Quantifying the Value of Investment in Adaptation for Small-Scale Agriculture

A Guidebook for Investors

The Nature Conservancy

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EXECUTIVE SUMMARY

Climate change creates significant risks for agriculture production and the many Small-Scale Producers (SSPs) who steward food systems, especially in places like Sub-Saharan Africa and South Asia where the frequency of climate-related disasters is increasing more rapidly than elsewhere in the world. Despite these risks, agriculture adaptation investments are severely underfunded–particularly by the private sector. This is in part because agriculture adaptation is not well understood and, as the pace of climate change increases, forecasting and pricing climate-related risks becomes more complicated.

To help the private sector identify, evaluate and integrate adaptation strategies that support SSPs into portfolios, TNC developed this guidebook to provide a step-by-step process, or adaptation lens, to support decision making. It is based on extensive interviews with "direct investors" (including fund managers, lending institutions and corporations) to address the main challenges they encounter when investing in agriculture adaptation. This guidebook contributes to the existing literature on adaptation investing and proposes a three-step process for applying an adaptation lens to a portfolio:

Step 1 Assess climate risks and vulnerabilities relevant to an investor's objectives.

The key challenges identified in the investor interviews:

- Investors desire more accessible climate change forecasts.
- Investors find it challenging to measure the risks of these types of investments as risk measures are predominantly rooted in historical trends that are increasingly less applicable because of changing climate trends.

How Step 1 addresses these challenges:

- Throughout this guidebook, investors will find tools for forecasting climate change provided by project partners, interviewees and trusted public sources.
- The guidebook proposes a conceptual approach for measuring the return on investment (ROI) of an adaptation strategy using insights gathered from climate risk tools. This means an understanding of three key metrics: probability of a climate disruption, estimated cost of a disruption, and expected change in business performance. Using this process, investors can begin to build an informed climate outlook that supports investment decision making.

Step 2 Identify and assess possible adaptation strategies.

The key challenges identified in the investor interviews:

- Investors need a greater understanding of specific adaptation strategies that respond to climate-related risks.
- Investors desire a methodology to assess a given adaptation strategy's relevance, applicability to a local context, and financial and non-financial costs and benefits.

How Step 2 addresses these challenges:

- This guidebook provides concrete examples of adaptation strategies, specific interventions and the benefits associated with those strategies along with providing examples of enabling conditions for implementing strategies.
- Step 2 includes a framework for how to assess the financial and non-financial costs and benefits of individual strategies within a local context. Step 2 also provides guidance on thinking through the benefits of bundling strategies.

Step 3 Integrate adaptation strategies into an investment portfolio.

The key challenge identified in the investor interviews:

- Investors are unsure of how to integrate adaptation strategies into their portfolios including what strategies might be considered, where in the investment process they are applicable and real-world examples that can provide the basis for a track record.

How Step 3 addresses this challenge:

- Steps 1 and 2 provide the inputs investors need to assess their climate risks, conceptually measure ROI, identify relevant adaptation strategies and assess the costs and benefits of those strategies. Step 3 demonstrates how investors can tie these inputs together via practical approaches specific to fund managers, lending institutions and corporations.

The guidebook concludes with relevant, real-world examples of agriculture adaptation investments made by the Acumen Resilient Agriculture Fund (ARAF), AgDevCo and Aceli Africa. These demonstrate that incorporating an adaptation lens for agriculture investments is critical to create resiliency. As the adaptation space continues to evolve and mature, investors have a unique opportunity to shape the investment process while generating business value from a risk exposure reduction and/or return perspective.

Importantly, this guidebook is a contribution to the wider body of knowledge related to agriculture adaptation and TNC hopes readers see opportunities to expand on the ideas shared here. The more effective the investment, development and conservation communities become at quantifying climate risk and resilience, and the more robust our knowledge of the financial and non-financial costs and benefits of adaptation strategies become, the more rapidly we can create a resilient future for the benefit of both people and nature.

Photo: © Smita Sharma

GUIDEBOOK OVERVIEW

This guidebook helps investors identify, evaluate and prioritize agriculture adaptation investments, with a focus on where those investments help SSPs, by providing resources to inform investment processes. Its end goal is to:

- Raise awareness of climate risks and adaptation strategies.
- Define the business case for agriculture adaptation and corresponding investment opportunities.
- Make the case for an action-oriented adaptation lens for investing.

Agriculture adaptation strategies are actions taken on and off the field that address specific climate risks or increase farmers' resilience to climate change. This guidebook contributes to the body of literature and evidence by creating an adaptation lens for investing.

SSPs, defined as farmers, pastoralists, foresters and fishers that have a low asset base and limited resources including land, capital, skills, and labor, typically farm on fewer than five hectares of land (Legal Information Institute, n.d.).[i] This guidebook focuses on the challenges these farmers face in Sub-Saharan Africa and South Asia because 60% of the world's SSPs are located there and face some of the most rapidly changing weather patterns due to climate change, impacting social and economic well-being at a regional and global level (Chiriac et al., 2023).[ii] While these geographies helped to focus the research, the frameworks and methods described in this guidebook can be applied elsewhere.

Within this guidebook, readers will find resources to help them understand the evolving landscape of climate risks, determine which adaptation strategies respond to those risks, and help integrate the costs, benefits and tradeoffs of a given strategy into their investment management decisions.

Audience

This guidebook is intended for anyone interested in agricultural resilience and is specifically written for:

Direct investors: those who directly provide capital to SSPs and agribusinesses adjacent to an SSP's supply chain. These include fund managers (real asset, private equity (PE) and venture capital (VC)), lending institutions (local, regional and micro-financing banks), accelerators, incubators, and corporations with direct (or close to direct) sourcing relationships with SSPs. For the purposes of this document, we consider development finance institutions (DFIs), family offices, pensions and endowment funds and fund-of-funds as **capital allocators**–those who finance direct investors (although these groups make direct investments from time to time). Shareholders, investor groups and non-governmental organizations (NGOs) are those who **influence capital**.

While the primary focus is on direct investors, capital allocators and capital influencers can also gain insight into how they might assess and shape the adaptation approaches of direct investors focused on agriculture and food system investments.

Guidebook Development

This guidebook is the result of a collaboration between the Bill & Melinda Gates Foundation and TNC in partnership with several key financial and technical partners, including but not limited to the African Centre for a Green Economy (AfriCGE), CrossBoundary Group, the International Water Management Institute (IWMI), The Alliance of Bioversity and the International Center for Tropical Agriculture (CIAT), and SouthSouthNorth. See the Appendix for a full list of supporting partners.

The content was developed mainly through primary research using a user-centered approach. TNC engaged with stakeholders at various levels of expertise across functions and industries, and curated and cultivated an advisory board (which included industry experts) to assist across the project. The main development phases included:

- **User selection:** Through various expert consultations and internal engagements, TNC selected a mixed group of direct investors that are either becoming market leaders in agricultural adaptation, have strong interest in navigating this space but are not sure where to start, or have provided support to industry players through technical and/or financial services.
- **Interviews:** TNC conducted a series of interviews with our core investor segment for insights into a general understanding of adaptation, their experiences with adaptation, the barriers that exist and the opportunities to make adaption a priority within their investment process.
- **Design:** TNC developed a prototype guidebook based on the most significant needs expressed in the interviews. TNC then held a design sprint with investors in the primary user group to refine the content and design the format of the guidebook.
- **Technical workshop:** A technical workshop was held with leaders in the science community who focus on SSPs and adaptation. Their input helped refine some of the content and influenced the development of the overall framework.
- **User feedback:** The content was tested with various users, including some from the initial interview period, to solicit feedback and further refine the guidebook.

The team also conducted secondary research to close any remaining knowledge gaps and highlight existing resources that might be useful to the reader. Throughout this guidebook recommended materials can be found from project partners, interviews and trusted public sources.

Key investor interview findings

As demonstrated through our interviews, adaptation finance is not well understood by the investor community and generally not seen as profitable enough to attract private funding. However, interviewees acknowledged that adaptation is important and expressed a desire for more guidance on how to get started investing in agriculture adaptation. Additional needs of investors uncovered during these interviews and addressed in this guidebook include:

- A desire for more easily accessible information on climate-change forecasts for relevant geographies.
- A greater understanding of specific adaptation strategies that respond to climate-related risks.
- A need for a methodology to assess a given adaptation strategy's relevance, costs and benefits.
- Examples of how to quantify those costs and benefits and integrate them into decision making.
- A method to consider resilience in fiscal terms alongside other measures of an investment's value creation potential.

"I think it's always quite useful if you can say, 'Here is what you actually stand to lose if you don't adapt.'"

— Senior Sustainability Manager and Principal of a private equity fund

Guidebook Outline

To address the key investor insights TNC identified, this guidebook is organized in three actionable steps. Additional emphasis is placed on the areas where investors reported the greatest challenges, as demonstrated in Steps 1 through 3 which provide a tangible methodology for effectively integrating agriculture adaptation strategies into investment management decisions (Figure 1).

Step 1

Provides a process for assessing climate risks and the vulnerabilities of a given investment or asset, and a theoretical framework for considering the ROI of a given adaptation strategy. In this step, investors will complete a climate risk and vulnerability assessment of their portfolio's region and agricultural asset(s).

Step 2

Uses the output of the climate risk assessment outlined in Step 1, along with information on local or regional contexts, to identify and assess potential adaptation strategies. Through this step, investors will identify one or more appropriate adaptation strategies and assess the costs and benefits of those strategies.

Step 3

Uses the outputs from Steps 1 and 2 to illustrate ways investors can integrate adaptation investments into their portfolios. Investors will find concrete, practical approaches they can use to apply an adaptation lens and better value adaptation investments.

Investment Case Studies

Provides illustrative case studies of real-life applications for investing in climate adaptation interventions that support SSPs.

Resource Library

A Zotero database houses the key resources provided on the topics of climate risk forecasting, agricultural adaptation strategies and climate investment modeling. Access the resource library here.

Figure 1: Adaptation Investment Lens Methodology

The steps an investor can follow to integrate an adaptation lens into their investment management decisions.

INTRODUCTION

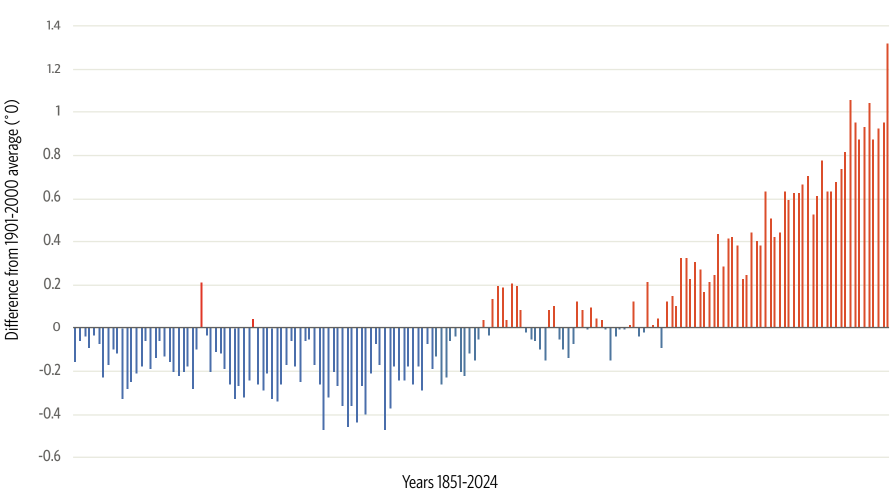
Climate trends and the need for an adaptation investing lens

INVESTOR INSIGHT

Lack of available data and evidence of impact is preventing both systemic change and investors from making additional investments.

The impacts of climate change are creating significant risks to global food systems. With increasing average temperatures and changes to hydrological and weather patterns, extreme drought and flood events are becoming more prevalent (Cawdrey, 2023).[iii] Global temperatures are projected to increase by about 2.0° C over the preindustrial average between 2040 and 2060 under an intermediate greenhouse gas (GHG) emissions scenario (SSP2-4.5) (IPCC, 2021).[iv] These trends will fundamentally change the volatility, viability and vulnerability of agriculture, especially in places like Sub-Saharan Africa and South Asia where the frequency of these events is increasing more rapidly than elsewhere in the world (Rodell & Li).[v]

Figure 2: Global Land and Ocean July - June Average Temperature Anomalies (1851-2024)



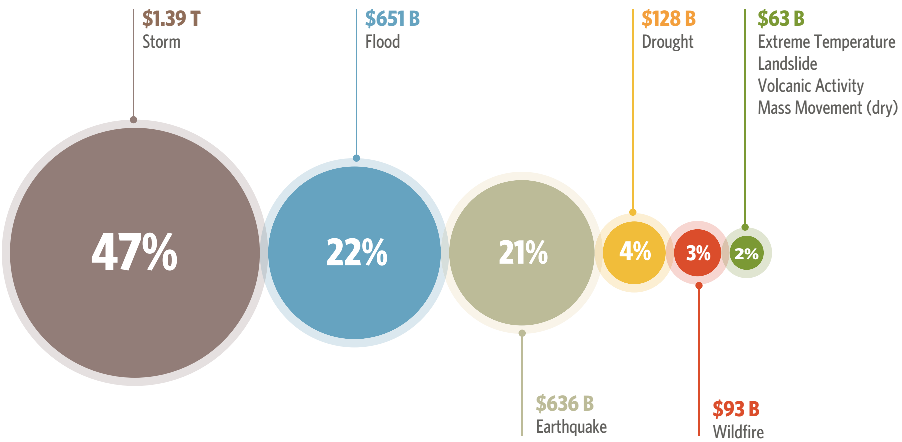
Data from the National Oceanic and Atmospheric Administration demonstrating global land and ocean average temperature anomalies for June-July compared to the mean for 1901-2000 (NOAA, 2024).[vi]

The costs of climate disasters in India and Africa

India ranks second in the world for flood impacts, experiencing an average of 17 flood events per year that affect approximately 345 million people (CRED & UNDRR, 2020).[vii] During the 2021 monsoon season in India, floods and storms in a four-month span (June to September) resulted in roughly 1,300 casualties and USD $3.2 billion in economic losses. In the same year, Asian countries saw USD $35.6 billion in financial losses (Prasad, 2022).[viii] However, these damages also create opportunities (limited by capacity and fit) to mitigate future floods through the building of dams, creating riparian buffers and establishing drainage systems (CRED & UNDRR, 2020). At the other end of the scale, droughts affect Africa more than any other continent. In the last 20 years, Emergency Events Database (EM-DAT) recorded 134 drought events in Africa (around 40% of the global total), including 70 droughts in East Africa alone (CRED & UNDRR, 2020). Unlike other climatic events, drought impacts last for years and result in widespread agricultural failures, loss of livestock, water shortages and outbreaks of epidemic diseases. In 2020, Ethiopia experienced severe floods followed by a prolonged drought due to four consecutive failed rainy seasons. It was East Africa's worst disaster of its kind in the last four decades and the damage was felt across human, environmental and economic levels. More than 37 million people faced acute food insecurity, over 3.5 million livestock are estimated to have died with another 25 million weakened and emaciated, and estimated damages (not including the four years of droughts since then) amounted to more than USD $135 million (Harmeling, 2022).[ix] A recent United Nations (UN) report estimates that losses from severe droughts in Africa over the past 50 years due to climate change have exceeded USD $70 billion, putting around 23 million people at the risk of food insecurity across the horn of Africa (Okoth, 2024).[x]

The agricultural sector is closely linked with climate. Agriculture is responsible for emitting around 30% of greenhouse gas emissions (IAEA, 2016)[xi] and those living in low income, food-importing countries where a large share of income is already devoted to purchasing basic food staples are the most vulnerable to climate change impacts (Tubiello et al., 2008).[xii] This is particularly the case for SSPs who are feeling the effects of climate change firsthand despite also playing an important role in safeguarding the world's food security (Dhillon & Moncur, 2023).[xiii]

Figure 3: Economic losses (USD) associated with major climate-related disasters (2000-2019)



Climate-related disasters have had significant economic impacts (modified from CREDD & UNDRR, 2020).

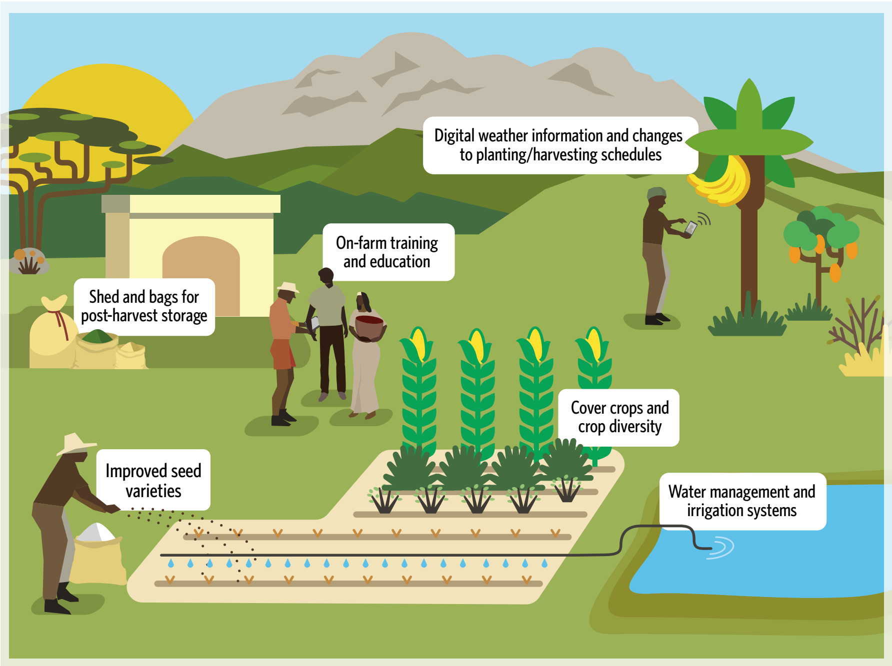
Adapting agriculture to withstand climate impacts requires interventions both on- and off-farm, increasing the ability to withstand or recover from extreme weather events and long-term changes in weather averages (e.g., higher temperatures, less overall rainfall, etc.). A unique challenge of adaptation solutions is the degree of sensitivity to local conditions such as different climates, geographies, crop types, etc. Each require different interventions and the uncertainty of climate impacts can make it hard to predict the comparative benefits of adaptation. Yet when properly implemented, adaptation solutions can yield significant benefits including risk reduction, greater productivity and increased or stabilized income.

A note on on-farm and off-farm adaptation interventions

On-Farm Adaptation Interventions: This refers to activities implemented directly on the farm that have the potential for increasing yields, limiting or eliminating resource losses, diversifying inputs, etc. Examples include agronomic practices, improved seeds or livestock breeds, water management systems and crop or livelihood diversification.

Off-Farm Adaptation Interventions: This refers to activities that benefit farm inputs and output but are not directly implemented at the farm level. Examples include technical assistance programs, crop-loss insurance, land tenure support services, improved technologies, enabling policies, early warning systems, and improved access to markets, among others.

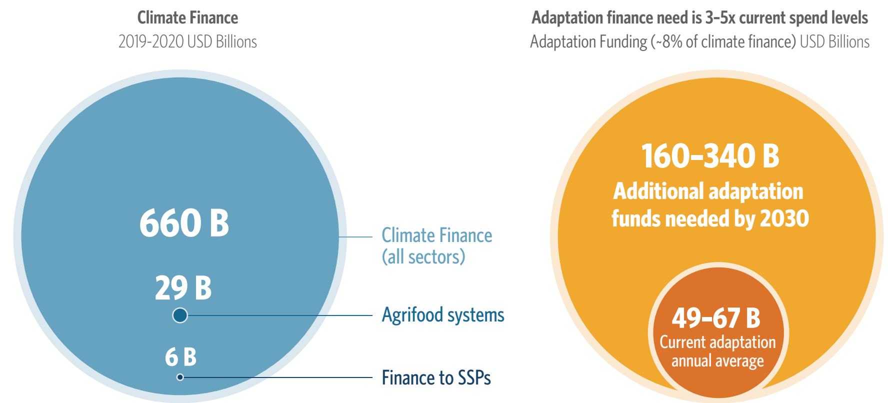
Figure 4: Examples of on-farm adaptation strategies



Conceptual diagram illustrating different adaptation strategies that can be applied at the farm level.

For the investor, this means that past approaches to understand the risk of an investment—whether defined by yield stability, quality stability, asset appreciation, loan portfolio risk or other measures—may not hold true going forward. Yet the tools and resources to assess and manage agriculture investments in this new climate reality (particularly in frontier and emerging markets most impacted by climate change) are limited.

Figure 5: Spending on agricultural adaptation relative to general spending on climate finance



Current expenditures on adaptation are far lower than projected needs, and financing provided for SSPs is far lower than general climate financing across all sectors (Vigerstol et al., 2023), (Chiriac et al., 2023).[xiv]

Investment lenses are mental models and decision-making processes that help investors, asset managers and corporate controllers make better informed choices where certain social and environmental risks and opportunities would otherwise be obscured by traditional profit biases (Tideline, n.d.).[xv] A well-developed adaptation lens to investing is needed and is described here as a process and set of tools to create resiliency in agriculture investments.

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BACKGROUND

Essential concepts for adaptation investing

This section provides a primer on adaptation and the financial rationale for adaptation investments, including an overview of valuation.

Adaptation 101

INVESTOR INSIGHT

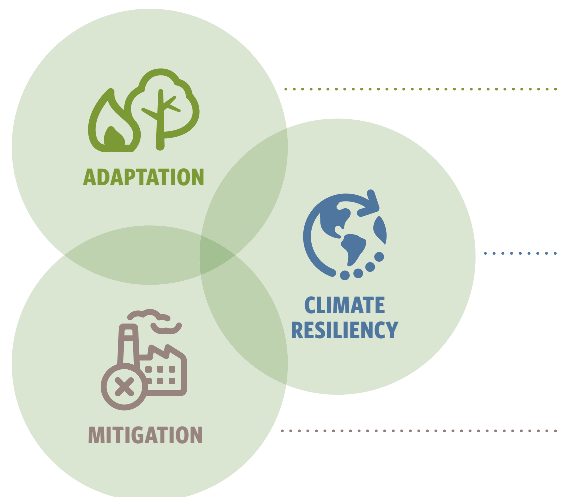
There is a lack of clearly defined criteria and terms within the climate adaptation space that make it challenging for investors to understand how to classify their investments and/or effectively measure desired outcomes of an adaptation intervention.

Adaptation, resilience, mitigation

According to the Intergovernmental Panel on Climate Change (IPCC), adaptation is the “process of adjustment to actual or expected climate and its effects.”[1] This can be anticipatory (before impacts have been observed), reactive or a combination of both. Similarly, the IPCC defines *climate resiliency* as “the capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure.” *Mitigation* is defined as human interventions that aim to reduce the emissions of greenhouse gases by sources or enhance their removal from the atmosphere through “sinks”—forests, vegetation or soils that can reabsorb CO_2. *Increased resilience* is the objective of adaptation while mitigation attempts to stem or reduce the severity of effects to which systems need to become more resilient (IPCC, 2014).[xvi]

The rise of climate adaptation activities adds a layer of complexity when distinguishing between traditional development activities and climate adaptation. Instead of defining a boundary between these two terms, many development and adaptation experts propose a continuum of approaches that may differ in the degree to which interventions address vulnerability versus climate change impacts. **The underlying link within this continuum is that they all contribute to adaptation, addressing issues related to poverty, social support, institutional strengthening, and planning and risk management** (Singh & Bose, 2021).[xvii]

Figure 6: Key climate definitions



The ‘process of adjustment to actual or expected climate and its effects’. This can be anticipatory (before impacts have been observed), reactive or a combination of both.

The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure

Human interventions that aim to reduce the emissions of greenhouse gases by sources or enhance their removal from the atmosphere by “sinks”, meaning forests, vegetation or soils that can reabsorb CO_2.

Adaptation, climate resiliency and mitigation are fundamental concepts (IPCC, 2014).

1 As a recent ISF and AgFunder report notes, there is not one recognized standard definition of adaptation. The authors of this report note that adaptation can be defined as *“measures taken to minimize the adverse impacts of actual or expected future climate change or to exploit beneficial opportunities.”* For more information, access the report here, which was produced in partnership with the Bill & Melinda Gates Foundation.

Figure 7: The connection between development and adaptation interventions

Addressing Drivers of Vulnerability	Building Response Capacity	Managing Climate Risk	Confronting Climate Change
Activities and investments focus on reducing poverty and on addressing other stressors and capacity deficits that make people vulnerable	Activities and investments focus on building strategies and systems for problem-solving	Activities and investments focus on incorporating climate-relevant information into decision-making	Activities and investments focus on addressing already occurring or anticipated climate change impacts and stresses
Example: Diversification of livelihood strategies; improved access to resources such as water or land	**Example:** Improved collection of climate related data; development of policies and plans	**Example:** Drilling of new wells to replace those lost to salinization or prolong drought; use of climate data to make planting decisions	**Example:** Construction of sea walls; substitution of livestock or crops with more more climate-tolerant species or varieties

Development
Focus on vulnerability

Adaptation
Focus on climate impacts

Need for climate information

Development and adaptation interventions exist along a continuum (modified from Singh & Bose, 2021).

However, splitting funding approaches by development vs. adaptation creates challenges. For example, a project proposed to the Green Climate Fund (GCF) in 2017 for Ethiopia titled *"Responding to the increasing risk of drought: building gender-responsive resilience of the most vulnerable communities"* failed to gain approval by the board which (among other issues) could not reach a consensus on the definition of the project-specific extent of adaptation. Although eventually approved, the project funding was substantially reduced (Singh et al., 2021). A more robust and effective approach is likely one that connects challenges to solutions based on robust climate risk analysis, delivers benefits beyond biophysical risk reduction, and connects more directly to resiliency (e.g., addressing system vulnerabilities, creating enabling conditions and improving social conditions). With this approach, many sectors of the economy could become more climate resilient through holistic and multi-sector adaptation strategies (ex: infrastructure, built environments, water availability, fisheries).

"A more **practical approach** [to the relationship between development and adaptation] would be to establish and define, on the basis of robust analysis and data, the causal connection between the proposed activities and context-specific climate risks, impacts, and vulnerabilities over various time horizons (e.g., short and long term)."

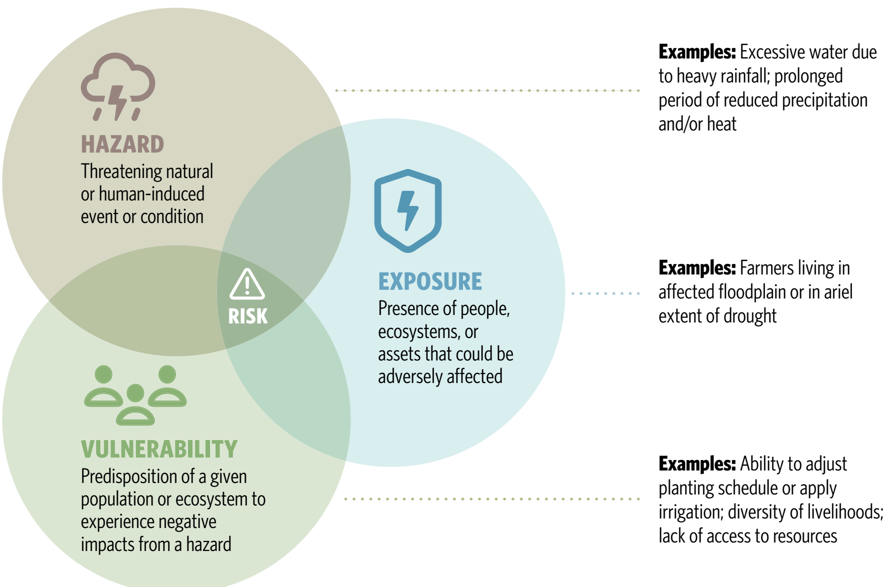
— World Resources Institute (WRI, 2018)[xviii]

Photo: © Andrew Kornylak

Agriculture Adaptation

Adapting agriculture systems to become more climate resilient focuses on the ability to withstand and recover from climate shocks while managing ongoing climate trends. Assessing the risks from current and future climate impacts includes identifying *exposure* (the presence of people, ecosystems and assets in areas that might be adversely affected) and *vulnerability* (the predisposition of a given population, ecosystem or asset to experience negative impacts from a hazard) (Figure 8). Exposure is particularly important for natural disasters—including whether populations are living or producing food in areas that might be inundated by floods or affected by fires or landslides—but is also relevant for longer term trends such as increasing temperatures and changing precipitation patterns.

Figure 8: Climate change risk factors



Components of climate change risk with examples (IPCC, 2022 & Vigerstol et al., 2023)..

Agricultural adaptation strategies focus on addressing the vulnerability of agriculture to climate hazards. Effective strategies can increase the resilience of the production system or individual farmer to succeed despite climate hazards and reduce the impacts that would have occurred otherwise. For example, access to water can help farmers maintain crop production despite increases in temperature or intermittent precipitation. Alternately, increasing the diversity of income sources can help farmers weather a drought or flood that devastates their main crops.

As the focus on climate adaptation grows in debates, policies and literature, the number of terms with multiple meanings is also increasing. Investors may find it helpful to become familiar with industry-defined terms to increase their use, applicability and standardization. See the Appendix for a brief list of commonly used terms in the climate adaptation space.

The financial rationale for adaptation investments

Along with the social, environmental, and operational imperatives for adaptation investments, there are two primary financial motivations for adaptation investments. Achieving agriculture resilience will depend on investors realizing and executing on both considerations.

1. **Realize the growing market for adaptation tools:** For newly established climate funds and investors looking for an area with significant growth potential, adaptation tools offer a sound market into which to deploy capital. Jay Koh of Lightsmith Group says, *"Climate change resilience and adaptation are not just this risk and impact, but an opportunity. It's an opportunity for entrepreneurs, technologists, and investors to understand that this is a major shift that is going to happen between now and 2030. Whoever figures out how to manage these risks and transcend them will build billion-dollar-plus companies"* (Harvard Business School, 2024).[xix] We will cover some of these specific opportunities in more depth in Step 3.

2. **Reduce the climate risk in agriculture-related portfolios:** For investors or companies whose strategies rely on agriculture products or services, adaptation investments can reduce many of the climate-related risks inherent to agriculture production. This supports two financial outcomes: First, it allows primary producers and agribusinesses to continue to produce at times of low supply and higher commodity prices due to climate shocks. Second, reducing overall volatility from climate-driven disruptions is key to managing returns through reducing losses and lowering discount rates. Acting on this opportunity does require the ability to measure the ROI of such risk-based investments–something that presents unique challenges with current data and tools. We will address this in Step 1.[2]

2 This thesis is applied at two scales: 1) annual production cycles where a given crop may fail or livestock suffer due to extreme weather events, leading to lower returns or net losses and 2) at a cumulative level where multiple shocks cause the financial collapse of whole food systems, leading to systemic financial and social impacts. Thus, adapting agriculture to climate change is essential to human wellbeing while also driving value for most direct investors in this space.

An overview of valuation

Figure 9 demonstrates the intrinsic valuation of investments, highlighting how investment value is a function of cash flows and discount rates. It also is a helpful reminder of how valuable limiting risk and volatility can be to overall investment performance.

Figure 9: Net present value formula

Expected cash flows over life (n) of asset

$$\textit{Net present value} = \frac{\Sigma(CF_1)}{(1+r)^1} + \frac{\Sigma(CF_2)}{(1+r)^2} + \cdots + \frac{\Sigma(CF_n)}{(1+r)^n}$$

r equals the discount rate and n equals the time of the cash flow (or period of the cash flow)

A quantitative method for deriving cash flows over the lifetime of an asset.

Keeping this in mind is helpful when looking at how to value adaptation investments specifically. The following steps of this guidebook will illustrate how investors can apply an adaptation lens to traditional valuation approaches.

Photo: © Anand Mishra

STEP 1

Assess climate risks and vulnerabilities relevant to your investment objectives

INVESTOR INSIGHT

There is a desire to understand future climate risks better and obtain easily accessible information on climate-change forecasts for relevant geographies.

Step 1 provides a theoretical framework to assess climate risks and vulnerabilities of a given investment or asset, along with a conceptual framework for considering the ROI of a given adaptation strategy. Both frameworks are mental models that offer a starting point to build risk assessment and valuation approaches relevant to a specific investment context.

This step contains three sub-steps:

- Step 1.1: Apply a conceptual approach for valuing climate adaptation interventions.
- Step 1.2: Determine how climate risks may impact investments.
- Step 1.3: Understand climate risks and determine the probability of disruptions.

At the conclusion of Step 1, the reader will have a more nuanced understanding of the probability and severity of climate risks relevant to their work as well as a theoretical understanding of the necessary stochastic and deterministic costs and benefits that need to be quantified to understand the ROI of an adaptation strategy. This allows the reader to then move to Step 2: *Identify and assess relevant adaptation strategies*. Table 1 demonstrates examples of the specific data inputs and outputs expanded on in this section.

Table 1: Data inputs and outputs for Step 1

Data Inputs	Data Outputs
Geographical scope of investment	Temperature and precipitation trends
Crop(s), livestock and land management specifications	Extreme weather events
Soil characteristics, if available	Crop, soil and water vulnerability
Irrigation sources	Predicted economic impacts
Yield data	Yield projections

Note that the level of detail will vary depending on an investor's geographical familiarity, the availability of data and the investment opportunity and maturity, among other factors.

Step 1.1

Apply a conceptual approach for valuing climate adaptation interventions

For corporations, lenders and PE/VC investors, the concept of valuing resilience is maturing in the face of questions from shareholders and stakeholders around preparations for a changing climate. Donors, NGOs and policymakers are also talking about system resilience—not just resilience to climate shocks but all manner of shocks to a system. This dialogue has been critical to integrating new concepts into established systems such as innovations around resilience credits, ways of reimagining Value at Risk (MSCI, 2020)[xx] and new approaches to incentivizing behavior through insurance premiums (Puri & Chowdhury, n.d.),[xxi] (Sherrick & Myers, 2023).[xxii] However, there is no effective financial metric that focuses on climate resilience, without which it is very difficult for leaders to make effective decisions about the ROI of any adaptation and resilience-focused investment.

Simply, the current state of climate forecasts contains too much uncertainty to directly include climate risk into a discount rate with traditional finance tools. Doing so will create exorbitantly high discount rates to account for such degrees of uncertainty and undermines the utility of even considering future climate impacts. Continuing to refine climate forecasts and their impact on the agriculture sector is essential to mobilizing capital despite how nascent existing tools and methodologies are for accurately assessing climate risks.

Fortunately, there are financial practices with non-climate risks to draw from. For example, a corporation investing in additional cybersecurity requires an informed view on the likelihood of a cyber-attack occurring and the degree of impact if one does occur. The Factor Analysis of Information Risk (FAIR) methodology is the international standard for quantifying cybersecurity risk and describes risk as *"probable frequency and probable magnitude of future loss"* (FAIR Institute, n.d.).[xxiii] Additionally, there are numerous annual reports that help assess both frequency and magnitude of loss, such as IBM's annual Cost of Data Breach report (IBM, 2024).[xxiv] Similarly, large manufacturing systems can have considerable working capital held in spare parts inventory and a key function of the Maintenance, Repair, and Operations (MRO) team is balancing sufficient availability to keep production running while limiting capital tied up in inventory. This creates an optimization process based on the probability a part may fail and the cost of a part's failure (often determined by the revenue lost each minute a production line is down). Other factors include the cost of a part and how quickly a part can be sourced at the last minute. Like cybersecurity, it forms a basic methodology for costing risk that can be expressed as:

$$\text{Probability of a disruption} * \text{cost of a disruption}$$

Parametric insurance is another industry with mature approaches to valuing risk (including nature-based risks) and provides a useful comparison for how climate risks and resilience can be valued. See Step 3 for more information on parametric insurance and its use in agriculture adaptation.

While mature sectors like cybersecurity have more robust data, more accepted valuation tools and an established track record for measuring risk, the climate industry is still early in its ability to express risk and resilience in financial terms. Proposed here is a basic theoretical concept for measuring the ROI of an adaptation investment. It is an initial step towards enhancing and strengthening valuation frameworks for the sector so that others can continue building and refining the concept.

Figure 10: Conceptual approach for measuring the ROI of an adaptation strategy

$$\text{ROI of an agriculture adaptation investment} = \frac{\sum (\text{Annual marginal value of risk reduction}) + \Delta \text{ in business performance}}{\text{Cost of adaptation project} + \sum (\text{annual maintenance cost})}$$

How an investor might assess the potential return of a given adaptation strategy in which the annual marginal cost of risk reduction = (Pre-investment annual probability of disruption * Pre-investment cost of disruption) – (post investment annual probability of disruption * post investment cost of disruption).

This is only a theoretical framework but is shared here to highlight the components of value in agriculture adaptation investing. While the function of calculating the marginal value of reduced risk is straightforward and not particularly innovative, the field of climate finance broadly—and agriculture investing specifically—has much to contribute to how each variable is quantified. Advancing our ability to quickly assess climate risk and developing a clear understanding of the risk-reduction and operating benefits of a given adaptation strategy will be critical contributions to advancing agriculture resilience. Lastly, it's important to note that each variable will be specific to both the geographic context and the agriculture value chain. Table 2 defines these terms in more detail and provides a theoretical example of applicability.

Table 2: Term definitions of the conceptual approach for measuring ROI

Term	Definition	Example
Pre-investment annual probability of a climate disruption	Expected frequency of climate disruptions	A significant drought may occur once every 10 years (10%)
Pre-investment cost of disruption	Estimated cost of disruption of an extreme climatic event	During drought years, on-farm revenue decreases by a certain dollar amount; during drought years, barley prices increase by a certain dollar amount
Post investment reduced probability of disruption or cost of disruption	Estimated avoided loss as a result of establishing adaptation approaches. The effect and severity of a disruption can be measured on the on the basis of likelihood, impact or both	A water pan may allow farms to maintain yields through drought, meaning a drought will need to be more severe to impact production (probability) and yields may stay higher than without a water pan, reducing the cost of disruption
Change in business performance	Expected cost savings/reductions and/or revenue increases across the enterprise post-adaptation integration	Water pans can reduce labor costs and increase yields, while a bank investing in agronomy services to increase the rate of adoption of practices may have indirect benefits such as sourcing new loans
Cost of the project and annual maintenance/operating costs	The initial CAPEX of the project and ongoing expenses to keep the project running	Water pans have an upfront purchase and installation cost and a nominal annual maintenance expense

With this framework in mind, we will next look at how to assess and understand climate risks and walk through an approach for understanding the probability and impact of business disruptions. Step 2 will focus on how to assess the cost and benefits of an adaptation strategy and Step 3 will provide examples of how adaptation investments using this framework can be incorporated into investing activities of VC/PE investors, lenders and corporations.

Step 1.2

Determine how climate risks may impact your investments

Despite the high degree of uncertainty and complexity in climate risk tools, developing informed climate forecasts is still a practical endeavor. An example of this is in the considerations for new fixed assets. Will a river remain sufficiently navigable to transport processed goods to a port? Is there sufficient water availability for the planned lifespan of a bottling plant to justify opening a new facility? Will the regional production of soybeans remain high enough to service a crushing facility? It is entirely plausible that a market will emerge for services that provide targeted climate forecasts for these large capital outlays.

But questions like these are also important to other types of direct investors:

- A VC may want to know if an agribusiness company supplying drip irrigation has a climate-driven growth strategy.
- A PE fund looking at a seed-tech company may wonder if seed varieties will remain viable under different climate forecasts.
- A real asset operator may change their annual operating plans and capital expenditures (CAPEX) spend if the risk of flooding is likely to increase from once every ten years to once every four years.
- A lender may want to know how to adjust the risk exposure of a portfolio that was underwritten with production estimates that are now changing due to altered weather patterns.
- A corporation may want to evaluate whether to invest in new adaptation BMPs in a region or look for a different source of supply altogether.

These and other questions are becoming more common and urgent. The answers to them will also determine what adaptation strategies are most relevant to meet particular investment goals.

Before discussing the existing climate forecasting tools, it is useful to understand some of the meta-climate risks affecting the whole agriculture sector. These can generally be categorized as increasing temperatures, changing precipitation patterns, increased risks for extreme weather events such as floods, droughts and extreme heat, and an increased prevalence of pests and diseases. People have already felt the effects of some of these climate risks and the scientific community is beginning to understand how to model potential risks. As part of their annual reporting, the IPCC provides research-backed climate projections across several sectors, including agriculture. Out of the risks identified, agriculture will be primarily affected by the following:

- **Additional warming will lead to more frequent and intense marine heatwaves and is projected to further amplify permafrost thawing and loss of seasonal snow cover, glaciers, land ice and Arctic Sea ice.** For the agricultural sector, this means a higher likelihood of droughts for longer periods. A study using atmospheric chemistry and a global integrated assessment model by Chuwah et al. (2015)[xxv] found that higher heat concentrations could lead to an increase in crop damage of up to 20% in agricultural regions by 2050. Other studies found that Africa could lose roughly 50% of its crop viability in the next 50 years if global temperatures reach 2.6° C.
- **Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation, and very wet and very dry weather and climate events and seasons.** The Food and Agriculture Organization (FAO) of the UN reported that floods were the second gravest agricultural disaster (next to droughts) as they were responsible for USD $21 billion in crop and livestock losses from 2008 to 2018 in the developing world (Kim et al., 2023).[xxvi] Additionally, an increased unpredictability in precipitation means farmers will struggle more with planning for optimal planting and harvesting times, resulting in a higher risk of crop loss.
- **The frequency, duration, and intensity of some extreme events will increase in the coming decades.** Some of these have already played out such as when a strong El Niño from late 2015 to early 2016 contributed to shifts in precipitation in the Sahel region. Significant drought across Ethiopia resulted in widespread crop failure and more than 10 million people requiring food aid (Anyamba et al., 2019).[xxvii]
- **Pest and disease outbreaks are likely to shift.** There are several studies that estimate about 50% of insects—which are often pests or disease vectors—will alter their ranges by about 50% by 2100 under current GHG emissions trajectories. These changes in insect pests will lead to crop losses and thus affect pest and disease management at the farm level (IPCC, 2019).[xxviii]

Despite these climate risks, the agricultural sector has significant opportunities for improvement and the potential to develop and promote food and livelihood systems that have greater environmental, economic and social resilience to risk. These opportunities can only be realized through the cross-sector, multi-level engagement of public and private actors. Step 3 will lay out some of these opportunities in the context of private investments.

Step 1.3

Understand climate risks and determine the probability of disruptions

There is an abundance of general climate and adaptation risk models and resources, many of which can be used to understand trends in the probability of a disruption occurring. Through stakeholder engagement and interviews, TNC curated a non-exhaustive list of applicable climate risk resources investors can rely on for climate risk assessments in different geographies. These can be found in the Zotero database and following are some suggested resources to begin the journey.

Table 3: Key climate risk forecasting resources

Climate Tool Name	Description	Relevant Data Provided
Climate Impact Lab	The Impact Lab provides a visualization of different temperature values (e.g., number of days >95°F) under different climate scenarios. The tool is a helpful starting point to see temperature changes from a historical baseline, near term (to 2039), mid-term (to 2059) and end of century. The raw data is also available for download.	U.S. and Global Temperature Data; Social Cost of Carbon
Climate Knowledge Portal	This provides country-level climate change data that helps users explore baseline temperature and precipitation values along with future forecasts and probabilities. The narrative descriptions at the country level can be both a useful starting point and helpful for interpreting the data. The IPCC's modules also provide narrative descriptions and sources for additional data at the continent and country level.	Temperature and Precipitation
Climate Impact Explorer	Visualizes numerous climate risks across different probability scenarios including floods, heat waves and cyclones across different climate scenarios.	Global and Regional Severity of Climate Change Impacts at Different RCP Scenarios
Africa Adaptation Atlas	The atlas is a data and tool repository to help stakeholders take climate action. While its focus is on Africa, it provides an excellent case study on emerging opportunities to structure and visualize data for risk assessment and adaptive action. Managed by a team at CGIAR, it should be a first stop to begin learning about the interplay between climate change, agriculture and adaptation strategies.	Historical Climate Patterns and Projections; Temperature; Precipitation; Crop Yields, Crop Performance; Adaptive Capacity; Adaptation Strategies
USDA Climate Hub	This has a U.S. focus but provides many globally relevant resources related to climate forecasts and adaptation strategies. Readers can also find COMET-Planner here which provides carbon sequestration and GHG emission reduction estimates for common agriculture practices at a site level.	GHG Emission Reduction Estimates; Agriculture Exposure Mapping; Precipitation; Temperature; Soil Moisture; Climatic Projections
ClimateToolbox	Hosted by UC Merced, this toolbox provides numerous tools to assess historical and future climate trends and their impacts on specific crops. While most relevant to the U.S., it can provide insights into broader future trends.	Temperature, Precipitation; Humidity; Regional Climate Projections; Extreme Weather Data (including frequency, intensity, and duration); Soil Moisture; Pest and Disease Risk; Yield Data; Adaptation Strategies
SPEI	The SPEI drought tool assesses drought severity using precipitation and potential evapotranspiration data, providing insights into drought duration and intensity for better drought risk management in various sectors.	Global and Regional Historical Flood and Drought Risk (including severity, duration, and spatial extent)
Raw Data Sources		
Climate Hazard Center at UC Santa Barbara	The Climate Hazards Center is an alliance of multidisciplinary scientists and food security analysts utilizing climate and crop models, satellite-based earth observations, and socioeconomic data sets to predict and monitor droughts and food shortages among the world's most vulnerable populations.	CHIRPS drought and rainfall data
International Institute for Applied Systems Analysis	IIASA is an international research institute that advances systems analysis and applies its research methods to identify policy solutions to reduce human footprints, enhance the resilience of natural and socioeconomic systems and help achieve the UN Sustainable Development Goals.	Many models and data sets, including the Integrated Assessment Modeling Consortium (IAMC) 1.5°C scenario explorer used in the IPCC report
Lobell Lab at Stanford	Focused on research into food security and crop productivity with numerous projects focused on climate and crop productivity.	LIDAR crop types, crop mapping, air pollution, crop productivity

The Bill & Melinda Gates foundation also collaborated with RTI International to develop a publicly available repository of climate-agriculture risk tools, with recommendations on tool subject applicability and target audience. Click here to access the database.

Case in practice

Following is a hypothetical approach to assess climate risk in a region and how it might apply to investment decisions. This approach is directional, meaning it can suggest ways to better sensitize financial models and create scenarios that inform decisions, but the uncertainty of climate forecasts remains too great to directly quantify risk at this stage. However, it illustrates and puts into practice each step of the adaptation investing lens introduced in this guidebook.

Consider an example of a Kenya-based food corporation that is expecting a supply disruption in maize, one of their key inputs. Step 1 is to understand the climate risk affecting this region and crop, particularly around extreme weather trends, economic impacts, sector vulnerabilities and yield projections.

Using information collected from the Climate Knowledge Portal, Kenya is recognized as highly vulnerable to climate change impacts. They are ranked 144 out of 181 countries in the 2021 ND-GAIN Index which measures a country's vulnerability to climate change (World Bank Group, 2021)[xxix] with expected rising temperatures and rainfall events increasing in frequency, duration and intensity. These repeated patterns of floods and droughts in the country have had large socio-economic impacts and high economic costs. For example, the extended 2008-2011 drought cost an estimated USD $12.1 billion, principally due to crops and livestock loss as well as forest fires, damage to fisheries, reduced hydropower generation, reduced industrial production and reduced water supplies (USAID, 2018).[xxx]

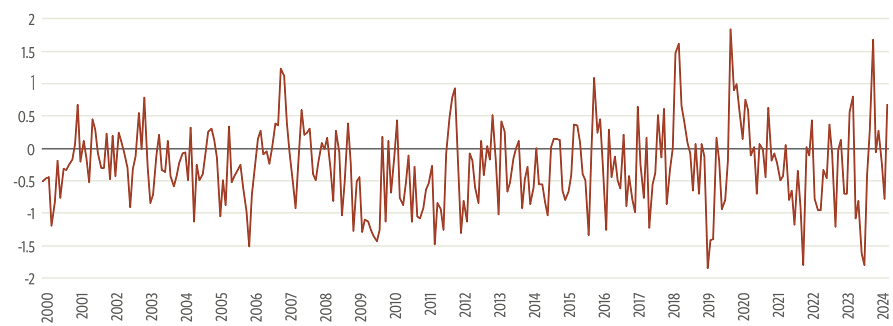
For the agriculture sector, these climate risks play a major role. Critically, this sector accounts for approximately 28% of Kenya's GDP, with the crop sub-sector comprising 78% of this. As of 2015, the agricultural sector provided 80% of total employment and supported over 80% of the rural population, underscoring the importance this sector has on overall food security and economic prosperity for the region. Given Kenya's reliance on agriculture, the projected changes in precipitation patterns are expected to directly increase the likelihood of short-term crop failures and long-term production declines if no adaptation interventions are implemented (World Bank Group, 2021).

While vulnerability assessments build an important foundation for understanding investment need opportunities, yield and climate data can also reveal key insights for the investor community. For the following example, yield data is pulled from Our World in Data (Ritchie et al., 2022)[xxxi] and historical climate data is derived from the Standardized Precipitation-Evapotranspiration Index (SPEI) (Beguería et al., n.d.)[xxxii] which provides historical measures of drought and flood. These data sets work well together as most maize is dry land farmed and responsive to precipitation. These sources and the process below are intentionally basic to allow readers to better add the data sources and statistical methods relevant to their context.

The yield data is a country-wide average which better facilitates the example compared to looking at the producers in a loan portfolio or local suppliers of a brewing facility. Further, SPEI does not include multiple factors that impact yield like temperature, disease, the cost of inputs or other political and social factors. Temperature is a component of evapotranspiration calculations in SPEI, but including a discrete data set for temperature may be useful, especially with temperature-sensitive crops like barley.

The regression of yield against the SPEI measurement during the planting season explains approximately 20% of yield volatility (see the Appendix for the full regression results and main takeaways for interpretation). While not a statistically significant predictor it is informative, especially as an isolated variable. As other variables are included, the response improves. In the case of the Kenya example—where climate forecasts indicate the region will experience increasing droughts with flood events that are farther apart but more extreme—even this simple level of data can generate useful insights.

Figure 11: SPEI global drought index performance (2000 – 2024)

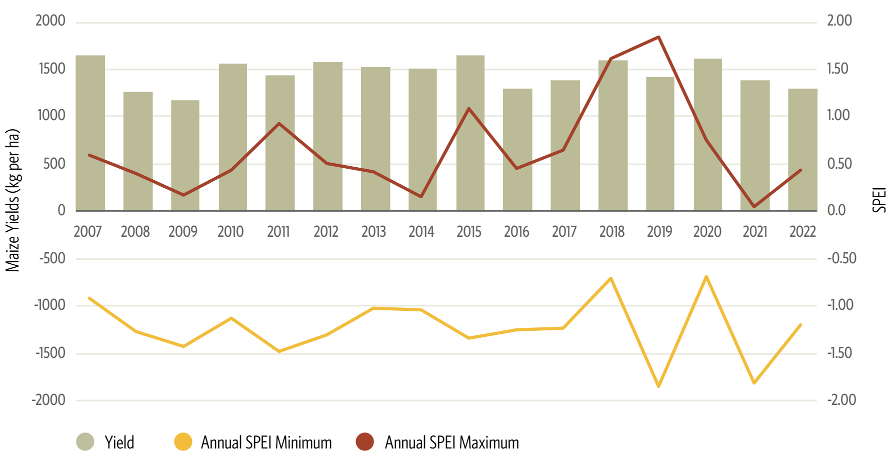


SPEI tracking of the variation from 'normal' to measure global drought conditions from 2000-2024 (Beguería et al., n.d.).

As with the cybersecurity example, climate risk (for financial purposes) can be considered a function of the *probability* that an event may occur and the *severity* of that event. First, let's consider how to develop an informed opinion on severity. On a monthly basis, SPEI tracks variations from "normal" using an index of 2 to –2 where a range between –1 and 1 is considered near normal, +1.5 and above is considered a very wet/extreme rainfall event and –1.5 or below is considered severe/extreme drought event. We can expect that extreme floods and droughts will impact yields which can be seen in the data. For example, 2007-08, 2014-15, and 2021-22 had SPEI indexes of approximately –1.3 and around the same period yields fell 12-14% each year below the average (the average volatility for 2000-2022 was about 10%). In 2019, Kenya experienced both the worst drought event in the 20-year record and the worst flood event. Despite that, maize yields were up 9% from the average the following year, perhaps due to the thirsty nature of maize. It is important to emphasize that these relationships are not statistically significant and many confounding variables exist, even with a specific crop. However, it does elucidate some basic relationships between certain climate events–in this case drought and flood–and farm productivity.

The historical record also helps investors understand the frequency of events occurring. Using an SPEI above 1.30 and below –1.30, the data shows that from 1950-1960 extreme climatic events occurred every 5 years. Between 2010-2020, these events occurred about once every year. This also shows up in the 5-year volatility which ends at 10% between 2015-2020 compared to 3% from 1960-1965. See the Appendix for a detailed 5-year yield and price volatility analysis.

Figure 12: SPEI impact on maize yields in Kenya (2007 – 2022)



Maize yields in Kenya from 2007-2022, taking into consideration the SPEI index (Pieter & Andrée, 2024),[xxxiii] (Ritchie et al., 2022).

Table 4: 10-year count and frequency analysis of extreme climatic events, including droughts and floods

Year	Number of Recorded Extreme Climatic Events	Average Years between Climate Events
1950-1960	2	5.00
1961-1970	12	0.83
1971-1980	1	10.00
1981-1990	2	5.00
1991-2000	4	2.50
2001-2010	3	3.33
2011-2020	9	1.11

Data collected from Beguería et al., n.d.

Applying these observations will vary depending on the type of investor. Regardless, several observations can form the basis of basic climate-based scenario planning. First, by looking at the climate forecast tools investors can generally spot a trend towards increasing temperatures, an increased incidence of drought, and perhaps less frequent (but more severe) floods. In short, droughts are likely to increase. Second, an informed assumption can be made that during periods of drought the volatility of maize yields will likely increase—perhaps by an additional 4-6%. From the two can be made reasonably grounded assumptions about how to sensitize the probability of a climate event and the severity of that event.

To apply these sensitivities, consider creating three scenarios to test things like stability of supply or farm production for a loan portfolio.

- **Base case:** projects yields based on the current case where an extreme climatic event occurs once every 6 years over a 10-year period, and yield and price volatilities are around 10% and 9%, respectively (using 2015-2020 data as referenced above).
- **Likely case:** assesses climate forecasts and incorporates observed changes in trends over time. An example set of assumptions may be that an extreme event occurs once every 4 years, and volatility increases by 1-2% during climate events.
- **Worst case:** assumes a more intense climatic outlook in which an extreme climatic event occurs every 2-3 years with volatility increasing further during climate events.

One could also test the compounding impacts of back-to-back events, perhaps exploring the potential impacts of severe supply disruptions but also considering the yield impacts of drought or flood events occurring closer together in that 10-year span. There are many ways to employ these types of scenarios based on individual needs, and additional data sets can be brought in to further refine issues like yield, price, the potential demand for inputs, etc. It is still more art than science to make well-informed assertions about future climate events but even a rough level of forecasting can be enough to build a scenario that helps identify risks and opportunities. Crucially, this may help determine where adaptation investments can reduce the added volatility driven by climate impacts.

Evaluating scenarios this way can offer a view into potential outcomes at the production level and inform response strategies. A lender may then consider how this will impact existing loan portfolios, a PE firm may see risks to the wider market or spot new opportunities, and a corporation may have a deeper understanding of possible supply disruptions. There are various adaptation strategies that may help with the risks highlighted in this scenario—the water pans and drought-tolerant seeds examples included in the Appendix are both relevant.

Using the processes described in Step 1 can begin to inform a view on the possible ROI of adaptation based in the context of an investor's operations and goals. This type of scenario planning highlights opportunities to further advance the field of agriculture resilience:

- More refined climate data to reduce the uncertainty of future climate shocks.
- Deeper analysis and more accessible tools to assess a given system's response to climate shocks.
- Better region-specific longitudinal data on a given adaptation strategy's impact on climate shocks.
- Better mathematical models to derive the value of resilience at the asset level.

Additional considerations for evaluating adaptation investments

There will be a degree of uncertainty

There are multiple sources of uncertainty when estimating the costs, benefits and impacts of different adaptation strategies. As with any agricultural intervention, the ability and willingness of farmers and other actors to adopt the strategies, the existence of specific enabling conditions such as policies or supporting institutions, and ongoing fluctuations in markets and socioeconomic trends will have an impact on outcomes. With adaptation-focused interventions, the climate change impacts themselves are also a huge source of uncertainty. Even if a particular emissions scenario is assumed, the complexities of global to local hydrometeorological systems mean that the range of possible climate impacts in a specific location can be significant, with a similar effect on the value of an adaptation strategy.

The urgency for adaptation investment requires acting despite these uncertainties. Progress has been made on approaches that incorporate uncertainty in a manner that still allow decision making to move forward. The following recommendations incorporate several of these and offer investors a range of options to suit varying levels of comfort with uncertainty and the willingness to invest resources to reduce that uncertainty:

- Conduct a sensitivity analysis of different factors used in the cost/benefit analysis. Clarify assumptions early and understand the level of uncertainty and the impact of that assumption on costs/benefits.
- Identify actions that can reduce uncertainties (for example, bundling adaptation interventions to increase the certainty of increased yield or decreased losses, or supporting an enabling condition such as on the ground technical assistance).
- Determine if specific uncertainties will ultimately impact an investment decision and decide if it is practical to invest in specific actions that can address them, and/or it is worthwhile investing resources into a more complex assessment of the likelihood of specific outcomes.
- Support a monitoring program to test assumptions and address uncertainties, and then undertake an adaptative management approach that incorporates the inclusion of updated information over time.
- Carry forward ranges of possible outcomes in assessing values and making investment decisions. For example, include the range of potential climate-related outcomes based on the most likely emissions scenarios and the range of follow-on impacts. Using a climate model with options to select different scenarios and model ensembles is a helpful way to assess this range. Investors might choose to use the average or most probable outcomes, but this could result in missing out on other possible outcomes and result in an incorrect assessment of a strategy's potential impact.
- Apply probability models to determine the likelihood of a strategy's specific outcomes and impacts. This requires engaging an expert who can apply these models to the various areas of uncertainty (Vermeulen et al., 2013),[xxxiv] (Rosenstock et al., 2014).[xxxv]

Time is relative, which is also true for climate benefits and capital returns

The time horizons of stakeholder decision making, climate and strategy impacts, and an investor's need for liquidity are often not in alignment. Therefore, it's important to consider the unique aspects of timing for agricultural adaptation investments and identify ways to address time-related challenges. A useful starting place is mapping the potential timing of costs and benefits across adaptation strategies and investment vehicles and identifying points of uncertainty and potential conflict. There are at least three aspects of timing to consider:

- **Investment vs. return:** Investors' return and liquidity expectations—be it for lenders or VC/PE investors—may not match with the time it takes for capital allocations to generate a return.
- **Seasonality of agriculture:** Agriculture is a highly seasonal business with periods of significant outflows and inflows of cash. Understanding the seasonality of each crop type and region is critical to understanding the health of an investment opportunity.
- **Timing of farmer decision-making:** As income fluctuates over a year, farmers tend to make different decisions when they have more money versus when they are struggling. For example, a farmer may be more willing to take on risk or engage in an adaptation intervention in post-harvest periods, but not necessarily when this action is most useful. Similarly, in a year with lower yields farmers might be more open to change, not want to risk any changes in practices, or not want to take on anything that requires investment of their time or resources.

There are several ways to potentially address these points of misalignment in terms of timing of investment, cost and benefits. These include:

- **Bundling of adaptation strategies:** For example, investing in one strategy that delivers returns sooner along with one that offers more long-term impact but takes longer to start delivering returns. Find more information on bundling in Step 2.
- **Co-investment with public funding:** Concessional finance can use incentives to address misalignments of intervention timing with a farmer's decision-making, or additional funding might help deliver on impact sooner. Find more information on blended finance in Step 3.
- **Consideration of co-benefits of adaptation strategies:** Most strategies provide more than one type of benefit. Even if the near-term benefits are not financial, being able to demonstrate them can be valuable.
- **Changing policy and other enabling conditions:** In a similar manner to concessional finance, providing incentives and supporting enabling conditions (such as technical assistance) can help mitigate some of the timing misalignment.

Practical examples include the following:

- **Certified Organic Transition:** At the outset of the USDA Organic certification, farmers faced steep challenges financing the transition from conventional production to organic. The three-year transition period resulted in a loss of current income which created difficulties in getting operating or transition loans underwritten despite the potential for increased future revenue. As growers and lenders better understood the costs of transition and gained confidence in the organic premium, financial institutions developed products to fit the need. Rabo AgriFinance launched one of the first transition funds in 2019 as data became available to show a transition loan as a secure investment.
- **Soil health:** Standard soil management practices can take several years to realize their operational benefits including increased yields, the reduced need for inputs and a greater resiliency to weather shocks. Reduced yield, cover cropping seeds and direct seeding equipment are all up-front costs and financing them can be a challenge due to the mismatch in time-to-return. Like organic transition financing, farmers and lenders are starting to better understand the long-term value of these practices—to the point that soil health and soil management practices are becoming components of farmland appraisals/valuations and priced into cash rents.

Step 1 conclusion

In summary, understanding the impacts of climate is complex. However, many resources are being devoted to enhancing climate risk tools. The conceptual approach for evaluating the ROI of an adaptation intervention serves as a directional method to put into practice the information gathered from these climate risk tools. By coupling this approach with the resources available in the Zotero database, investors can begin to inform their judgement on emerging climate risks and opportunities relevant to an investment strategy. Step 2 builds off these identified climate risks to better assess, select and prioritize climate adaptation strategies that address these risks.

STEP 2

Identify and assess relevant adaptation strategies

Step 2 introduces a process for selecting adaptation strategies that specifically address the climate risks identified in Step 1 and are appropriate for the food system(s) of focus. It uses the output of the climate risk assessment outlined in Step 1 along with information on the local or regional context to identify and assess potential adaptation strategies. Step 2 also helps an investor assess financial and non-financial costs and benefits related to those strategies, which supports Step 3: *Integrate Adaptation into Your Portfolio*. Step 2 is comprised of two sub-steps:

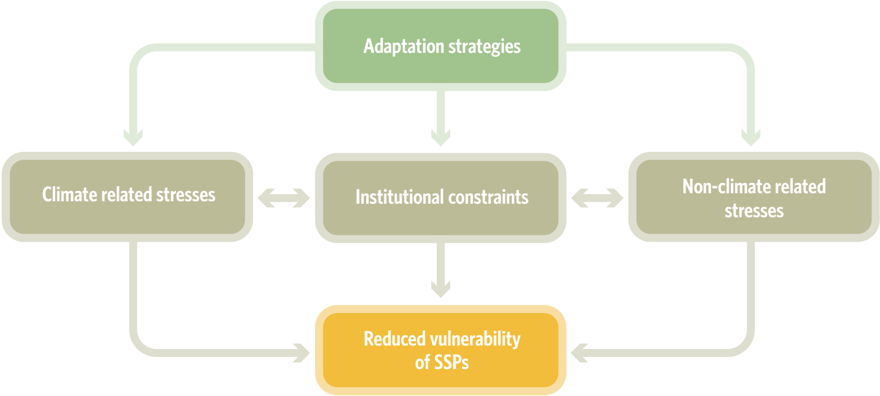
- Step 2.1: Identify relevant adaptation strategies.
- Step 2.2: Assess selected adaptation strategies.

Step 2.1 Identify relevant adaptation strategies

Step 1 provides guidance on accessing information about climate-related hazards that can impact agricultural production and agriculture-related investments. However, SSPs are also vulnerable to non-climatic factors, including insufficient access to land, high levels of poverty, poor education levels and limited access to training opportunities, markets, finance and critical infrastructure. When investing in a region and value chain, identifying these vulnerabilities across climate and non-climatic factors will help to narrow down the list of potential adaptation strategies to those that address gaps in adaptive capacity and help reduce the risk of climate impacts.[3]

3 A binding constraints analysis can be adapted to identify these areas.

Figure 13: Non-climactic factors of adaptation strategies



SSPs are vulnerable to these non-climatic factors of adaptation strategies (modified from Owusu et al., 2015).[xxxvi]

Adaptation strategies for agriculture can take many forms, from water management to diversification of products to agricultural insurance. Table 5 provides a menu of adaptation strategies that include on the ground actions, supporting or enabling actions, and risk management strategies. Each type of strategy addresses a different part of the agricultural system and has the potential to deliver on a variety of direct and indirect adaptation benefits, potential co-benefits and tradeoffs. It also provides a sample list of interventions for each strategy type and a few of the potential direct benefits, but the appropriateness of each intervention, the ability for it to deliver on a specific suite of benefits and the enabling conditions required for success will differ based on local context. The example interventions listed do not include all possible permutations of the primary adaptation strategies as they can take many specific forms depending on local conditions and intended outcomes.

Effectively selecting adaptation strategies for a given context, from the farm to the food system to the national or regional level, depends on a variety of factors. These include the ability to address climate hazards and reduce exposure and vulnerabilities, the appropriate applications for given food system(s), the presence of key enabling conditions or barriers, and the potential benefits and costs for implementers and investors. Table 5 provides an initial list of strategies that are known to address specific climate risk(s) and are appropriate for the given food system. This menu is not exhaustive and there may be additional strategies unique to the location or food system that should be considered. Information gathered in Step 1 on key climate risks should be paired with knowledge of the food system and local context to get to a shortlist of strategies.

Table 5: Example adaptation strategies

	Strategy	Example Interventions	Benefits
On-farm actions	Water management	Drip irrigation, water pans, rainwater harvesting	Increased production, decreased losses during drier periods / droughts, potential to grow different crops or add another annual rotation
	Soil and nutrient management	Cover crop, minimum tillage, fertilizer use, terracing	Improved soil health for increased longterm productivity, increased soil water holding capacity to increase resilience to drier periods
	Sustainable land management	Terracing, gully treatment, hedgerows	Reduced soil erosion, which is expected to increase with more intense rainfall. Helps maintain production in the medium to long-term
	Improved seeds and livestock breeds	Drought tolerant seeds, higher productivity cultivars and breeds, more resilient breeds	Higher productivity, reduced losses during drier periods, increased resilience to other risks
	Diversification of crops or livelihoods	Introduction of new crops or livestock types, new streams of income	Diversity of income increases resilience to climate impacts, market fluctuations and other risks
	Changing planting or harvesting schedules	Altering the timing of planting or harvesting in any given year based on climate or market information	Adaptation to specific weather patterns to maximize productivity
	Shifting systems (silvopastoral, agroforestry, other land use, etc.)	Introduction of silvopastoral or agroforestry systems into previous monoculture systems; crop switching; other change of land use	Depends on the type of shift or transition. Can increase incomes, provide more diversity of incomes for increased resilience and provide co-benefits (such as carbon sequestration, biodiversity, etc.)
	Improved storage / post-harvest handling	Providing on-site storage bags; building a shared storage shed / container; improved conditions of current storage to reduce losses; improved post-harvest processing to reduce losses	Reduced losses and more flexibility in timing sale of products to match higher market prices
Supporting or enabling actions	Information services (climate, market, etc.) to inform planting and management actions	Digital climate or market information	Optimized timing and management of production system to increase production and reduce losses
	Technical training / extension or advisory services	Training on improved management of water / soil / fertilizer application / seeds, etc.; ongong advisory services to help with adaptive management of production	Can help improve productivity and reduce losses; can help adaptively manage to changing climate
	Improved or diversified access to markets	Connecting producers to buyers; reducing transport costs; reducing market entry costs	Potential to get a better price for products; when diversifying helps find a market for new products
	Improved technologies	Innovations in irrigation, seeds, fertilizers, breeds, etc.	More effective water management and resilient production, including with unpredictable climate changes
	Increased venture capital	Creating capacity of producers to add processing; forming producer collaboratives/ associations for joint marketing/processing	Increased and higher diversity of incomes to increase resilience
	Enabling policies	Providing incentives or reduce barriers to adaptation strategy uptake (and remove perverse or biased incentives); reducing market barriers by elimination of onerous or contradictory regulations; reduce corruption	Can support resilience building and reduce barriers to success for small-scale producers; can provide incentives for adaptation strategies
Risk management	Insurance	Insurance to cover losses for events such as droughts, floods and pest infestation	Reduced financial losses and increased farmer and community resilience despite increased risks of loss events due to climate change
	Early warning systems	Communication systems to provide early warning about natural disasters	Reduced loss of lives and property during natural disasters such as floods

From the initial list of adaptation strategies based on climate risks and agricultural system type, assess the feasibility and potential impact of each strategy. This will rule out strategies that are not practical and help identify the specific interventions[4] most likely to deliver the desired impact. This includes integrating information on the biophysical and socioeconomic setting, relevant policies and regulations, an assessment of the scale of potential impact, awareness of past or present efforts to scale up different adaptation interventions, identification of potential implementation and supporting entities and consideration of potential funding support. Conversations with local land managers, organizations, universities, extension services and other local stakeholders can be helpful during this process.

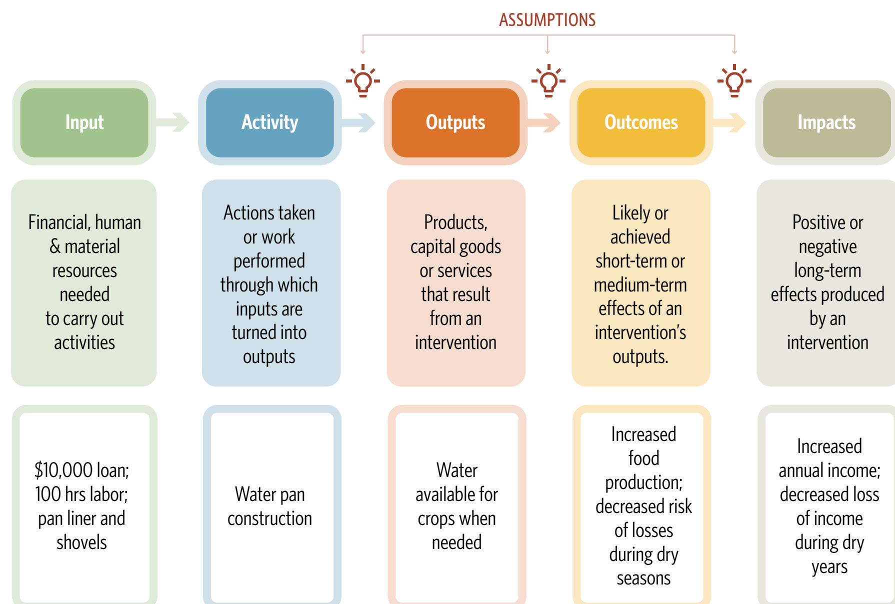
The following list of questions can support an assessment of potential enabling conditions and help to narrow the focus from strategies to specific interventions:

- Is the biophysical setting conducive to successfully applying the intervention, including factors such as proximity to a water source, consistent availability of water, annual precipitation patterns, soil types, slopes, physical barriers, etc.?
- Are farmers or other relevant actors able to adopt the intervention based on existing technical knowledge, land tenure (where applicable) and resources? Are there any cultural norms, behavioral factors, or individual or community attitudes or preferences that would get in the way of adoption?
- Are there policies in place that do not allow an intervention or that make it burdensome or challenging to implement? Are there policies incentivizing land uses incompatible with the intervention? Are there policies in place that incentivize the intervention?
- What adaptation strategies and specific interventions have already been implemented in this area? Did the scale-up of specific interventions fail or succeed? Why?
- Are there organizations, extension services or programs already in place that could help implement and scale adoption?
- Is there potential concessionary funding to help support the creation of missing enabling conditions, or technical training or other aspects helpful to successfully initiate and sustain the intervention?

A note on results chains

A results chain is a complementary way to help assess the feasibility and impact of adaptation interventions. It is a logic model that traces out under what conditions an initial (set of) intervention(s) leads to specific target outcomes (often via multiple intermediate results) while clearly identifying needed inputs and assumptions along each step of the logic chain. Ideally, it indicates effect sizes and uncertainties along the whole chain.

Figure 14: Example results chain



Creating a results chain can be a useful exercise for identifying what is needed to deliver on the intended impacts of an adaptation strategy.

4 For this guide, adaptation 'strategies' are categories of activities that take a similar approach but may look different in their implementation. Adaptation 'interventions' are the specific activities within the defined strategy. For example, 'water management' is an adaptation strategy, while 'water pan' is a specific adaptation intervention that aligns with the water management strategy.

Understanding what is needed to deliver on the intended impacts, highlighting the enabling conditions to ensure an activity results in a specific output, outcome and impact, and identifying any gaps in these links can help assess whether the intervention is feasible given the context, available resources and enabling conditions, or identify where more work is needed to reach a point of feasibility.

Once the longer list of adaptation strategies has been assessed for feasibility, and specific interventions have been identified for more in-depth consideration, an assessment of costs and benefits should be conducted for this short-list of adaptation interventions to support investment decision making in Step 3.

Case in practice: Step 2.1

This section presents an example of applying Step 2.1, *identify relevant adaptation strategies*. The output of this assessment will be one or more adaptation interventions for the cost and benefit assessment in Step 2.2.

The example assessment here focuses on cocoa production in Ghana. Ghana is the world's second largest producer of cocoa, a major agricultural commodity supporting over 800,000 households. Ghana is already experiencing impacts on cocoa production from climate change, including erratic rainfall, increased temperatures and increased prevalence of weather-related pests and disease (Afele et al. 2024).[xxxvii] The most direct impacts will likely be felt from floods and extended dry periods (Okoffo et al., 2016).[xxxviii] For 2023-2024, cocoa production is expected to be 40% below the country's annual production target. This is due primarily to high winds and a lack of rain but also swollen shoot disease, cocoa smuggling and illegal gold mining on cocoa farmland (Reuters, 2024).[xxxix] Cocoa production in Ghana is also experiencing a degradation of soil, particularly in places where monoculture or high-tech cocoa production systems replaced more traditional agroforestry practices, with declines in production expected to accelerate in the coming decades. Many of these factors are connected and are indicative of an agricultural production system that desperately needs a greater investment in strategies that support the production of consistently viable crops.

Considering the expected climate impacts on cocoa production in Ghana and the other non-climate related stresses that need to be addressed, the following potential adaptation strategies may be considered:

- Water management
- Extension services / training
- Agronomic practices
- Diversification of crops
- Information services
- Improved technology
- Insurance
- Shifting production system

Although all these potential adaptation strategies could address some of the threats to cocoa production, shifting the production system has the greatest potential for ensuring long-term resilience due to its potential to address issues of soil health and diversify food products.[5] When considering the regional context, agroforestry (which sits within the 'shifting production systems' strategy) stands out for the following reasons:

- Agroforestry was the more traditional system for cocoa farming in Ghana before government programs encouraged the shift to full sun and high-tech systems in the late 1900s.
- The presence of agroforestry programs and extension services already in Ghana indicates both feasibility and the presence of existing organizations, providers and technical advisors who may be able to help deliver on agroforestry investments.
- The increasing demand for shade-grown cocoa from chocolate producers who source cocoa from West Africa.
- The potential for co-benefits such as climate mitigation and biodiversity improvements.

However, there are also some important enabling conditions and assumptions that need to be considered for agroforestry, including:

- **Farmer recruitment challenges:** Significant work went into converting farmers from traditional cocoa practices (which looked much like agroforestry) to full sun or high-tech production in previous decades. There will be challenges in convincing farmers to convert back to agroforestry systems given this history and the positive impacts full-sun and high-tech systems have shown in terms of cocoa production.
- **Ongoing smuggling of cocoa and increased surface mining on agricultural lands:** These pressures may impact the overall cocoa market and may influence farmers in deciding whether to commit to making a change to agroforestry.
- **Access to markets:** Diversifying food production requires access to markets for the new products. Ensuring farmers can profit from the additional products is essential to deliver on any potential benefits from agroforestry.
- **National policies on cocoa pricing:** For some areas, farmers can generate additional profits by converting to shade-grown production and receiving higher prices from companies looking to offer shade-grown products (such as chocolate) to their customers. In Ghana, cocoa prices are currently fixed at the national level so this additional benefit would not be available for farmers who convert to agroforestry.

5 Although only one adaptation intervention is selected for the purpose of the case study, in many cases more than one adaptation intervention may be selected to be implemented in tandem to build the resilience of the system. This is an example of 'bundling', which is described in 'A note on bundling.'

In this example agroforestry is selected as the primary adaptation intervention considered for investment due to its ability to address climate and other risks to cocoa production and based on a check of the enabling conditions. However, it likely makes sense to pair this intervention with one or more of the other strategies under consideration to help ensure successful resilience-building efforts. For more discussion on pairing two or more adaptation strategies, see the note on bundling.

A note on bundling

Although this step breaks down adaptation investments into individual strategies or interventions to simplify the presentation and discussion, effective investments in adaptation typically integrate several interventions, whether simultaneously, over time, or both. It is unlikely that one intervention will fully address the impacts of climate change and adequately build the resilience of farmers and farming communities. Bundling can help address different components of vulnerability and mitigate issues around uncertainty and timing.

One example of bundling is combining improved (e.g., higher yield, more drought-resistant) seeds with agronomic practices that help bolster yields. This combination can help deliver on improved yields during average years, but more importantly buffer yields from large losses due to increasingly erratic precipitation patterns and higher temperatures.

Another bundling example is improved water management (such as water storage and/or irrigation) with a diversification of crops. Improving water management could allow a farmer to grow higher-value crops that require irrigation. By diversifying their crops, the farmer has more resilience to changes in market prices or crop-specific diseases which are likely to increase with climate change.

For most on-the-ground adaptation strategies, bundling with enabling strategies can help ensure the successful delivery of their intended impacts. For example, for most of the on-the-ground strategies also investing in information services and/or technical assistance can help farmers maximize their potential outputs. In many cases a private investor may partner with a public funder to help cover some of these enabling strategies, or there may be extension services or organizations already in place that can help support these strategies.

Step 2.2

Assess the costs and benefits of the adaptation interventions

In Step 2.2, the costs and benefits of adaptation interventions are identified and assessed. Although an investor analysis for adaptation can take several forms—particularly depending on the type of investor and potential investment vehicles—the assessment of specific adaptation interventions (including the farm level analysis of costs and benefits) can serve as a common building block.

For on-farm interventions, cost estimates should include the full cost of planning, program development (if applicable), implementation, support services and maintenance (e.g., farmer recruitment, technical advising, maintenance assistance, and monitoring costs). The assessment of benefits should include both financial and non-financial benefits with non-financial benefits assessed quantitatively where possible.

It is important to identify who bears what costs and incurs what benefits since the flow of resources and benefits is critical to understanding the intervention feasibility, scalability and potential investment structures. Equally important during this assessment is identifying the data inputs that have the biggest impact on the potential costs and benefits and/or are the most uncertain. This will help guide where an investor's time or resources should be focused to get accurate information and clarify potential areas of uncertainty.

Potential data sources

Information sources on costs and benefits for an intervention in a specific location may vary but some potential resources include:

- Existing programs that are already implementing the intervention in a similar location (white papers, academic publications or interviews with program staff).
- Commercial prices for equipment or materials which may be listed on websites or sought out via direct communication.
- Published literature (academic or white papers) on the cost of interventions, ideally in the same country or region.
- National databases on labor or other common costs, and on ranges of typical market prices for specific commodities.
- Interviews with local or regional experts in this food system and/or these types of interventions.
- Information gathered via sector coalitions or partnerships such as the World Cocoa Foundation.
- Academic literature on the measured benefits of interventions, including financial and non-financial benefits.

Case in practice: Step 2.2

In this section an example assessment of costs and benefits for the chosen primary adaptation intervention, agroforestry, is provided. Examples of other adaptation intervention cost and benefit assessments, for drought-tolerant seeds and water pans, are presented in the Appendix.

Background on agroforestry: "Agroforestry is the intentional integration of trees and shrubs into crop and animal farm systems to produce environmental, economic and social benefits" (USDA, n.d.).[xl] Globally, crops such as coffee and cocoa were traditionally grown in shaded systems. However, there was a movement away from shade-grown to full sun, mono-cropped systems for productivity gains in many regions, including in West Africa (Obiri et al., 2007).[xli] This region, which supplies around 70% of the world's cocoa, has faced unpredictable rainfall and disease outbreak due to climate change and depleted soil fertility. These, along with the impacts of illegal gold mining, have driven cocoa prices up from around USD $2,500/metric ton in April 2023 to USD $11,000/metric ton in April 2024. These trends are reflective of climate impact studies conducted up to ten years ago (Lucas, 2024).[xlii]

Benefits of agroforestry: The major benefits of agroforestry are an increased resilience of the production system through improved soil health, potential pollination and pest and disease control, increased income stability for farmers through product diversity, increased carbon storage and improved biodiversity. More specifically for climate adaptation, studies have shown that agroforestry can buffer against large fluctuations in temperature (Niether et al., 2020)[xliii] and reduce the impact on crop production (Lin, 2011),[xliv] provide cooler conditions for labor, protect crops from reductions in precipitation as the tree system reduces soil evaporation and increases soil infiltration, and even reduce the potentially devastating impacts of events such as hurricanes (Holt-Giménez, 2002)[xlv] (Rosset et al., 2011).[xlvi]

The commercial case for agroforestry is threefold:

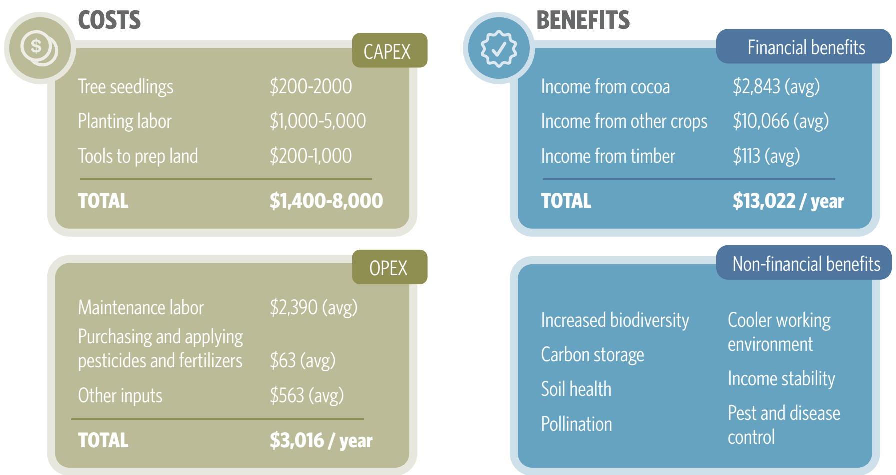
- **Lower costs:** Costs are generally lower while total production (across cocoa and other crops) and incomes are higher in agroforestry than with monoculture production, although this balance is very context-dependent (Niether et al., 2020).
- **Higher crop diversity:** Agroforestry provides several climate adaptation benefits—including regulation of temperature and water and resilience in the face of natural disasters—that help maintain production as climate impacts increase (Niether et al., 2020). Crop diversity also helps build farmer resilience to climate and market fluctuations.
- **Improved yields over time:** Monoculture production, particularly for cocoa, is expected to experience a collapse in the coming decades due to soil degradation (Andres et al., 2016).[xlvii] Agroforestry naturally builds soil health, helping to support long-term production and sustained yields over time.
- **Challenges:** Some of the barriers that limit uptake of agroforestry include a lack of (or access to) markets for the additional food crops, the initial costs of converting to agroforestry, a perception of additional ongoing labor costs and gaps in information on the full benefits of trees (Torquebiau, 2024).[xlviii] Many of these barriers can be addressed with the help of extension services and outreach to farmers, an important enabling condition for many on-farm adaptation strategies.
- **Bundling:** As with other adaptation interventions, the success of agroforestry production and resilience-building in the production system can be supported by bundling with other interventions. Some of the most common strategies that pair well with agroforestry include agronomic practices like application of fertilizer, post-harvesting processing improvements, extension services and insurance.

The initial work of conversion includes development of a planting plan, preparing the soil, planting shade tree seedlings, applying fertilizers and other agrochemicals, and potential watering. Over time, this system requires maintenance including the application of fertilizers for the first four years (at minimum) and agrochemicals such as fungicides, pesticides and herbicides, and may require additional or different labor inputs than monoculture cocoa.

The primary outputs of this intervention are more trees and an increased diversity of production, even as cocoa production itself is generally lower with agroforestry systems. These changes will lead to an increased diversity of food products, the potential to harvest timber and non-timber forest products, an increased habitat for birds and other animals, increased CO_2 storage, improved soil health (including soil water regulation) and a potential reduction in pests and disease. The primary potential financial impact of this intervention over the medium-term (within a few years) is increased income due to the additional crop diversity and lower production costs.

In the longer-term, given the trends in soil health and the potential for cocoa production collapse in monoculture/full sun systems, there are even larger potential financial benefits for agroforestry (Wainaina et al., 2021).[xlix] Specific to climate change-related benefits, with predicted temperature increases and unpredictable precipitation, shade-grown systems can provide greater production resilience over time due to the ability of shade to reduce temperatures and ability of healthier soils to hold water longer. This can result in higher cocoa production and a reduced loss of production during natural disasters, leading to higher incomes over time as compared to full sun systems.

Figure 15: Assessing the costs and benefits of the agroforestry example



An example of how to assess the costs and benefits of an adaptation strategy based on general data collated from Wainaina et al., 2021, cost data collated from Jiji (n.d.)[l] and Tropenbos International (n.d.),[li] and benefits data collated from Andres et al. (2018),[lii] Claus et al., (2018),[liii] and Frimpong et al. (2011).[liv]

Figure 15 summarizes the costs and benefits for cocoa agroforestry conversion and maintenance. This analysis uses ranges and averages across a variety of studies in Ghana, but the actual costs for agroforestry conversion are very dependent on context. Some of the factors that have the biggest impacts on the potential costs and benefits for an agroforestry cocoa system compared to a full sun or high-tech cocoa production system include:

- Market rates for material inputs and labor.
- Market rates for cocoa and other crops produced on an agroforestry farm.
- Frequency and intensity of dry and/or extremely hot periods.
- Frequency and intensity of floods and droughts.
- Rate of average increase in temperatures.
- Decline in average annual rainfall.

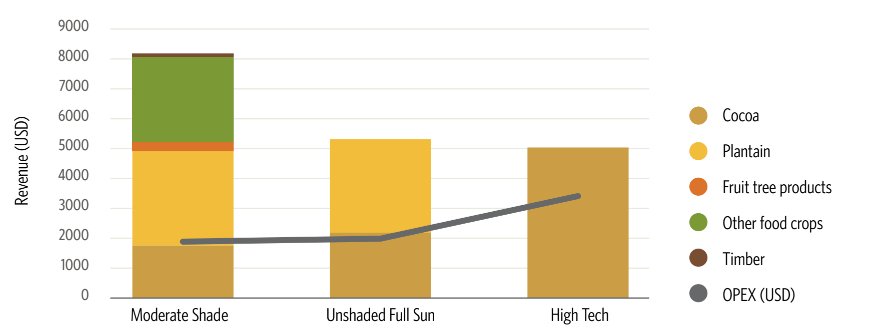
Figure 16 demonstrates the comparison of current operational costs and benefits on average per year (gathered from a metanalysis of sites) with the lower costs and higher incomes associated with the agroforestry system. This does not account for up-front conversion costs from monoculture to agroforestry but compares the ongoing costs and benefits for the different systems. This assessment also leaves out the potential longer-term benefits mentioned previously, anticipating a decline in production for monoculture and high-tech systems in the coming decades.

There are also a range of non-financial benefits as compared with a full sun/partial shade system:

- **Increased biodiversity:** 70% more bird species and an improved biodiversity index.
- **Increased carbon storage:** 2.5X more carbon storage.
- **Improved soil heath:** increased carbon, nitrogen (N) and phosphorus (P) content (+0.4 g/kg N per hectare; +0.1 g/kg P per hectare) along with increased soil water holding capacity.
- **Increased habitat for pollinators:** a higher insect and pollinator diversity.
- **Cooler working environment:** increasingly important as temperatures rise.
- **Income stability:** increasing the diversity of income sources improves resilience to climate and market impacts (see Figure 15).
- **Follow-on impacts from increased income on health, well-being and education.**
- **Improved pest and disease control:** some studies show a greater avoidance of crop loss due to pests as compared to full sun cocoa although this varies due to context or disease types.

These non-financial benefits could be of interest to the local communities or to government agencies or organizations that are interested to co-fund investments in agroforestry and therefore are important to identify and quantify where possible. To explore agroforestry in more depth through real-world cases of implementation at scale, including in Ghana, Tropenbos offers a valuable collection here.

Figure 16: Operational costs and benefits of cocoa



Output products and value (USD) for three different types of cocoa farming (moderate shade, full sun and high tech) are shown in the bars while the total input cost for each type of farming method is represented by the dark line, demonstrating that moderate shade farming provides the highest output value with the lowest input cost (Wainaina et al., 2021).

Additional considerations for identifying adaptation strategies

Distribution of costs, benefits and tradeoffs

For all climate adaptation strategies, understanding how the costs, benefits and tradeoffs are distributed among different actors is critical to ensure that value will be delivered to specific stakeholders, that issues of equity and potential negative impacts are considered, and that potential risks from related conflicts or reputational issues are identified and addressed. Some considerations include:

- Who will incur the direct and indirect financial costs of the strategy or program? Are there any hidden costs that are not being accounted for?
- Who will benefit from the expected impacts and in what ways? How can the investment or program ensure delivery of those benefits?
- Do all stakeholders have equal access to participate in the adaptation strategy or program and are all relevant stakeholders and community groups represented? If not, how might these inequities be addressed?
- What considerations have been made in the design of this investment, if any, to address structural social inequities of climate impacts?
- What negative impacts or tradeoffs might result from implementation of the adaptation strategy? How might these impacts or tradeoffs be mitigated or compensated for? Do these negative impacts outweigh the positive impacts of the strategy and, if so, what alternative strategies might be undertaken in its place?

There are several ways to incorporate distributional considerations into the assessment of an adaptation strategy. One way is to include information about the distributional impacts of adaptation strategies, based on the questions above, alongside the costs and benefits for additional context in investment decision-making (AECOM & Institute for Global Environmental Strategies, 2016).[lv]

Another option is to weigh the costs and benefits for specific stakeholders differently, for example by giving more weight to women or particularly vulnerable communities. Finally, a more comprehensive solution is to conduct a community-based risk assessment or a vulnerability assessment, to ensure potential strategies and investments are selected with awareness of their impact on addressing or exacerbating communities' risks and vulnerabilities.

Equity and climate change

The impacts of climate change are not felt equally, with evidence pointing to the outsized impact on poor and vulnerable populations. Unfortunately, the design and implementation of climate adaptation measures are not naturally grounded in equitable approaches and therefore equity must be intentionally considered to ensure adaptation investments reach those most in need. Some authors argue that failing to integrate issues of social equity into agricultural climate adaptation investments can produce distortions and inefficiencies that threaten the long-term success of those investments and the ability of the agricultural sector to deliver on the Sustainable Development Goals (Fisher et al., 2018).[lvi]

There are at least four dimensions of social equity that should be considered for agricultural adaptation investments. These include equity of access, procedures, representation and distribution. Across these, it can be helpful to consider as a starting point the 'what' and the 'who' of equity (CGIAR, 2022).[lvii] Fisher et al. offers more details on the four dimensions of equity, including a set of questions to broadly understand each for a given place and adaptation strategy.

Figure 17: Four dimensions of social equity

A diagram outlining types of social equity and who is impacted (figure modified from CGIAR, 2022).

Significant work has been done to understand the impact of gender on the uptake of agricultural BMP and adaptation strategies. Many studies show men are more likely to take on agricultural adaptation strategies (Gebre et al., 2023),[lviii] (Deressa et al., 2009),[lix] (Aryal et al., 2020)[lx] although some show the opposite effect or no significant difference between genders (Nhemachena & Nhem, 2007),[lxi] (Ali & Erenstein, 2017).[lxii] The primary reasons offered for this difference include a lack of land tenure and access to the resources needed to take up an intervention. Other influencing factors are age, with younger famers more likely to take up new practices (Gebre et al., 2023), (Ali and Erenstein, 2017), (Jamshidi et al., 2020),[lxiii] and farmer education (Gebre et al., 2023), (Thomas, Twyman, Osbahr & Hewitson, 2007),[lxiv] (Hassan & Nhemachena, 2008),[lxv] (Deressa et al., 2009), (Bryan et al., 2013),[lxvi] (Abid et al., 2015),[lxvii] (Ali & Erenstein, 2017), (Jamshidi et al., 2020).

Investments in agricultural adaptation need to ensure the ability of the most vulnerable to positively benefit from these investments, either as a participant or indirect beneficiary. Care must be taken to design investments that avoid negative impacts, and if unavoidable find ways to mitigate or offset these impacts.

Maladaptation

The IPCC defines maladaptation as "any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli," or "an adaptation that does not succeed in reducing vulnerability but increases it instead" (IPCC, n.d.).[lxviii] Juhola et al. (2016)[lxix] argue there are three types of maladaptive outcomes based on their review of existing literature: rebounding vulnerability, shifting vulnerability and eroding sustainable development. While maladaptation may typically be viewed from a scientific lens, Boutroue et al. (2022)[lxx] explain that qualifying an event as an example of maladaptation is as much political as it is scientific and can be the result of inadequate knowledge, focusing on issues in isolation and emphasizing short-term gains without accounting for the longer-term impacts of the adaptation strategy (Eckstein, 2022).[lxxi] A more familiar way of viewing adaptation for investors may be to think of maladaptation as actions that result in negative outcomes.

Investors need to be aware of the risks of maladaptation and have a strategy for assessing whether a possible investment could result in maladaptation. The IPCC recommends flexible, inclusive and long-term planning around adaptation strategies, integrated and flexible governance mechanisms, and robust monitoring and evaluation (M&E) strategies to prevent maladaptation (Eckstein, 2022). Pierre Serkine (n.d.)[lxxii], in a report evaluating whether maladaptation poses a potential risk for investment profitability, suggests investors evaluate a project on water uses, energy uses, structural dependence and functional dependence to not only assess the impact of the project on the environment, but the possible impact of the environment on the project accounting for future climate changes. In assessing whether a potential investment could result in maladaptation, an investor should ask the following kinds of questions:

- **Might this adaptation strategy result in diminished well-being?** This means there is the potential for large intended or unintended negative effects on people's well-being.
- **Is there an equitable distribution of the impacts of the adaptation strategy?** A situation in which a poorly implemented adaptation strategy could strengthen some people's ability to deal with climate risk while making it worse for others needs to be avoided (Jones, 2015).[lxxiii]

Solar pumps in India are an example of a maladaptive strategy. While they provide a low-cost way for farmers to irrigate their fields—eliminating the need for fossil fuels and increasing crop production—they are simultaneously resulting in serious groundwater depletion. In the arid state of Rajasthan, the Indian government has subsidized these pumps for nearly 100,000 farmers now watering more than a million acres. As a result, water tables are falling rapidly, and the rocks are now dry in places to 400 feet below ground. Richer farmers have also been buying more powerful solar pumps, leaving other farmers with either no water or the need to buy water from their wealthier neighbors (Pearce, n.d.).[lxxiv] This strategy will work until the water runs out, at which point agricultural production will be in serious trouble.

Step 2 conclusion

The output of Step 2 is one or more financially viable and locally appropriate adaptation interventions that can address the primary climate risks for the food system of interest. Step 2 also provides estimates of costs and benefits that, along with an understanding of timing and uncertainty from Step 1, can be applied in Step 3 to integrate the potential adaptation investment into an existing or new investment portfolio.

STEP 3

Practical applications of adaptation in your portfolio

Disclaimer: References to any investment are intended to illustrate the potential impact and financial benefits of agricultural adaptation investments and should not be used as the basis for making any decision about purchasing, holding or selling any securities. Nothing herein should be interpreted or used in any manner as investment advice. The information provided about investments is intended to be illustrative and it is not intended to be used as an indication of the current or future performance of any investments. Case studies presented in this section are intended to provide examples of the types of transactions executed for agricultural adaptation. Investment rationales and other considerations are based on TNC's internal analysis. References to a particular investment should not be considered a recommendation of any security or investment.

This step offers concrete, practical approaches investors can use to apply an adaptation lens and better value adaptation investments. Using the inputs of Steps 1 and 2, it suggests ways direct investors can integrate adaptation investments into investment practices. For the VC/PE space, this means opportunities to develop and scale new technologies and businesses that enhance on-farm resilience. For lenders, this means incentivizing portfolios to better adapt to a changing risk environment or entering new markets that may not have been viable. And for corporations, a winning sourcing strategy will involve understanding and proactively supporting the climate resilience of suppliers.

VC/PE: Deal structuring, pipeline development, and exits

Investing in adaptation as a growth market should be seen as an exciting opportunity for investors. Even as the agriculture VC/PE space continues to experience corrections due to macroeconomic conditions that are also driving wider trends, agriculture biotech and precision agriculture remain bright spots. Many of these investments are adaptation-related, helping to create new cultivars and farming methods that are in tune with the changing climate.

As the industry becomes more sophisticated in assessing climate risk and spotting opportunities, it is reasonable to believe that agriculture biotech, precisions agriculture, and other agriculture-focused climate technologies will continue to grow.

Opportunities

Priority areas to strengthen the sector are diversifying crops, improving productivity along the value chain, creating resilience against climate and water-related shocks, and increasing the capacity of farmers and marginalized groups (Borsellino, 2020).[lxxv]

There are several ways this can be achieved in the short- to long-term, each of which represents an opportunity for the VC/PE investor:

- **Improving access to inputs and best practices:** Closing yield gaps through adapted cultivars, sustainable land management combining production and preservation of an ecosystem's essential functions (such as sustainable intensification approaches based on conservation agriculture and community-based adaptation) with functioning support services and market access (IPCC, 2014).
- **Strengthening local supply chain linkages:** Another key approach is enhancing the connective tissues within local supply chains. On the production side, this has the potential of reducing dependencies on global supply chains. On the consumption end, this can greatly increase food availability and affordability (Borsellino, 2020).
- **Democratizing knowledge:** Building on local knowledge, culture and traditions while seeking innovations for food waste reduction, transformation of agricultural products and yield improvements (IPCC, 2014).
- **Improving equitable market access:** Implementing institutional designs focused on youth and women through new economic models that help enable access to credit and loans to support policies that balance cash and food crops (IPCC, 2014).
- **Transforming digital platforms:** As one of the fastest growing opportunities, the digitalization of services is opening markets, providing access to best practices and services that increase productivity and reduce losses, and decreasing prohibitively high transaction costs (Borsellino, 2020).

For each of these opportunities, considering broader public policy implications is crucial. Tax incentives and other policies that support market growth can enable and strengthen investment opportunities. Conversely, they can also replace or hinder private sector action. As an example, a Kenyan agriculture technology company that helped distributors of agricultural inputs source from manufactures struggled to sell inventory after the government launched a fertilizer subsidy scheme.[6]

6 The authors of the guidebook thank Paul Ouma of CrossBoundary Group for providing this information.

PE/VC fund managers who focus on this opportunity set can implement and communicate the strategy using an adaptation lens. This lens can be used as a core focus and impact outcome for a fund (something that may qualify for Article 8 or 9 of the Sustainable Finance Disclosure Regulation (SFDR)) or managers may use the methodology in this guidebook to inform investors of risks or screen for pipeline opportunities. Regardless, adaptation is essential to enhance the credibility and performance of any fund with exposure to the agriculture industry. There are specific aspects of a fund's structure where we suggest incorporating adaptation:

- **Fund purpose and risk disclosures:** Applying the methods in Steps 1 and 2 to create an adaptation lens can be codified within the fund's documentation, starting with the fund's purpose and risk disclosures. If seeking to raise capital from European investors or domicile the fund in Europe, the use of an adaptation lens can help with SFDR compliance regardless of the intended article to pursue. Including insights gleaned during the assessment of climate change impacts in the risk disclosures may help lay the groundwork for describing the role sustainability risks play in decision making. A climate risk assessment may also help highlight important risks (and thus mitigating strategies) that will be relevant to limited partners (LPs) and can meaningfully inform an investment process.
- **To meet Article 8 or 9 requirements, or to be credibly viewed as an impact-oriented fund for non-EU domiciles:** Including relevant language in the fund's statement of purpose can be important. A focus on adaptation, along with supporting information on the non-financial social and environmental benefits as described in Step 2, may serve as a starting point. This statement of purpose can also be important if the intent is to target certain investors or align with public financing initiatives that are allocating concessional capital. Supporting this statement of purpose with credible, governable processes will be essential, including how investments are identified, selected and monitored for impact.
- **Carry incentives:** Linking a portion of carried interest to social and environmental outcomes is becoming more common, primarily as a method to better align incentives between a fund's financial objectives and its impact objectives. For some funders (such as the European Investment Fund) this approach is mandatory (European Investment Fund, n.d.).[lxxvi] While aligning incentives between impact and financial performance is essential to a well-structured fund, it also is an essential tool to structure the investment-making process. There are many examples of this on the market, and the Global Impact Investing Network's (GIIN) Impact-Based Incentive Structures is recommended as a starting point to explore various approaches. This guidebook will not weigh in on the merits of different approaches, but the example offered below is illustrative of how impact-linked incentives can support the investment-making process in a VC/PE context. For an adaptation lens, fund managers could incorporate the assessment process in Step 2 into the diligence framework of a fund to arrive at a general view of the adaptation value of a given investment. This can form the basis of designing an impact link incentive (like the example shown below), offer a method to diligence a pipeline or respond to risk. By rewarding staff for selecting investments with a certain likelihood of contributing to adaptation outcomes, managers can build adaptation into the heart of the fund. In the context of a rapidly changing climate that drives significant risk for the agribusiness sector, this can differentiate a product and potentially incentivize investment-making activities that will highlight novel sources of value.
- **Pipeline:** Using an adaptation lens in cultivating a fund's pipeline can highlight risks and opportunities that may otherwise not be identified. Starting with creating a view of potential climate-driven risks, then assessing the potential adaptation strategies that might respond to those risks, can highlight gaps in markets or new areas of growth. For instance, this may include a belief that demand for drip systems will increase based on an increased prevalence of drought or scoping a different seed company to meet barley demand where rising temperatures will make existing varieties untenable. Perhaps it includes seeking out farms with superior soil health—while priced relatively in line with other comps for the moment, essentially free value is implied in both production upside and downside protection. Screening for these items in diligence is a skill that competent managers can develop. Using tools listed in this guidebook, like the ARAF Climate Assessment Tool referenced in the case study, can help managers get started. Additionally, paying close attention to public finance initiatives can point to sources of concessional capital or public sector investment. These include deals coming out of Global Environment Facility (GEF), GCF, World Bank and Development Finance Corporation (DFC). The Convergence Network is a good place to track emerging blended finance deals.
- **Exits:** While the methodologies to value deals at exit are well established for business as usual, markets may be mispricing climate risk and there could be a case to track other emerging forms of value as climate change resilience becomes more important. An example would be looking at soil health for a commercial farming property in the U.S. While not yet a standard component of farmland appraisals, soil health is becoming more closely linked to productivity, farmland rents and land values. Adding other adaptive capacity into valuation—whether on farmland or agribusinesses that support adaptation—may very well become a differentiator to future exits in the same way soil health and soil health management is becoming a signal of value. Measurements of how farmland fared with a given agribusiness solution compared to farms without that solution, the uptake of a product by public finance initiatives to meet publicly mandated adaptation outcomes, or secondary non-financial benefits may all be useful components of value for a future exit. Considerations for measuring these and other adaptation or resilience outcomes may require a nominal investment from management while creating an opportunity for long-term benefit.

Example of impact-linked incentives – Blue Revolution Fund

The Blue Revolution Fund (BRF) is a regenerative aquaculture venture fund managed by Hatch Blue with TNC serving as the fund's conservation advisor. 50% of the general partner's (GP's) carried interest in the BRF is tied to meeting impact metrics set for the fund. The metrics include portions of sustainable seafood produced, tons of carbon sequestered, emissions avoided, hectares of habitat forming area created, hectares of coastal area impacted by existing farms with improved environmental outcomes, tons of nitrogen removed from waterways, and new jobs created in coastal communities. Each metric has a quantified annual and end-of-fund target. Any time carry is generated, 50% can immediately be distributed to the GP while the remainder is distributed proportionally in meeting the annual impact targets. Any unearned carry is placed in escrow and can be earned later in the Fund's life, although if targets are not achieved by the end of the fund unearned carry is distributed to other NGOs engaged in regenerative aquaculture projects (in this case, as TNC is the conservation advisor unearned carry cannot be distributed to TNC). It is the responsibility of the conservation advisor to help measure impact and validate achievement of targets.

This structure helps incentivize management to select companies that meaningfully contribute to the Fund's stated purpose and impact objectives. Like any impact-linked incentive, there are many other details that enable the implementation and good governance of carried interest yet approaches like this can be applied to the agriculture adaptation space.

Potential metrics may include farms with improved water and other input efficiency, increases in post-harvest storage capacity, new customers receiving agronomy services that were previously unserved or farms with increased water security. Such metrics, when designed with appropriate monitoring and measurement in mind, can steer a fund towards adaptation. One argument against impact-linked incentives (especially for VC funds) is the limited control that fund management has over portfolio companies to meet specific impact outcomes. But designing metrics appropriately means fund managers can meet their targets through a careful selection of a portfolio company's likelihood to contribute to an impact target while screening against red-flag issues. For example, if increasing post-harvest storage is an impact target of the fund then this will incentivize management to look for small to medium enterprises (SMEs) with good storage solutions in pipeline development and help structure the terms of the deal to collect the necessary data to measure if and how post-harvest storage capacity has grown. Thus, the focus of management is on appropriate deal selection, diligence and deal structuring such that there is a high likelihood of delivering on an impact target through the portfolio company's success rather than through active management. It's worth emphasizing that some capital allocators require explicit impact targets that can be monitored and measured.

Example of public finance as a source of pipeline and deal development

Climate adaptation is emerging as a top public policy priority including with various adaptation-focused financing initiatives from GEF, GCF, World Bank and DFC. These public finance vehicles often provide capital through grants and various de-risking measures which can become a valuable signal to the private sector showing where concessional capital is flowing to cultivate new markets. These types of initiatives can be viewed in a similar way to subsidies or other tax-incentives used to stimulate new markets like renewable energy development. For the fund manager, this can point to good sources of pipeline and potential opportunities to engage catalytic forms of capital.

Kenya's Financing Locally Led Climate Adaptation program (FLLOCA), a World Bank-funded initiative to fund county-level climate mitigation and adaptation activities, is a good example of this. This entails capitalizing national and county climate change funds through locally-led entities to finance program activities. The pilot program funded 100 initiatives, most of which targeted the installation of solar equipment, water storage, harvest and distribution equipment and sanitation facilities. An assessment of the pilot program found the following results:

> *"A large-scale household survey conducted in 2018 in the counties of Isiolo, Makueni and Wajir found that respondents reported 100% greater access to water for households and livestock and a two-hour saving per household per day on water collection (equivalent to 700 hours a year), providing direct benefits of more than KES 400 million (£3 million) a year across the three counties, with average net annual benefits of more than KES 14,170 (£109) per household. This represents an 8% increase in annual household income (Crick et al., 2019)."* [lxxvii]

A plan to scale up is a strong indication of the future demand for adaptation strategies. While the initial pilot focused on water access and storage, it is expected counties will include other adaptation strategies for financing. Tracking developments like these can be an important signal for demand and growth in certain markets, as well as potential sources of collaborative or concessional funding.

These are examples of how an adaptation lens can inform the structure and operations of a fund by supporting risk management and disclosure, finding deal flows and accessing capital.

Lending: Integration into new lending markets and managing existing portfolios

A lending institution, which can either be a deposit-taking institution (a bank) or a private credit fund (which includes microfinance institutions and most non-bank financial institutions), is both an asset allocator (deciding which market segments to allocate capital to) and a direct investor (making decisions on specific loans to agribusiness and/or farmers). They are often under pressure to invest in agriculture both as a means of supporting hard currency inflows (in the case of exported crops) and strengthening food security (in the case of crops sold locally). Their loans are an important source of capital for adaptation investment but lenders often lack the knowledge and levers to promote adaptation strategies with their borrowers.

- **Increasing lending to the agriculture sector:** While lending institutions are under pressure to provide credit to the agriculture sector, doing so can be challenging and not only because of climate change headwinds. For instance:
  - **For commercial banks operating in South Asia and Sub-Saharan Africa, credit is already tight.** As sovereign fiscal positions continue to deteriorate as they refinance debt in a higher interest rate environment, credit for these banks will become tighter as more of their capital is tied up in government loans.
  - **Creditworthiness of off-takers:** In interviews, investors and lenders to the agriculture sector expressed concern about the strength of purchase orders and offtake agreements. Some lenders have experiences with off-takers of agriculture products reneging on agreements when it becomes cheaper or easier to secure supply elsewhere.
  - **Currency risk of staple crops:** For export-oriented crops, revenues are in hard currency which can more easily be lent against. For staple crops, sales come in local currency and are often subject to devaluation while the investments made in inputs and equipment are denominated in hard currency. This leaves a significant risk that the farmer or agribusiness will struggle to repay loans denominated in hard currency or the bank will lose money on loans denominated in local currency. This is what drives the significant spreads between hard currency and local currency loans in frontier and emerging markets.
  - **Climate risk:** Compared to other sectors, agriculture faces climate risk more directly with significant impacts to production.

Because lenders are under significant pressure from governments across Africa and South Asia to increase lending to the agriculture sector to improve food security and generate hard currency, they are finding ways to increase the amount of capital they deploy to the sector while reducing their climate risk exposure. They can do this by either transferring risk onto a willing party at commercial or concessional rates or finding a means of reducing the portfolio's exposure to risk. Adaptation strategies present a viable means of doing the latter by reducing the climate risk exposure in these institutions. The adaptation lens provides a pathway.

Applying an adaptation lens to address climate risk

With 87% of lenders to the agriculture sector citing climate change as a material risk to their business, investing in adaptation approaches will be critical to maintaining a strong portfolio of loans in the agriculture sector (Environmental Defense Fund, 2022).[lxxviii] Incorporating incentives for adaptation strategies within agricultural loans is a defensive measure as this protects the downside of existing portfolios. Looking at a net present value (NPV) calculation, cash flows from existing lending activity are capped but reducing the discount rate by reducing risk exposure to the portfolio can make a portfolio of loans more valuable.

Yet, the ability of these institutions to effectively identify climate risks and incorporate incentives for adaptation strategies into specific loans is extremely limited. Partially this is because the tools for identifying and evaluating climate risk are either not available, not known, or cannot be actuarially relied upon. These institutions also (for the most part) do not have the ability to effectively assess which adaptation strategies will yield the biggest reduction in risk.

Without the tools to effectively evaluate climate risk or the tools to evaluate climate adaptation strategies within agricultural loan portfolios, climate risk will remain an outsized drag on credit and adaptation as an investment lens remains theoretical.

Integration into business as usual for lenders in Sub-Saharan Africa and South Asia

A changing climate requires a changing perspective in agricultural lending. From discussions with lenders and asset allocators who have invested in them, TNC identified three ways to integrate a climate adaptation strategy into an agricultural portfolio:

1. **Include agronomic support as part of the monitoring of loans.** The cost of loan monitoring is a significant challenge for banks expanding into the agriculture space. Often the farmers and enterprises to whom they are loaning capital are farther away from urban centers and it is more difficult to monitor their financial health given the time it takes to grow crops. Including agronomic support might increase this expense, but doing so also enhances adaptation strategies and reduces the overall climate risk to the portfolio.

2. **Centralize agronomic support for the industry.** Creating a shared service—such as a guarantee provider that can de-risk loans across multiple banks—creates an opportunity to bundle agronomic support on how to properly structure and incentivize good adaptation strategies for the financial institution itself.

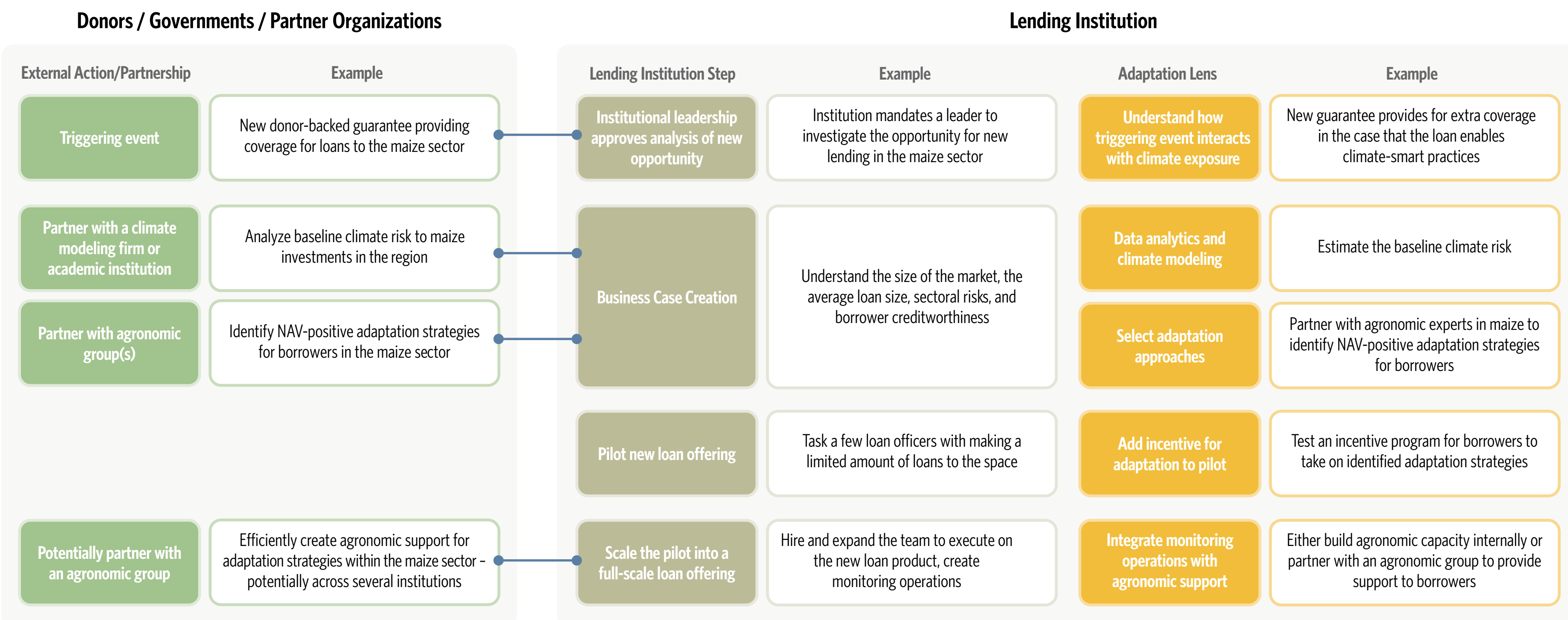
3. **Design new strategies and lending programs with senior leaders within each lending institution.** Leaders within each lending institution should be engaged to discuss how to best design new lending programs that consider climate risk. If solutions are not designed with buy-in from division leaders within the bank, relevant programs will likely have design flaws and remain underutilized.

Each of these can be done through guarantees, on-lending, and technical assistance programs that, when properly designed for the region and crops, can help lending institutions expand further into the agriculture sector in a way that reduces their climate risk and creates more resiliency in the system.

Integration into the launch of a new lending program

During the engagement with lenders, TNC mapped the process of a financial institution allocating capital into a new product or vertical in the agricultural space (Figure 18). From that was built a hypothetical approach for how a financial institution might use climate forecasting and established adaptation strategies to build a more resilient approach.

Figure 18: Capital allocation process for lenders



Examples of how various events may trigger capital allocation decisions by lending institutions.

Corporate Sourcing: Integration into managing sources of supply

Corporations who purchase directly from farmers or aggregators have similar challenges to lenders. Any corporate player that relies on food production for its business model needs a supply chain that can provide the right quantity of products at the right standards of quality for the right price and right time. Unexpected volatility in sources of supply can change the overall cost of producing goods, which in turn can reduce a product's margin and potential profitability. A secure, stable supply chain is essential to compete in any market that relies on agriculture inputs, especially with commodities where the end consumer is quite price sensitive.

> "We know we need to adapt, but we don't even know where to start."
>
> — Head of Sustainable Agriculture for large consumer packaged goods firm

It is believed that understanding adaptation will be among the main drivers of future growth for those companies that rely on agriculture supply chains. Firms able to integrate climate risk assessments and select strategies to adapt to those risks will be best positioned to manage their bottom line and maintain steady, predictable margins. While there is a good competition argument to be made for investing in adaptation (continuing to operate during periods of high volatility when others face higher costs or lose sources of production altogether) the likely stronger argument for a corporation who sources from SSPs begins with better managing their own profit targets, growth goals and corporate commitments. Thus, there may be cases where it is in the interest of companies who source different products from the same foodshed to think collaboratively about adapting a given foodshed to meet their individual corporate interests.

> "Ecosystem resilience is business resilience."
>
> — Jay Watson, Regenerative Agriculture Director, General Mills

Regardless of the motivation to adapt a supply chain to climate change, adaptation strategies are like any BMPs firms may require of their suppliers to meet sourcing objectives. As such, adaptation can be readily integrated into sourcing strategies already in place. The following will consider an adaptation lens for common sourcing practices including specifications, preferred provider relationships and technical assistance.

An adaptation lens to sourcing specifications

Firms are already adept at adding various sourcing specifications (specs) into their provider models. Beyond the primary production requirements, these can include requirements to maintain certain certifications, keep types of chemical compounds to certain levels or even integrate production practices like the use of certain seed varieties or soil health management practices. Adding an adaptation lens to sourcing specifications can be a natural next step after assessing climate risk and selecting adaptation strategies. Adaptation-oriented sourcing specs can include using drought-tolerant seed varieties or certain certifications that align with climate resilience such as Rainforest Alliance Certification or Shade Grown. That said, SSPs may not be able to meet some specifications due to cost, technical assistance requirements or other issues. For some sourcing requirements, like agricultural inputs, directly providing preferred seed or biotics that improve resiliency may be the most efficient and cost-effective avenue to lowering production volatility. Certifications are often too expensive to achieve and maintain at an SSP's scale (this will be touched on next), but aggregators and traders may put together projects to certify large groups of producers as part of agreements with off-takers. Some of the examples below provide other ideas to address this issue.

Opportunity for collective action

One issue that companies often face when considering investing in suppliers is that a grower may be selling products to multiple buyers. This can lead to difficult issues as investing in a grower's on-farm practices will likely affect all aspects of production—not just the crop you are sourcing. Should you bear the full cost of the investment when others will likely benefit from that investment? How can you claim or account for the non-financial benefits (such as scope 3 emission reductions, water quality benefits or people benefits) when you are only buying a portion of a farmer's production? This also impacts growers who may have to submit multiple sustainability reports to multiple buyers.

Corporations with shared supply chains have an opportunity to approach agriculture adaptation collaboratively. Indeed, there are signs of this already taking place. Where companies are coming together, they find that there is much more collective benefit to sharing the cost of investing in suppliers than there is competitive downside, resulting in lower overall investments for equal or greater outcomes.

An adaptation lens to privileged/preferred providers

Companies work with providers and intermediaries to establish longer, more relational approaches to sourcing. This is especially useful in the agriculture space where the technical skill of a given farmer or collective is critical to meeting sourcing specifications. Examples include organic farmers, producers of grass-fed beef or producers that need to meet certain regenerative farming standards like no-till farming. Becoming adept at these practices can take time and investment from the farmer, and maintaining a long-term relationship with the best available producers becomes strategic for the buyer. Adaptation, depending on the strategy, may require an investment into the farm (as with the case of water pans) or into the farmer to build a skill (as with the case of agroforestry). **Thus, the same principles used to make relationships with buyers stickier can work with adaptation: longer-term contracts, master agreements with annual terms, and commitments to additional, preferential terms when certain outcomes are achieved.** Creating these relationships with SSPs can be too expensive and cumbersome on a farmer-by-farmer basis, so farmer cooperatives, aggregators and outgrowers are likely the most effective platforms to cultivate more relational engagements with producers.

A note on IFACC

Innovative Finance for the Amazon, Cerrado and Chaco (IFACC), a collaboration between TNC, The Tropical Forest Alliance and UNEP, brings together signatories across the agriculture capital markets to accelerate lending and investing in beef and soy production practices that reduce deforestation and reduce other climate impacts. To date, the signatories have launched 14 financial mechanisms, nine of which are described in the referenced report at the time of writing (IFACC, 2024).[lxxix] While the primary focus of IFACC is financial institutions, it has also brought in retailers (such as Tesco and Sainsbury's in the UK) to better manage and gain visibility into scope 3 emissions. A similar approach may be applicable for other foodsheds to enable collective investment into climate adaptation. Such a partnership could overcome some of the challenges corporations face when considering how much to invest in suppliers while increasing innovation and access to catalytic forms of capital. Of equal importance, it may (as it has in IFACC) become a platform to better connect aggregators and buyers when establishing long-term relationships around climate-smart agriculture practices.

Where IFACC was convened principally by the NGO partners, the founding signatories were essential to bring in other participants. Corporate leaders with shared foodsheds can be powerful conveners as holders of relationships with producers, financial institutions and other key stakeholders. While there is an important role for NGOs to help create credible guidelines, and for local NGOs to navigate the enabling conditions and ensure any engagement with SSPs is just and equitable, corporations can play a leading role in collectively advancing foodshed resilience without sacrificing a competitive advantage.

Photo: © Smita Sharma

Technical support for adaptation

The use of direct technical support to producers is a common tool within the agriculture supply chain. This can range from directly employing agronomists to work with growers up to large scale, multi-partner programs. A common strategy—especially where outcomes require expertise that may not be core to a company (such as in-depth environmental or social impact expertise)—is to partner with NGOs as implementing entities. Examples include SABMiller working with TechnoServe (TechnoServe, n.d.)[lxxx] to enhance inclusive agriculture business models, or Syngenta and US Dairy's Net Zero initiative collaborating with TNC on feed/forage production BMPs (TNC et al., 2023).[lxxxi] These strategies allow one or more corporations to fund a portion of a program while the NGO partner can catalyze that corporate investment by accessing additional public sources of funding. Many of these initiatives are underway across the globe for climate adaptation and mitigation purposes, but companies can find it challenging to reach a meaningful level of scale through a project-by-project approach. This is especially true with SSPs. Moving enough capital and expertise rapidly enough requires innovation in how technical assistance is delivered to a supply chain.

Louis Dreyfus Company's innovative pay-for-impact strategy

Years of monocropping coffee plantations has created increased root and stem diseases compared to less intensively managed coffee systems. Converting a coffee plantation to shade-grown or full agroforestry systems can be complex and costly with the benefits of these conversions shared broadly between communities, buyers and end consumers. Thus, internalizing value can be difficult (Beche et al., 2023).[lxxxii]

But when done well, coffee can become more resilient to pests, disease, soil erosion and other climate impacts. An example of an innovation in capitalizing projects throughout a supply chain is Louis Dreyfus Company's (LDC) pay-for-impact strategy. As a global merchant, LDC sits between coffee growers and the largest coffee buyers in the market and plays an important role in helping those end buyers meet goals such as practice improvements, supply quality and corporate climate targets. As coffee buyers increasingly see the social, environmental and business benefits of agroforestry, they design and implement projects, typically with a local NGO, to transition growers toward shade-grown, agroforestry production models that help end buyers meet emission reduction goals. This approach can be effective, but it is hard to scale, risky (trees die, farmers revert to old practices, etc.) and not bankable.

LDC's pay-for-impact strategy is different as it develops contractual relationships with end buyers first, whereby the buyer agrees to buy the impact, only when it is delivered and verified by a credible third-party control body (e.g. SustainCert).

In the case of LDC's pilot for this program, which will work with 4,500 coffee growers in Uganda, the transition to agroforestry can create high-quality carbon removals which end buyers are seeking to manage their scope 3 emissions. Creating a pay-for-impact relationship with the end buyer gives LDC the option to deliver the impact (and finance the program) with much greater flexibility, moving away from a siloed project approach to a large global program where carbon reductions become commoditized and can be delivered from various farmers' groups to different clients. This, in turn can increase the pace and flow of investment into agroforestry transitions.

Another example of innovation is a yield warranty offered by Growers Edge. This product was developed to assist agriculture retailers when distributing new products (Growers Edge, n.d.).[lxxxiii] Farmers assume some measure of risk when adopting a new product or practice with limited track records. There is an understandable concern about how the product will work and if it will deliver its promised results or somehow negatively impact yields. This risk has tended to be a key barrier for new agriculture products gaining traction in the market. Growers Edge created the warranty to help de-risk innovation. They create a baseline with the farmers and work between the farmer and retailer of the new product to track impacts to yield. If yield drops below certain thresholds, farmers can issue a warranty claim and be credited for lost yield. The Growers Edge platform has helped agriculture retailers increase sales considerably (Growers Edge, 2022).[lxxxiv]

This product was developed for agriculture retailers working with commercial farmers in the U.S., but it offers insights into tools available to companies who want to help their producers try new production practices. De-risking a new practice through yield coverage can be a relatively inexpensive way to scale uptake of new practices or products with producers by removing one of the main challenges local partners often experience when working with individual producers. Given a SSP's margins are so small—and the risk to their livelihoods is so existential if a new practice doesn't work out—many technical assistance programs can spend months or even years working with farming communities to develop a track record and secure buy-in to help them adopt a new practice. Using concepts like the Growers Edge warranty may encourage uptake of practices at a lower cost and less risk to the farmer.

Our aim with this section is to show how one might apply an adaptation lens to a strategy, the third step of the Adaptation Investing Lens. We also hope to demonstrate the opportunities for continued innovation with how we calculate risk and resilience benefits, how corporate partners collaborate for resilient food systems and how we educate capital allocators on the benefits of better adapted food systems (just to name a few). Through the application of the theory above, and with a belief that resilient food systems are in the best interest of us all, we hope readers can contribute to the body of knowledge that helps us achieve that.

Additional considerations for applying adaptation to your portfolio

Leveraging blended finance tools for adaptation

Blended finance can be a critical tool to bridge the significant financing gap. It involves the strategic use of public or philanthropic capital to mobilize private sector investment into projects with substantial social and environmental benefits. By enhancing the creditworthiness of these projects and mitigating various risks, blended finance makes it feasible for private investors to engage in high-impact adaptation initiatives that would otherwise be considered too risky.

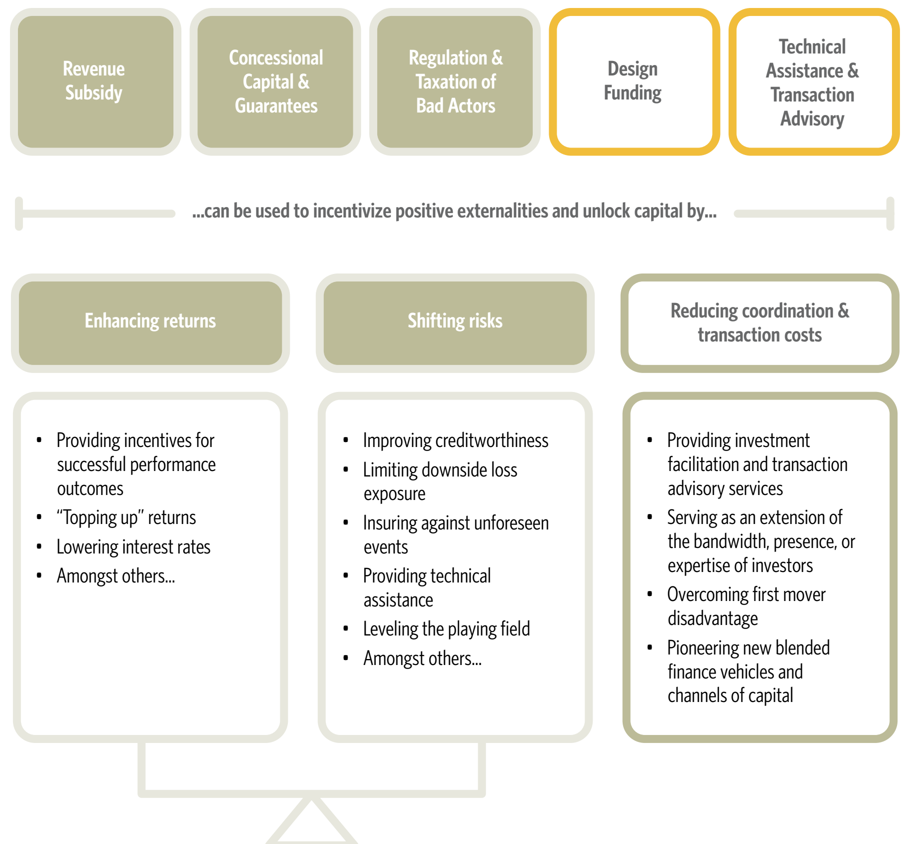
Investors should always think about the positive and negative externalities of their investments and how those externalities surface potential subsidies/taxes and catalytic/concessional structuring opportunities (Cusack, 2024).[lxxxv]

By using this framework, a philanthropic capital partnership could enable an agribusiness to reach previously inaccessible SSPs, expanding their customer base and providing access to innovative agricultural technologies sooner than otherwise possible. For instance, an investor might realize that advocating strongly in the policy arena is crucial because their investment is delivering substantial public goods, such as enhanced food security and climate resilience, which are not adequately rewarded under the current government framework. This proactive approach can lead to policy changes that recognize and incentivize the positive externalities generated by such investments.

Application in agricultural adaptation: In the context of agricultural adaptation, blended finance tools can be strategically applied to address the sector's specific challenges:

- **Enhancing returns:** Revenue subsidies and lower interest rates can support SSPs in adopting climate-smart practices like crop diversification and sustainable land management.
- **Shifting risks:** Concessional capital and guarantees can de-risk investments in high-impact projects like solar-powered irrigation systems and resilient seed varieties, making them more attractive to private investors.
- **Reducing coordination costs:** Technical assistance and transaction advisory services can facilitate the development and implementation of large-scale adaptation projects, ensuring they are financially viable and sustainable.

Figure 19: Blended finance tools across the public, philanthropic and private sectors



Examples of blended finance tools (modified from Cusack, 2024 with portions inspired by Convergence).

Figure 20: Examples of blended finance tools and their applications

Revenue Subsidy

Financial incentives that enhance returns for successful performance outcomes. For SSPs, revenue subsidies can ensure a stable income despite variable climatic conditions, making investments in sustainable practices more attractive.

Concessional Capital & Guarantees

Instruments that improve creditworthiness and limit downside loss exposure by providing low-interest loans and guaranteeing investment returns. These tools are essential for de-risking agricultural investments, encouraging private sector participation.

Regulation & Taxation of Bad Actors

Implementing regulatory measures and taxing entities that negatively impact the environment can shift investments towards sustainable agricultural practices. This can discourage harmful practices like deforestation and incentivize climate-smart agriculture.

Design Funding

Financial support for the initial design and development of adaptation projects helps overcome high upfront costs associated with innovative agricultural solutions. This includes funding for research and development of drought-resistant crops or efficient irrigation systems.

Technical Assistance & Transaction Advisory

Expertise and advisory services to farmers and agribusinesses can significantly reduce transaction costs and improve project implementation. This support is crucial for scaling up successful adaptation practices and technologies.

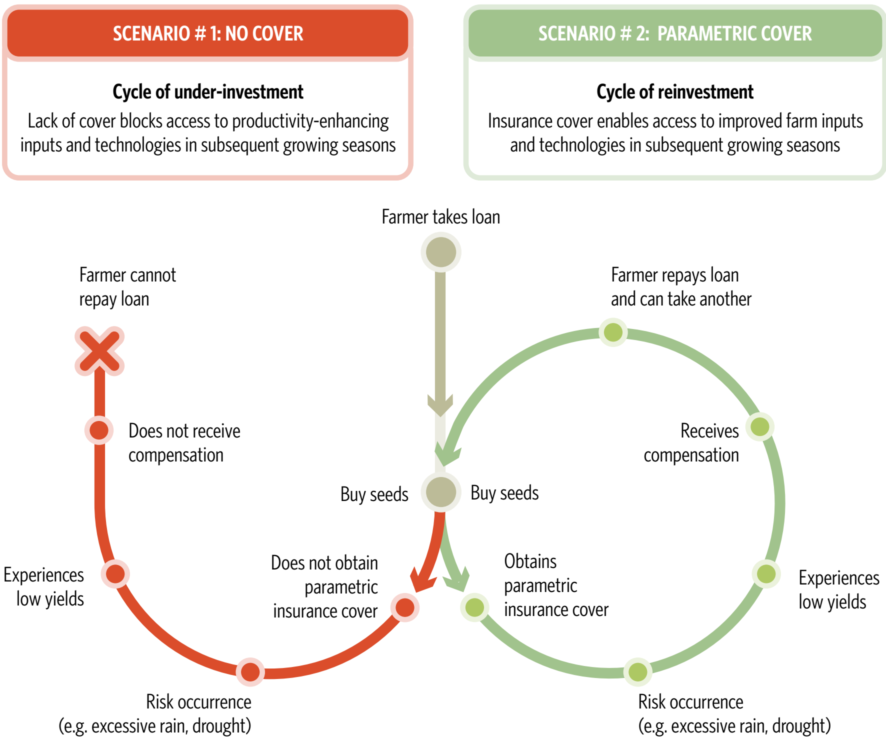
Various blended finance tools an investor may consider and how to use them.

Photo: © Diptanu Majhi/TNC Photo Contest 2022

A functional approach to parametric insurance in adaptation for investors

Parametric insurance is a type of insurance that pays out upon the occurrence of a predefined event as measured by specific parameters (e.g., rainfall levels or temperature thresholds) rather than based on actual loss incurred. This approach ensures quick and efficient payouts, crucial for mitigating the impacts of climate-related events on operations.

Figure 21: Impact of parametric insurance coverage across growing seasons



Outcomes of scenarios in which parametric insurance is/is not purchased (modified from Howden Group, 2023).[lxxxvi]

Parametric insurance is being developed and used as an effective means of insuring SSPs across Africa. New programs are utilizing changes in technology that reduce the cost of processing claims and improve access across the continent. As Figure 21 demonstrates, this could have a radical change on the creditworthiness of the sector, especially in the face of climate change.

Photo: © Rahmad Himawan/TNC Photo Contest 2023

Figure 22: Steps for investors to implement parametric insurance

Risk Assessment and Data Collection

Identify climate risks

- Analyse climate risk impacting the target agricultural sector using tools like Climate Impact Explorer and Standardized Precipitation-Evapo-transpiration Index (SPEI).

Gather historical data

- Collect historical weather and agricultural yield data to understand past trends and establish a baseline.

Designing the Insurance Product

Select relevant parameters

- Choose parameters that accurately reflect the key climate risks identified.

Define payout structure

- Develop a clear payout structure that specifies the conditions under which payouts will be made.

Pilot testing

- Implement pilot programs to test the product effectiveness and gather feedback.

Stakeholder Engagement and Education

Collaborate with local stakeholders

- Partner with investors, local governments, NGOs, and communities to promote the insurance product and educate farmers about its benefit.

Conduct training programs

- Develop training programs to help stakeholders understand how parametric insurance works.

Financial Structuring and Investment

Utilize blended finance models

- Combine public and private funding sources to share risk and attract broader investment.

Integrate insurance into investment decisions

- Use parametric insurance product to mitigate climate risks in agricultural investments thereby enhancing the attractiveness of these investments.

Consider bundling

- The proposed product could be bundled with other offerings to make it more attractive to farmers.

Monitoring and Evaluation

Track performance metrics

- Monitor key performance indicators such as payout efficiency, farmer satisfaction, and resilience improvements to assess the impact of the insurance product.
- Gather feedback from pilot programs and early adopters to refine the insurance product and improve its effectiveness.

How an investor might use parametric insurance as mechanism to mitigate risk.

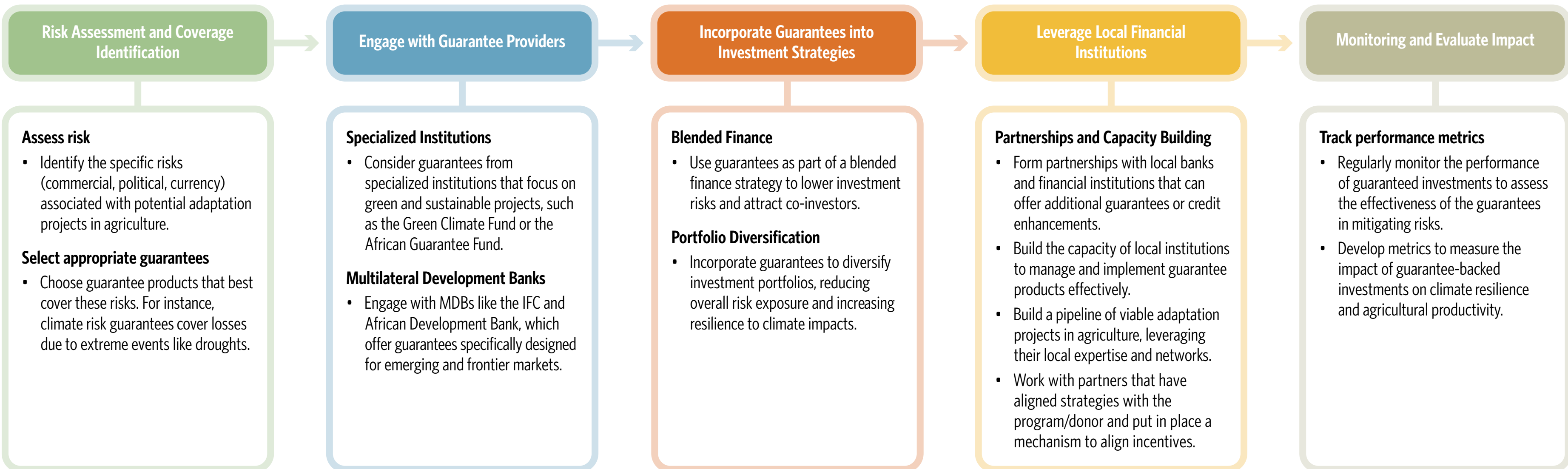
Some key features of parametric insurance are:

- **Trigger-based payouts:** Payments are triggered by specific, objective criteria such as rainfall levels falling below a certain threshold during a drought.
- **Timely disbursements:** Payouts are made rapidly after the trigger event, providing immediate financial relief.
- **Flexibility in use:** Funds can be used for various purposes, from emergency relief to infrastructure repair, based on the needs of the insured.

For example, Kenya's [Index-Based Livestock Insurance (IBLI)] developed by the International Livestock Research Institute serves as a robust example of how an index-based parametric insurance product has been successfully implemented in its vulnerable livestock agricultural sector. IBLI uses satellite data to monitor forage availability and triggers payouts when vegetation falls below a critical threshold, ensuring pastoralists receive timely financial support during droughts. Key success factors include:

- **Data-driven triggers:** The use of objective, satellite-based data to determine forage availability reduces disputes and ensures transparency.
- **Partnerships:** Collaboration between research institutions (e.g., ILRI), private insurers and international donors (e.g., EU, World Bank) has been crucial in developing and scaling the product.
- **Community engagement:** Extensive outreach and education efforts have helped build trust and understanding among pastoralists, enhancing uptake.

Figure 23: Functional approach to guarantees for investors



Steps for how an investor might incorporate guarantees into their investment strategy.

Utilizing guarantee products for adaptation investments in agriculture

Cross-border guarantees are an important but underutilized tool for mobilizing private capital. An OECD evaluation found that guarantees leveraged 26% of all mobilized private finance between 2018-2020 and were among the preferred risk mitigation tools of private investors.

Guarantee products offer financial protection to lenders and investors against various risks, making climate adaptation projects in agriculture more attractive and feasible. These guarantees can cover commercial, political and currency risks which are significant barriers to investment in high-risk regions like EMDEs. Some of their key features include:

- **Credit enhancement:** Guarantees improve the credit profile of borrowers by covering potential losses, thereby lowering the cost of capital.
- **Risk mitigation:** They protect against specific risks such as political instability, currency fluctuations and commercial failures.
- **Flexibility:** Guarantees can be tailored to cover different types of financial instruments, including debt, bonds and equity investments.

Step 3 conclusion

Step 3 has provided concrete examples of where adaptation investments can fit into an array of investment types. By bringing to these examples the activities from Steps 1 and 2, the reader has tools, both from a quantification and strategy perspective, to apply an adaptation lens. The next section contains detailed case studies where many elements of the adaptation lens have been applied in practice.

CASE STUDIES

Investing in agricultural adaptation

This chapter provides examples of agricultural adaptation investments, highlighting successful examples from ARAF, AgDevCo, and Aceli Africa. This is not an exhaustive list and other investment examples can be found in the Zotero database.

Photo: © Maíra Erlich

Photo: © Smita Sharma

ARAF (FarmWorks)

Quick Facts

Geography: Kenya

Timeline: FarmWorks was founded in 2020; ARAF invested in 2021

Key investor insight: ARAF utilizes an in-house, pre-investment climate assessment tool to determine which investment opportunities are likely to have the largest climate impact

ARAF is a USD $58 million impact fund and the world's first equity fund designed to build the climate resilience of SSPs in East and West Africa. ARAF supports SSPs in Africa by investing in early and early-growth stage agribusinesses that enable them to anticipate, weather and bounce-back from climate events, resulting in increased yields and incomes. They identify, select and invest through a transformative lens by supporting agribusinesses that deliver solutions that augment and accelerate positive changes in farmer behavior, and are committed to building profitable and scalable enterprises that prioritize the needs of SSPs. Since its inception they have invested in 13 companies. In 2021, ARAF identified FarmWorks as an investment opportunity (ARAF, n.d.).[lxxxvii]

FarmWorks has built its business model by integrating the Kenyan agricultural ecosystem. The company works with over 3,000 SSPs, providing inputs and financing at the farm level, essential machinery and machinery services, and education through their farmer field schools. FarmWorks also offtakes for SSPs, removing a market risk that SSPs often face. Through 30 branches across Kenya, FarmWorks has served 5,000 customers and each month exports 100 tons of outputs to Europe and sells 1,000 tons in Kenya (FarmWorks, n.d.).[lxxxviii]

Through FarmWorks, ARAF saw a market opportunity for services others in the region had not capitalized on. Because of their deep expertise in the regional challenges that exist, including a lack of educational infrastructure and abundance of mid-sized farms that are under-utilized, they recognized that FarmWorks' approach was transformative. FarmWorks stood up its own apprentice-based training institute that follows a 'heavy touch' approach where the farmer is trained on better farming practices and applies them on their farms. They do this by covering the cost and educating on the application of fertilizer and pesticides (as farmers do not often apply the right amounts) and establishing a unique demonstration approach whereby FarmWorks and the farmer reach an agreement to use a small fraction of the farmer's land (typically 1/8 of an acre) to do farming "the FarmWorks way" while the rest remains under the farmer's preferred growing practice. By using this approach, the farmer can compare the change in yield performance.

ARAF also evaluated the climate potential of FarmWorks by using an in-house pre-investment climate assessment tool (ARIS) that assesses a company's climate potential based on its services and predicts whether the enterprise has a high, moderate or low likelihood of helping SSPs become more climate resilient. The tool covers historical climatic conditions, business model health, and unintended consequences and is externally validated upon assessment completion. This assessment has become an integral part of ARAF's pre-investment due diligence process—ARAF only proceeds with companies that receive a *high likelihood* rating as this ensures that there is a defensible case for expected climate impact. They found FarmWorks with a high likelihood of helping SSPs adapt to climate change (Mincy, 2024).[lxxxix]

As of the publication of this guidebook, FarmWorks has exceeded both its climate impacts and revenue targets. Using an in-house climate resilience assessment commissioned by 60 Decibels, ARAF can measure and monitor climate impacts and farm productivity gains. Since the time of investment, ARAF has reported year-over-year increases in farmer skills, agronomic knowledge and overall resiliency on the farm. As a result, FarmWorks also experienced a ten-fold increase in revenue between April 2022 and March 2024, signaling strong projections and upside potential at the time of investment exit. Given ARAF's success disbursing capital to higher risk, early-stage businesses and attracting other strategic and financial investors, its investments have attracted an additional 4.49x in co-investments into existing portfolio companies (Ahmad, 2024).[xc] ARAF hopes to continue supporting enterprises delivering transformative climate solutions that benefit SSPs (and ultimately the agriculture sector as a whole) by utilizing its methodical approach to scoping investment opportunities, including the use of climate assessments to evaluate impact (Mincy, 2024).

Photo: © Erik Lopes/TNC

Photo: © Phata Sugar Cooperative

AgDevCo (Phata Sugar Cooperative)

Quick Facts

Geography: Malawi

Timeline: The cooperative was formed in 2011; AgDevCo invested in 2016

Key investor insight: For their deal review committee, AgDevCo's team prepares thorough impact assessments that detail an investment's potential impact but also the potential climate change vulnerability of the investment as well as how adaptation strategies build resilience and minimize carbon emissions

Phata Sugarcane Outgrowers is a smallholder farmer-owned cooperative in Malawi established in 2011 in partnership with Agricane, an agricultural development management company that provides technical assistance to smallholder farmers and the commercial sector. The cooperative is composed of 380 households who, before growing sugarcane, were growing cotton and sorghum. The cooperative developed a constitution, is governed by a board made up of farmer representatives and has three independent directors (Agricane, 2019).[xci] Importantly, Agricane advised the cooperative on identifying and securing funding for a center-pivot irrigation system.

The European Union (EU) provided a USD $3.2 million grant facility for the development of 300 hectares of sugarcane production, leaving another 10 acres for collective food crop production. Through this grant, the cooperative was able to purchase the irrigation equipment. The grant required a contribution of USD $503,810 which AgDevCo provided as a loan secured on the irrigation equipment. AgDevCo also helped the cooperative secure a USD $700,000 loan from Opportunity Bank of Malawi to provide the annual working capital to cover the initial operational costs. Illovo offered a 25-year offtake agreement—subject to renegotiation every five years—which has been a key element of success as the offtake agreement ensures market access for the cooperative and covers the full period of the debt facility. Cooperative members receive annual dividends based on the size of the land they contributed. Phata employees (who are often members of the cooperative) receive monthly wages. Both members and employees have seen their earnings rise significantly (AgDevCo, n.d.).[xcii]

AgDevCo's impact assessment process

AgDevCo develops thorough ex-ante impact assessments that are presented to their investment committee before agreeing to an investment opportunity. These assessments are gender-sensitive and detail the logic and assumptions behind how the investment will create impact at the firm, market and livelihood level. One of the key components of this thesis is climate resilience. AgDevCo assesses the climate change vulnerability of all its investments, as well as the resilience and adaptation measures that are put in place. This is to ensure they are minimizing their carbon emissions while preserving value and their other development impact goals (AgDevCo, 2024).[xciii]

The first sugarcane harvest was in August 2013 and yields have been consistently high since then, providing a sustained source of revenue and profits for the cooperative. During the first phase of the project, the Board agreed to the following: a dividend policy which pays out 60% of profits and keeps 40% to cover operational expenses, repaying the capital loan ahead of schedule, and building a reserve to fund future investments. Because of this, Phata was able to repay its initial working capital loan from Opportunity Bank after the first harvest in 2013 and completed payment on the AgDevCo loan three years ahead of schedule. In 2018, the Board increased members' dividends to 70%. Due to the success of the first phase of the project, more farmers wanted to join Phase Two and in 2015, Phata was awarded a second EU grant of USD $2.3 million to develop an additional 312 hectares of sugarcane and 50 hectares of food crops. This grant required a contribution and AgDevCo provided a USD $1,201,600 capital loan and a USD $400,000 working capital loan to meet these needs (AgDevCo, n.d.).

Beyond field operations, AgDevCo, Agricane and the Cooperative management have focused on building the capacity of the cooperative through training courses on agronomic practices and business knowledge, securing grant funding for diversification initiatives, requiring members of the cooperative to work on the farm 1-2 times per week to reinforce skills and ownership, and developing a detailed financial model and cropping plan (AgDevCo, n.d.).

The cooperative has had a significant impact on the wages of members and employees. The average income per member farming sorghum and cotton in 2011 was USD $120, while the average member in 2017 earned USD $649 through the cooperative. Most of the employees and members have reinvested their wages and dividends into business and household assets. In a case study on the AgDevCo investment, one member discussed being able to buy land and a water pump to grow and sell tomatoes and onions year-round. Community members have also reported an increase in their food security and ability to pay for school fees. After the cooperative was established, secondary school enrollment rates jumped from 35% to 95% (AgDevCo, n.d.).

The main lessons that AgDevCo reports learning through its engagement with the Phata Sugar Cooperative are:

- **Communication is key:** AgDevCo found that most problems occurred when community members were not fully informed about decisions or did not understand the rationale of decisions made by Board members. Poor literacy heightened this problem. To solve this problem, Phata is continuing to invest in an extension team, testing the most effective ways to share information, and hosting adult literacy classes.
- **There should be no minimum land size to join the cooperative:** Phase One rules stipulated farmers had to have one hectare of land to join the cooperative but this requirement was done away with for Phase Two. Members are now much happier about the system and there is a better representation of women farmers who typically own less land.
- **Farmers should be allowed to measure their own land:** In Phase One, measurements were copied by hand on paper which led to concerns about fairness and accuracy—a particularly sensitive topic because of the dividends system. For Phase Two, farmers were asked to measure their land with a GPS device and upload this information digitally. This approach was much preferred by the farmers.
- **An electricity contingency plan is key:** Because electricity is an essential input for irrigation, outages impacted the sugarcane crops—particularly in 2017. The Phata Board sought to solve this problem by investing in four generators to ensure the irrigation can still function if there is an outage.
- **Support indigenous trees:** Some trees had to be removed for the irrigation system and were replaced with seedling woodlots which contain a mix of trees that the community can sustainably harvest when they're mature. Some community members complained that medicinal trees were not always being replaced. To address this problem, the management team has been consulting with the community to understand which indigenous trees are most important to community members and will ensure these trees are prominent on future planting sites.
- **Ensure AgDevCo covers its costs:** Because the loan was repaid three years early, AgDevCo recovered the money lent in Phase One but did not recoup all its team's time and expenses associated with the due diligence work on Phata and acting as a Board observer. AgDevCo addressed this problem by offering the Phase Two working capital component of the loan at commercial rates while the term loan was offered at a concessional rate. AgDevCo also added early repayment clauses to the loan agreement (AgDevCo, n.d.).


Photo: © Phata Sugar Cooperative


Photo: © Phata Sugar Cooperative

AgDevCo reports that there is significant demand from the community for the cooperative to further expand and has said they will continue to be a Board observer and support community development initiatives (like the women's action group) during Phase Two. AgDevCo is also keen to explore a third phase of the project if there continues to be demand from the community, if Illovo continues to commit to buying additional volumes of sugarcane and if the financial forecasts are healthy (AgDevCo, n.d.). Agricane is also continuing to build the capacity of cooperative members and staff so that the cooperative can eventually be independently managed (Agricane, 2019).

> "Every year we're saving more money to invest in either repaying our debt, investing in the fields, or building up our reserve. The Cooperative has a cushion of over [USD] $200k in an interest-bearing account now."
>
> — MD, Agricane (AgDevCo, n.d.)

Photo: © XJoão Ramid

ACELI AFRICA

Quick Facts

Geography: Kenya, Rwanda, Tanzania, and Uganda

Timeline: Launched in 2020

Key investor insight: Aceli provides incentives for lenders to make loans for borrowers that will invest in their resiliency through the implementation of regenerative agriculture practices.

Aceli is a catalytic market financing facility that offers concessional financing in the form of financial incentives for lenders that then provide commercial financing to agricultural small-and-medium enterprises (SMEs). Aceli was created to address the misalignment between the risk-return hurdle lenders face and the capital demanded by agricultural SMEs (Convergence, 2020).[xciv] Aceli also supports capacity building for borrowers to ensure they can repay their loans and provides technical assistance to lenders to adjust their financial products to meet the specific needs of agricultural SMEs (Konig, 2022).[xcv] Furthermore, Aceli is building an evidence base through data and learning to inform policy-making that promotes market development on a large scale (Convergence, 2020).

Aceli's blending component works downstream at the underlying loan level and is a grant-funded facility that provides concessional financing to lenders that then provide commercial financing to agricultural SMEs. It offers lenders first-loss coverage at a portfolio level for qualifying loans between USD $25,000 and $1.5 million. Lenders who make qualifying loans earn money in a reserve account, a structure that helps avoid the moral hazards typically associated with first-loss coverage. Aceli also provides origination incentives to support lenders that would traditionally be deterred from serving market segments that have lower revenues and higher operating costs. This service is through cash payments to top up lender revenue from loan interest and fees for smaller ticket sizes (USD $25,000 to $500,000) and for loans for food crops that would otherwise not be profitable.

Furthermore, Aceli offers additional first-loss coverage (up to an additional 2%) and origination incentives for any loan that meets a higher standard in food security, gender inclusion and climate-smart and resilient agriculture. On this third impact metric specifically, 20% or more of the loans were initially projected to meet a higher standard for agricultural practices related to soil and water management, waste and energy (Convergence, 2020). Aceli raised the target of loans that meet this criterion to 25% in 2022 (Aceli Africa, 2024).[xcvi] A loan qualifies for the bonus if the borrower does at least one of the following:

- **Regenerative practices** which include implementing or sourcing from farmers who implement agricultural practices that restore soil health and apply holistic land and ecosystem management practices. These practices must impact at least 50% of the farm level activities and include soil health improvement, enhancing ecosystem functions and integrated pest management. This also involves implementing activities that increase biodiversity, agroforestry and reforestation of the ecosystem.
- **Circular agri-based systems** which encompass approaches that optimize the use of biomass and renewable resources on-farm, in value-added processing, and along value chains.
- **Certification** from at least one of the following organizations: Rainforest Alliance/UTZ, Organic, or the Forest Stewardship Council.
- **Validation of climate and environment practices by a recognized third party.** Aceli maintains a list of programs that have been successful in the implementation of regenerative and circular agricultural practices (Aceli Africa, 2024).

Finally, the technical assistance packages that Aceli provides are tiered to fit the specific agricultural SME's profile. For example, less than USD $2,000 might be provided for an SME considered to be entry level whereas USD $20,000 might be provided for an SME that demonstrates high growth and impact potential, in addition to the technical assistance provided to lenders (Convergence, 2020).

Highlighting Aceli's impact

In a survey Aceli contracted with 60 Decibels, preliminary findings indicated that 72% of farmers are gaining market access and feeling more secure due to their relationship with an SME receiving Aceli-supported financing. In the words of one Tanzania cassava farmer who was able to access financing from Tanzania Commercial Bank after the bank partnered with Aceli: "I have bought an agricultural land and was able to build my own house" (Aceli Africa, 2024).[xcvii]

For its 2024 Financial Benchmarking Report, Aceli in collaboration with Dalberg examined over 20,000 loans with data from 35 different lenders to provide an analysis of key agricultural SME lending trends in East Africa. Through this type of analysis involving lender loan performance based on total income, operating costs, expected credit losses and cost of funds, Aceli assessed the impact it is having on its partner lenders. They demonstrated that the value of the agricultural SME lending book has more than tripled between 2019 and 2022 (primarily driven by growth in Tanzania), the share of overall bank lending to agricultural SMEs doubled between 2019 and 2022, and Aceli's origination and first-loss coverage mechanisms are viewed favorably and considered impactful (Aceli Africa, 2024).[xcviii] For farmers, as of the end of 2023 this has resulted in USD $152 million in mobilized capital via 1,567 loans impacting 883,000 farmers and workers—40% of whom are women.

In its Year Three Learnings report, Aceli noted that *"the largest opportunity for bridging capital supply and demand to generate our intended impact is at ticket sizes well below both our original target and the focus of other donor-funded agri-SME finance initiatives."* Furthermore, Aceli reported that sustained lender behavioral change requires both incentives to shift the risk-return profile of financing agricultural SMEs, and deep engagement that aligns strategic commitments with operational practices. Through a robust data collection effort, Aceli also pointed to an emerging case for African governments and international donors to allocate more funding and fortify enabling conditions for agricultural SMEs—especially those with lower financing needs (Aceli Africa, 2024).

Aceli-Lender Partnership Success: Family Bank

Founded in 1985, Family Bank Limited is a woman-led commercial bank in Kenya that provides a range of retail and consumer products, with a strong emphasis on lending to SMEs. Agricultural finance is part of the bank's core objectives, and the bank was originally founded to meet the needs of tea farmers in the Central and Rift Valley Provinces (USAID, n.d.).[xcix] In recent years, Family Bank has signed multiple partnerships to solve the critical challenge of access to capital for agricultural SMEs, including through partnerships with Aceli, CIAT, and the International Food Policy Research Institute (IFPRI).

For example, through its partnerships with CIAT and IFPRI, Family Bank has focused on making loans for farmers in the sorghum and maize value chains. In an interview with the report authors, Family Bank's Head of Agribusiness Anthony Mutuki Mbithi reported that their resiliency program has ensured that farmers can harvest because it helps the farmers gain access to drought-resilient seeds and increases the uptake of financial services that help guard against losses. They have found that, on average, farmers have doubled their yields from previous harvests, meaning greater food security and an ability to sell excess yield. Technical assistance supported by the bank has provided financial literacy, an understanding of climate risks and access to agronomical services. Farmers are also doing water harvesting through shallow water pans and water tanks. Mbithi noted that Family Bank also monitors climatic risks for borrowers to ensure that they are compliant with best practices around managing climate risk– an important part of Family Bank's other partnership with Aceli as they report to Aceli on this kind of data (Mbithi, 2024).[c]

Through their partnership with Aceli, Family Bank also launched a woman's market initiative in 2022 in which the bank incorporated gender metrics across the lending process to support a gender lens portfolio analysis, delivered capacity building training to staff on gender equality and applied key gender concepts to their work (USAID, n.d.). In recognition of Family Bank's excellence in this space, Aceli awarded Family Bank with its Bank of the Year award in 2022 for its high-impact agricultural lending.

Family Bank's collaborations with institutions like Aceli demonstrate the great impact that can be had through strong partnerships, and they will continue to engage such initiatives. For example, through their resiliency program Family Bank hopes to reach 40,000 smallholder producers in the maize value chain and 10,000 in the sorghum value chain, as well as to scale up the number of acres they are providing financing for (Mbithi, 2024).

CONCLUSION

Incorporating an adaptation lens for agriculture investments is critical to create resiliency in agriculture investments and the long-term wellbeing of SSPs. The steps in applying an adaptation lens have been designed specifically to address the key barriers and challenges investors and other stakeholders identified as limiting their ability to make adaptation investments.

While there are several meta-climate risks that are broadly affecting the agriculture sector, Step 1 of this guidebook demonstrates a conceptual framework and tools investors can use to integrate climate forecasts into their decision-making process.

Step 2 provides examples of adaptation strategies and introduces a process for assessing the enabling conditions and potential impact of an adaptation strategy, along with the associated costs and benefits. Common resources like academic publications, commercial price listings and national databases contain relevant data investors can use to make these determinations.

Step 3 demonstrates how to integrate an adaptation lens into an investor's portfolio, focusing on how lenders, VC/PE investors, and corporations might each approach doing so. The case studies provide real examples of successful adaptation investments as well as an important reminder about the risks of maladaptation.

Lastly, this guidebook is one contribution to the wider global discussion about climate adaptation. Fortunately, the community of practitioners focused on agriculture adaptation is robust. This includes the many partners who supported this guidebook: farmers, SMEs, and advisors in the finance, development, and non-profit spaces. TNC invites others to help build on the concepts shared here and ultimately advance agriculture investing to a place where climate risks and vulnerabilities, and the benefits of appropriately managing them, become business as usual.

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APPENDIX

Partners

TNC is grateful for the support of the Bill & Melinda Gates Foundation, CrossBoundary Group, the African Centre for a Green Economy (AfriCGE), International Water Management Institute (IWMI), the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), and SouthSouthNorth in producing this guidebook. TNC is also appreciative of the advisory board group and owes a special thanks to Pascal Chapot of Nestle, Jahan Chowdhury of IFAD, Julie Greene of Olam, Tara Guelig of The Lightsmith Group, Anthony Mbithi of Family Bank, Madleine Mwithiga of ADAPTA, and Jonathan Phillips of Duke University for their time and insights which we have incorporated into this final product. Thank you also to Apertures, Inc. for their design and formatting support, and to Darin Jones for providing copyediting services. TNC is enormously appreciative of their guidance and expertise as well as the time many of our colleagues took to review various drafts of the guidebook.

Essential concepts in adaptation

Unless otherwise noted, the Intergovernmental Panel on Climate Change (IPCC) defines these commonly used terms in adaptation debates, literature, and policy as such:

- **Adaptative Capacity:** (in relation to climate change impacts) The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences.
- **Coping Capacity:** The ability of people, institutions, organizations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage and overcome adverse conditions in the short- to medium-term.
- **Capacity Building:** The practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society or organization to respond to change.
- **Absorptive Capacity:** a company's capability to recognize, absorb, modify, and apply knowledge from external sources. Essentially, it is the extent to which a company can quickly absorb and implement external scientific, technological or various types of knowledge that are not originally part of the organization (The Oxford Review, n.d.).[ci]
- **Vulnerability:** The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity. Therefore, adaptation would also include any efforts to address these components.
- **Adaptation Benefits:** The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures.
- **Adaptation Costs:** Costs of planning, preparing for, facilitating and implementing adaptation measures.
- **Maladaptation:** Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.
- **Transformational Adaptation:** Adaptation that changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts.
- **Incremental Adaptation:** Adaptation that maintains the essence and integrity of a system or process at a given scale. In some cases, incremental adaptation can accrue to result in transformational adaptation. Incremental adaptations to a change in climate are understood as extensions of actions and behaviors that already reduce the losses or enhance the benefits of natural variations in extreme weather/climate events.
- **Nature-Based Solutions:** Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.
- **Resiliency:** The process of reducing the vulnerability of human and natural systems to climate-related hazard. Unlike adaptation which is generally a standalone project (i.e., installing water pans), it requires a multi-dimensional and systemic approach to coping with and recovering from climate change impacts.
- **Enabling Conditions:** Conditions that enhance the feasibility of adaptation and mitigation options. Enabling conditions include finance, technological innovation, strengthening policy instruments, institutional capacity, multi-level governance and changes in human behavior and lifestyles.

STEP 1

5-year yield and price volatility analysis for maize in Kenya (1960-2024)

Volatility = SD/Mean

YIELDS				PRICE		
Year	Mean	SD	Volatility	Mean	SD	Volatility
1960	1111	34.36259	3.09%	No Data		
1965	1067	86.72168	8.13%			
1970	1149	47.49274	4.13%			
1975	1348	130.3756	9.67%			
1980	1463	299.0821	20.44%			
1985	1674	120.6441	7.20%			
1990	1599	167.8248	10.50%			
1995	1442	165.6337	11.48%			
2000	1489	172.111	11.56%			
2005	1426	199.7984	14.01%	$ 28.96	$ 7.70	26.59%
2010	1524	55.54186	3.65%	$ 43.61	$ 7.00	16.06%
2015	1470	151.3445	10.29%	$ 48.62	$ 4.49	9.24%
2020	1430	160.8728	11.25%	$ 61.56	$ 10.74	17.44%

5-YR Volatility Summary	Yield	Price
Overall Volatility (full period)	16%	27%
Average 5-YR Volatility	10%	17%
CAGR	6%	4%
5-YR Increase (slope of trendline)	0.0031	-

Yield-SPEI Regression Analysis

The regression below corresponds to the relationship between yields and SPEI ratios during the planting season (i.e., March – May) for maize in Kenya. In general, the outputs indicate that SPEI can help broadly explain yield performance in part, because:

- SPEI can explain roughly 20% of the variation in yields (measured in R square).
- Both drought (planting_spei_min) and flood (planting_spei_max) events have almost significant p-values of 0.07, meaning the relationship between climate data and yields is somewhat significantly strong.
- The overall p-value of the regression model (Significance F) is 0.11, indicating a relatively strong model output (the closer to 0.05, the better).

With these results, it is possible to build a formula for predicting yields given different SPEI scenarios. In this case, this formula is built by using the variable coefficients as follows:

$$\text{Maize Yields} = \text{Intercept} + \text{planting\_spei\_min} * (\text{spei drought forecast}) + \text{planting\_spei\_max} * (\text{spei flood forecast})$$

for this regression, it means:

$$\text{Maize Yields} = 1821.77 + 410.36 * (\text{SPEI Drought Forecast}) - 497.66 * (\text{SPEI Flood Forecast})$$

Hence, using SPEI forecasted values, one can predict yields for a given year. However, it is important to note that climate predictions are incredibly difficult (if not almost impossible) to accurately estimate. As such, it is recommended to limit these assessments to their directional nature rather than taking the outputs at face value.

Regression Output Tables

Summary Output

Regression Statistics	
Multiple R	0.426
R Square	0.181
Adjusted R Square	0.107
Standard Error	406.809
Observations	25.000

ANOVA	df	SS	MS	F	Significance F
Regression	2.000	805594.648	402797.324	2.434	0.111
Residual	22.000	3640853.239	165493.329		
Total	24.000	4446447.887			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1821.772	233.933	7.788	0.000	1336.624	2306.921	1336.624	2306.921
planting_spei_min	410.363	220.792	1.859	0.077	-47.531	868.257	-47.531	868.257
planting_spei_max	-497.662	259.285	-1.919	0.068	-1035.386	40.062	-1035.386	40.062

Summary Output

ANOVA	df	SS	MS	F	Significance F
Regression	3	6027.087	2009.029	5.068	0.111
Residual	21	8325.132	396.435		
Total	24	14352.219			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	18.452	25.187	0.733	0.472	-33.926	70.831	-33.926	70.831
maize_yield	-0.017	0.010	-1.694	0.105	-0.039	0.004	-0.039	0.004
7mo_spei_min	-28.548	13.023	-2.192	0.040	-55.632	-1.465	-55.632	-1.465
7mo_spei_max	25.209	13.070	1.929	0.067	-1.972	52.390	-1.972	52.390

Yield, Price, and SPEI data for Kenya

The table below summarizes yield, price, and climate (i.e., SPEI) data for Kenya between 2000 and 2024. This data was used to inform yield performances and volatility measures covered in Step 1. The SPEI columns captures the strongest droughts (-2 to 0) and flood (0-2) events recorded for the given year as indicated by the SPEI ratio. The colors displayed for SPEI indicate lower (blues) SPEI values and higher (red) SPEI values for droughts and flood events in relation to their degree of severity.

	Yield Stats	Price Stats
Mean	1,471.09	$ 47.55
SD	145	12.82
Volatility	10%	27%

Year	Yield	% Distance from Mean	% Chance from Prior Year	Kenya Market Price (KES)	SPEI Drought (Annual Min)	SPEI Flood (Annual Max)
2000	1,306.35	-11%	—		-1.19	0.06
2001	1,543.30	5%	15%		-0.51	0.67
2002	1,372.21	-7%	-12%		-0.90	0.79
2003	1,471.82	0%	7%	No Data	-0.83	0.21
2004	1,750.23	19%	16%		-1.13	0.33
2005	1,488.24	1%	-18%		-1.50	0.34
2006	1,560.09	6%	5%		-0.71	1.23
2007	1,644.91	12%	5%	$ 20.18	-0.92	0.60
2008	1,263.26	-14%	-30%	$ 32.12	-1.27	0.40
2009	1,174.17	-20%	-8%	$ 34.58	-1.43	0.18
2010	1,564.98	6%	25%	$ 31.35	-1.12	0.43
2011	1,436.98	-2%	-9%	$ 44.54	-1.48	0.92
2012	1,575.42	7%	9%	$ 48.44	-1.31	0.51
2013	1,535.14	4%	-3%	$ 46.38	-1.02	0.41
2014	1,506.11	2%	-2%	$ 47.33	-1.04	0.15
2015	1,653.80	12%	9%	$ 45.94	-1.34	1.09
2016	1,295.82	-12%	-28%	$ 43.75	-1.26	0.45
2017	1,385.45	-6%	6%	$ 55.44	-1.23	0.64
2018	1,601.73	9%	14%	$ 47.73	-0.70	1.61
2019	1,415.21	-4%	-13%	$ 50.23	-1.84	1.84
2020	1,609.44	9%	12%	$ 49.37	-0.69	0.75
2021	1,381.73	-6%	-16%	$ 52.82	-1.81	0.06
2022	1,298.73	-12%	-6%	$ 60.84	-1.20	0.44
2023	No Data			$ 71.73	-1.80	1.69
2024				$ 73.06	-0.78	0.67

STEP 2

Drought-tolerant seeds example

Background

Drought-tolerant seeds are bred to perform well under mild to moderate drought conditions that occur because of shifting or unpredictable rainfall patterns and/or restrictions on water availability for irrigation. These types of seeds are critical to help farmers, particularly those in rain-fed production systems, maintain a minimum level of production during dry years. With climate change, the frequency and intensity of droughts are expected to increase in many areas of the globe, increasing the importance of drought-tolerant seeds for rain-fed agriculture.

In Africa drought is the main cause of crop yield loss, leading to reduced incomes, food insecurity and famine (Noelle et al., 2018).[cii] Drought is common across the continent, but weather patterns are becoming more unpredictable and often more severe. For example, the combined droughts of 2014-2017 resulted in an estimated loss of USD $372 billion (Demisse et al., 2019).[ciii] In South Asia there were extreme drought events in several locations across the region in recent years, including in India (Aadhar & Mishra, 2019),[civ] Pakistan (Ullah et al., 2022),[cv] Afghanistan (Qutbudin et al., 2019),[cvi] and Bangladesh (Rahman & Lateh, 2016),[cvii] that resulted in extensive impacts on agricultural systems and the economy that affected the livelihoods of millions of people (Sein et al., 2022[cviii]; Singh & Bose, 2021[cix]; Wakazuki et al., 2015[cx]). 50-year historical droughts could double across a vast majority of the region even under a 1.5°C scenario (Ullah et al., 2022).

Small-scale producers often bear the brunt of drought as many of them rely solely on rain for their crops and have limited crop diversity and income sources. The uptake of drought-tolerant seeds, particularly for maize, cowpeas and rice, has accelerated over the last two decades with about 40 million small-scale producers in sub-Saharan Africa employing more than 200 drought-tolerant maize varieties (Nuccio et al., 2018)[cxi], (CIMMYT, 2016[cxii]).

Benefits

Drought-tolerant seeds offer one way to manage against drought and its increasing frequency and intensity expected with climate change. The primary benefit is the reduced loss of crop yields and income during dry periods. Decreasing risks during dry years can provide more confidence to farmers that investments in other inputs (such as fertilizers) will be worthwhile, potentially further increasing yields through the application of such investments (Simtowe et al., 2019).[cxiii]

The financing case

The primary financial benefit of drought-tolerant seeds is a reduced loss of yield during dry years and subsequent loss of income during those years. Accordingly, they are cited as a way to protect farmers' food security and income though yield and income improvements vary depending on the specific seed varietal planted, drought conditions, geography and market prices, the inputs the farmer uses and other considerations. As climate change increases the frequency and intensity of drought in many areas of South Asia and sub-Saharan Africa, the potential for losses for rain-fed agriculture is expected to accelerate with many potential devastating follow-on effects such as famine and the collapse of food systems. By investing in a scale-up of drought-tolerant seeds, value is created in reducing losses in yield and incomes in any particularly dry year, and on average over several years that include wet, normal and dry years. With expected increases in the frequency of dry years, these benefits are likely to accelerate over time.

Challenges: Challenges to scaling uptake remain, including the cost and access to the seeds (especially as the seeds generally need to be purchased each year to maintain their ability to withstand drought) and in producing these improved seeds, particularly beyond the most common crop types. Many farmers across Asia and sub-Saharan Africa note that access is not consistent and that a government subsidy is needed to afford the seeds. There are also information barriers, from lack of awareness of drought-tolerant seeds to misunderstandings about their ability to deliver strong crop yields in non-drought years. There is a close correlation between access to information and technical extension services to the use of drought-tolerant seeds, which indicates the importance of such services and potentially an equity issue when it comes to access to information (Ayedun, 2018).[cxiv] Finally, it is important to consider that drought-tolerant seeds have the greatest potential to deliver benefits when they are included in a holistic management system where water availability is a concern. Some of the bundling options below are examples of elements that support such a holistic approach.

Bundling

Other adaptation interventions or best practices that drought-tolerant seeds might be bundled with to improve yields and build system resilience include:

- Seeds with other types of improvements such as for pests or disease, or that may more generally improve yields for the local soil types and climate
- Nutrient and pest management
- Conservation agriculture
- Changes in planting or harvesting timing
- Digital or extension services
- Insurance

Example valuation of drought tolerant seeds for maize

This example integrates data from multiple locations in Sub-Saharan Africa where maize is grown, with ranges provided for costs and benefits. The analysis is conducted for a rain-fed farm with no mechanization and labor provided by the farmer and their family. The costs for planting and harvesting drought-tolerant and non-drought-tolerant maize are similar, including labor and (for many farms) fertilizer, pesticides and herbicides. The primary difference in cost is that drought-tolerant seeds are usually more expensive, with a range in the literature of USD $38-160 per hectare versus USD $38-48 for non-drought-tolerant seeds, or on average 48% more expensive (Zaidi et al., 2023).[cxv]

The primary financial benefit is in average yield over several years due to reduced losses during drier years. Drought-tolerant seeds are designed to reduce losses (and therefore provide higher yields) than non-drought-tolerant seeds during dry years within the range of approximately 5-50% higher yields. During normal precipitation years studies show that, depending on the specific seed type and local context, drought-tolerant seeds might perform worse than, the same as, or better than non-drought tolerant seeds (within a range of -20% to +15%) though as seed development research progresses, the majority of drought-tolerant seeds are performing as well as or better than non-drought tolerant seeds (Habte et al., 2023)[cxvi], (Simtowe et al, 2019).

Investing in drought-tolerant seeds in a specific year may or may not produce a financial benefit but over several years, knowing precipitation patterns and temperatures fluctuate year to year, they are likely to produce a yield and income benefit. As climate change is expected to increase the variability of precipitation, increase temperatures, and impact the frequency and severity of droughts, drought-tolerant seeds are increasingly likely to be worth the investment on average over a period of years.

Some of the factors that have the strongest influence on the potential for financial benefits for drought-tolerant seeds include:

- The specific seed purchased and how much better it performs during normal and drought years as compared to non-drought-tolerant seeds for the given biophysical context.
- Number of dry years over the target period, the magnitude of precipitation deficit in those years and the timing of precipitation within the crop growth cycle.
- Use of integrated nutrient and pest management.
- Market prices for seeds and maize.
- Access to weather information and technical advising.
- Other agronomic practices already in place, such as mulching, to help reduce evapotranspiration from the soil.

With these factors in mind, a package of investments that includes drought-tolerant seeds proven to increase yields in both normal and dry years for the specific region, the use of fertilizers and other agrochemicals, and access to information and technical advising are likely to increase the likelihood of improved yields and, subsequently, increased incomes. As drought-tolerant seed varieties continue to improve so that maize yields are equal to or more than non-drought-tolerant seeds in average precipitation years, the financial case for investment in drought-tolerant seeds becomes even stronger.

Example Case Study

The Affordable, Accessible, Asian (AAA) drought-tolerant maize program sells affordable seeds to smallholder farmers in India. This program started as a public-private breeding project by Syngenta and the International Maize and Wheat Improvement Center (CIMMYT), and now aims to increase smallholder yields by promoting hybrid seed varieties. AAA hosts trainings with local companies and NGOs (called Seed Partners) to share how to market drought-tolerant seeds to smallholder farmers. Seed Partners then sell the varieties to local farmers. With the help of the program, the number of farmers growing drought-tolerant maize has grown from 900 to 1,400 in four years, increasing yield and resilience in the region (Syngenta Foundation, n.d.).cxvii

Water Pans

Background

Water pans are a low-tech water capture and storage solution that provides water to a farmer for irrigating crops. A water pan might be implemented to create the opportunity to irrigate where crops were previously rain-fed, to supplement other water sources or to reduce time and labor from water collection. They are built on-farm or on a community property, usually close to where irrigation is needed. Water pans vary in size and structure depending on factors such as water needs, available space and access to materials and machinery, but the concept of providing a way for the farmer to manage water for crops is the same. Often water pans are accompanied by a connected irrigation system from the pan to crops, but not always.

Implementing a water pan requires allocating a small plot of land on which the water pan is dug out using shovels or heavy equipment. A plastic liner is installed to keep water from infiltrating into the soil and groundwater. The dimensions of the pan might depend on the calculated water needs, the land space available and the ease with which additional depth can be reached with digging. The intervention is relatively low maintenance, consisting of potential application of *Bacillus thuringiensis israelensis* (BTi) or a similar treatment to prevent mosquitos from breeding in the water and changing out the liner once it is degraded, likely after 10 years or more. An irrigation system may be installed to carry water directly to the crops, which requires additional materials, labor and maintenance, but the case considered here will exclude the irrigation system given it represents a different adaptation intervention and is not always applied in tandem.

Benefits

The primary benefit of water pans is to introduce or increase water application to crops, which can increase yields and / or allow the farmer to grow additional crops and reduce losses during increasingly unpredictable precipitation patterns. Water pans could also provide water where needed for livestock. Increased crop yields can result from a reduction in water deficit for crops in any growing season (therefore increasing the yield in that growing season) and/or the opportunity to add a growing cycle to the annual production. An increased availability of water for livestock could allow the farmer to establish livestock on their farm or increase the number or type of livestock. These changes can drastically improve a farmer's income and potentially improve diets through increased caloric intake and/or food diversity. The benefits of a water pan will become even more important as precipitation patterns become more erratic due to climate change and increasing temperatures. The ability to access water for irrigation can ensure crop yields and livestock health or production are maximized and losses during drying events are minimized.

The financing case

An investment in a water pan will start to deliver a positive cost-benefit ratio when the incremental benefit from increased income due to increased yields is greater than the cost of the intervention. The payoff timing will vary based on several factors but once the intervention is paid off, the maintenance costs are relatively low compared to the annual benefit from the water pan. The example below will show this in more detail.

Challenges

Some of the common challenges with the scaling up of water pans include making space for pans on the farm, access to equipment and supplies, technical knowledge and mosquito control. Making room on the farm for a water pan may require displacing other activities such as growing crops or animal husbandry. Lacking access to equipment and supplies, and the technical knowledge to implement a water pan, can be a hinderance but can generally be addressed through technical extension services and programs that facilitate the purchase of materials and equipment. Given a water pan is a standing body of water, they can serve as a breeding ground for mosquitos or other disease-carrying vectors which requires some sort of treatment to mitigate.

Bundling

Other adaptation interventions or best practices that water pans might be bundled with to increase farmer and system resilience include:

- Irrigation
- Conservation agriculture
- Changes in planting or harvesting timing
- Digital or extension services
- Insurance
- Early warning systems

Example valuation of water pans: Kenya

An example cost-benefit analysis for a water pan is provided for Kenya, with costs derived from Kenya when possible and regionally when not available in-country. The analysis is based on a 0.6-hectare farm and a water pan volume of 3,611 cubic meters, which was chosen based on estimated water needs during dry years including expected evaporative losses from the pond. The pan will be lined with a 0.5-millimeter plastic liner which has an expected life span of about 10 years. The water pan is built on the farmer's property and the water stored in the pan will be used to irrigate their vegetable crops which are sold in the local market.

The primary installation costs include the water pan liner (USD $2,232 - $2,432), excavation labor (USD $30), and optional irrigation hook-up (USD $0 - $50). The costs do not include the irrigation system (considered a separate intervention) or the potential opportunity cost of lost value for the plot of land on which the water pan sits. This would need to be included in any specific cost-benefit analysis. The operational costs of the water pan include pest and disease control such as preventing mosquitos from breeding in the water (USD $15 - $50), annual maintenance of the pond and an optional conveyance system (USD $20 - $210), and an optional cost for pumping (USD $0 - $150) if water needs to be pumped up to the water pan, although in most cases water pans are fed by rain.

The primary financial benefit from the water pan is increased crop yield due to water application (USD $6,000), with an additional benefit of reduced crop loss during dry years due to the ability to meet full crop water demand (USD $400 - $3,950 on average per year over 10 years assuming two years of loss). Other potential benefits include the ability to add animals to the farm, increased crop diversity and follow-on impacts on diet and increased stability in income despite market fluctuations for any individual crop, and follow-on impacts from increased income on health, well-being and education.

Some of the factors that have the strongest influence on the magnitude of costs and financial return for water pans include:

- How the farmer uses the stored water, specifically for which crops and other on-farm uses (such as animals).
- Market prices for the crops and other products benefiting from water application from the water pan.
- Lost production for the piece of land set aside for the water pan.
- Other agronomic practices used in tandem with water application.
- The market price for water pan liners.
- Excavation by hand or machinery.
- Inclusion of an irrigation system to convey water from the pan to crops.
- Cost of labor for digging and maintenance.
- Cost of chemicals for pest and disease control.

Timing

Water pans require a large investment up front for the establishment of the intervention, with minimal ongoing costs to maintain the water pan. The payoff period for these capital costs varies based on the specifics of the water pan, how a farmer utilizes the water on their farm, local market costs for materials, labor and equipment, and the local market for the crops or animal products produced using the additional water. Once paid off, the water pan can continue to provide financial and non-financial benefits to the farmer with comparative benefits (with and without a water pan) greatest in years with lower precipitation.

Example Case Study

The Tana River in Kenya provides 95% of Nairobi's water but water quality issues from upstream limit access by Nairobi residents. Forests and wetlands in the Upper Tana have been removed to make room for agriculture, causing erosion and high levels of turbidity in the water that clog downstream treatment plants and cause disruptions in water services. Building water pans is one method of decreasing erosion while benefitting farmer livelihoods. The Upper Tana-Nairobi Water Fund, an independent trust, provides materials at subsidized cost along with trainings to demonstrate building and maintenance techniques to farmers. These pans allow rain-fed farms to transition to irrigation with little cost while reducing erosion, providing a reliable water source to the farmer during the dry season and increasing farmer resiliency to climate change throughout the watershed (Upper Tana-Nairobi Water Fund, 2020).[cxviii]

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