabwe.

There are a wide variety of available sources, in both public and private sectors, for the financing of CSA investments. While Zimbabwe spent US$900 million on agricultural adaptation between 2010 and 2015, implementing the provisions of the country's National Climate Change Response Strategy within the agricultural sector is estimated to cost US$2.3 billion (CIAT World Bank 2017). There are limited government funds available for financing CSA, and the policies and political uncertainty of the country have affected the possibility of involvement by private foreign investment (CIAT World Bank 2017). Furthermore, international financial institutions are currently limited in their financial support (due to arrears), placing more pressure on public spending to support CSA investments.

Zimbabwe's financial sector is comprised of 13 commercial banks, 5 building societies, 1 savings bank, 2 development financial institutions, and over 180 microfinance institutions (Reserve Bank of Zimbabwe, 2018). The richest repository for financing opportunities are found in the various bilateral and multilateral development, agencies, banks, and funds. Zimbabwe has relied heavily upon the Global Environment Facility and the United Nations Development Program for the financing of CSA investments. Entities like the Zimbabwe Agricultural Development Trust have funded, through banks and microfinance institutions, smallholder farming at a national level. Other trust funds, such as the World Bank's Zimbabwe Reconstruction Fund and the African Development Bank's Zimbabwe Multi Donor Trust Fund, have also financed climate-smart investments in the area.

Efforts are underway to grant Zimbabwe access to additional sources of funding through the Adaptation Fund, the African Union Climate Facility and the Green Climate Fund. One recent report suggested that most of the financing received in Zimbabwe was directed toward agricultural productivity and adaptation projects, leaving numerous potential opportunities for funding of other climate-smart investments (CIAT World Bank 2017). The World Bank is currently supporting accreditation of the Infrastructure Development Bank of Zimbabwe (IDBZ) with the Green Climate Fund, along with establishment of a Climate Finance Facility.

In addition to the entities and funds mentioned above, there are numerous sources of financing or funding available from public and private sources for the agricultural sector at the regional and international level, including:

- **Africa Climate Change Fund.** Managed by the African Development Bank, the Africa Climate Change Fund was founded in 2014 to help African countries achieve increased resiliency to the impacts of climate change and to foster low carbon growth. From the initial round of proposals, the fund has approved US$3.3 million for eight projects. Projects are selected for, among other reasons, their contribution to the preparation and financing of climate change adaptation and mitigation projects, capacity building and institutional strengthening, and the development of climate resilient strategies and policies.

- **African Development Fund.** Managed by the African Development Bank, the African Development Fund was founded in 1972 with the aim of fostering poverty reduction and economic and social development throughout Africa, with 38 countries currently eligible to receive African

Development Fund funds. Having invested over US$44 billion during its history, the contributions from donor countries in 2017 replenished the African Development Fund with over US$7 billion.

- **Africa Enterprise Challenge Fund.** Since its founding in 2008, the Africa Enterprise Challenge Fund has supported 268 companies across 26 sub-Saharan African countries. The Africa Enterprise Challenge Fund focuses primarily on renewable energy and agribusiness. Within agribusiness, the fund supports endeavors that grant smallholder farmers access to innovations that increase agricultural productivity, commercialize new technology, or create local financing mechanisms. The Africa Enterprise Challenge Fund Zimbabwe Window currently funds 30 agribusiness projects focused on rural communities in Zimbabwe.

- **The Global Environmental Facility Trust Fund.** Currently administered by the World Bank, the Global Environmental Facility Trust Fund was founded in 1992 with US$1 billion in funds for its pilot phase and was replenished most recently in 2014 with over US$4.4 billion in support from donor countries. The purpose of the Global Environmental Facility Trust Fund is to assist developing countries and countries with economies in transition in satisfying the requirements of international environmental conventions. The Global Environmental Facility Trust Fund has provided funds to over 40 projects in Zimbabwe with focal areas including biodiversity, climate change, and land degradation.

- **Special Climate Change Fund.** Founded in 2001, the Special Climate Change Fund grants funds to vulnerable developing countries for the purpose of addressing climate change. While the Special Climate Change Fund prioritizes adaptation to climate change, it also supports technology transfer and mitigation in several sectors, including agriculture. As of 2019, Zimbabwe has received funds for two projects addressing climate change.

- **International Fund for Agricultural Development.** The International Fund for Agricultural Development is an agency of the United Nations that was founded in 1977 with a focus on addressing food insecurity and famine in rural, impoverished areas. It funds projects that address livestock and crops, and Zimbabwe has received over US$90 million in support from the International Fund for Agricultural Development across six projects that address irrigation and crops.

- **The Organization of the Petroleum** Exporting Countries Fund for International Development. The Fund for International Development was founded in 1976 with the purpose of assisting in the socioeconomic development of developing countries. Supporting efforts at country and regional levels, the fund focuses on ensuring access to energy, food, and water, while also funding endeavors in education, transportation, telecommunications, and more. Zimbabwe has received over US$64 million from the Fund for International Development for six projects across different sectors, including two small-scale irrigation projects.

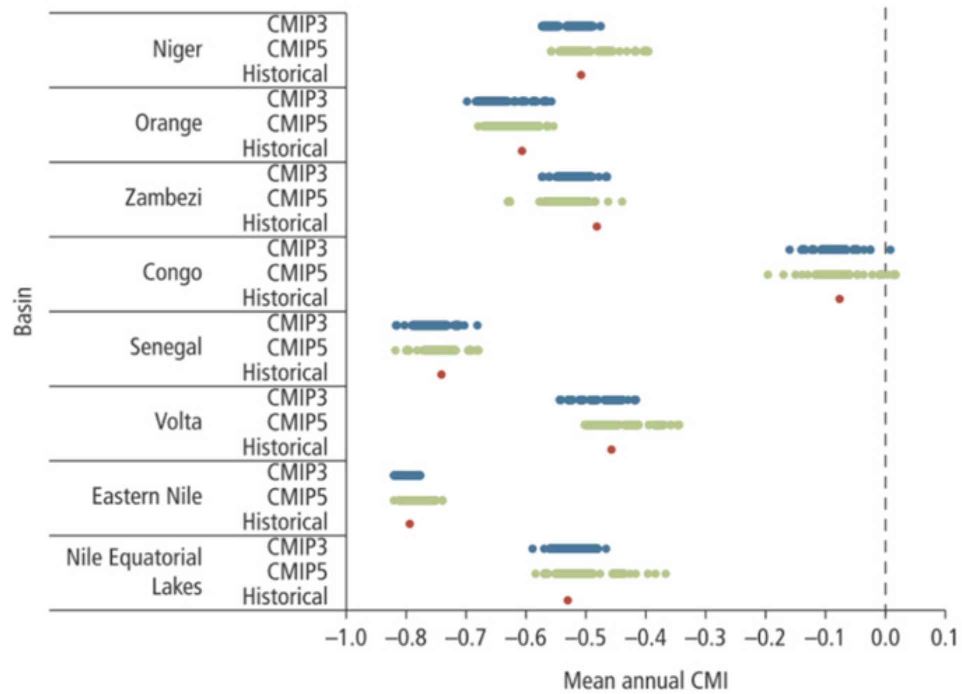
Appendix K: Study Caveats

This appendix documents a number of important assumptions and caveats to the analyses completed in this work, and suggests areas where further analysis may be warranted.

This study is subject to several key sources of uncertainty, some of which are partly addressed in the analytical design (climate projections) and others that are well outside of the scope of this study (e.g. geopolitical uncertainty).

Uncertainty in climatic projections. Taking the Zambezi River basin as an example, climate projections obtained from general circulation models reflect deep uncertainty as illustrated by the Climate Moisture Index in Figure K-1. The Climate Moisture Index is a measure of aridity in the region and the green and blue dots corresponding to the Zambezi display the uncertainty in the results spectrum obtained from the Coupled Model Intercomparison Project phase 3 (CMIP3) and phase 5 (CMIP5) suite of models. Hence, it is of paramount importance to consider this inherent climate uncertainty while formulating agricultural response options (Boehlert et al. 2015, Strzepek et al. 2013).

Figure K1. Climate Change Projections across Africa's River Basins



Source: Cervigni et al. (2015).
Note: The Climate Moisture Index combines the effect of rainfall and temperature projections. The index values vary between −1 and +1, with lower values representing more arid conditions. The chart reports Climate Moisture Index values (averaged over the period 2010–50) projected by climate models included in the CMIP3 and CMIP5 ensembles. In each basin, the red dot denotes the average value of Climate Moisture Index in the historical baseline. Dots to the right of the historical value refer to projections of wetter climate; dots to the left indicate projections of drier climate.

Climate variability in cropland suitability analysis. The Sys et al. (1993) method to quantify cropland suitability is primarily based on a linear piece-wise approximation for average climate during the growing season. As such, the method does not take into account variability in climate from year-to-year or weather differences within the growing season.

Representative crop modeling (AquaCrop). Since crop models are computationally expensive, AquaCrop models a representative crop for a given region and farm type using typical field management practices, average daily temperature and precipitation, as well as soil parameters. Of course, crops, soil, and farm management vary within a region and farm type. Although AquaCrop was run over multiple years for each climate realization, taking the mean change, there is uncertainty introduced when using representative crops. Also, farmers are likely to respond in various ways to improve production, especially if future conditions are significantly worsened by climate change.

Crop model calibration. When calibrating AquaCrop, the ZIMSTAT reported yields were used, which are likely to have been impacted by factors that are not simulated in AquaCrop such as post-harvest losses or pests. As a result, it is possible that the calibrated crop parameters, which often have physical significance (such as crop height) may be somewhat inaccurate. While these effects could be accounted for, data on the impacts of pests and post-harvest losses for each crop were not available.

Effects of climate change on pest behavior. Climate change can also affect agricultural output by changing pest behavior. For instance, the rapid spread of fall army worm from the Americas to Africa is probably driven by climate change. Its impact is already substantial and could potentially be devastating. Since it appears to be most destructive in rainy periods immediately following a drought, it could reduce the potential for recovery from severe drought periods. This was not modelled.

Water availability. Water for livestock or irrigation would need to be transferred from the source either by river, groundwater pumping, or ponds/reservoirs. In order to properly account for changes in water demand, availability (from climate change or competing demands) or transfer losses, a complex modeling of the river/reservoir system would be required. This was not taken into account in this study.

National-level livestock modeling (GLEAM). The livestock model used to simulate meat, protein, feed intake, and emissions runs on a national-level and does not take into account variations within the country. A spatially resolved version of GLEAM exists but is not publicly available.

Multipurpose livestock. In many cases, livestock are used for multiple purposes, e.g. the same cow may be used for both draught power and meat production. The livestock modeling does not take into account multipurpose livestock, which may impact food intake or slaughter weight.

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PRODUCTIVITY RESILIENCE LOWER EMISSIONS

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