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Economics of Climate-Smart Agriculture.

Considerations for Economic and Financial Analyses of Climate-Smart Agriculture Projects

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Acknowledgements

This report was prepared by World Bank staff Christine Heumesser (Economist) with support from a team from the Food and Agriculture Organization (FAO), Economic and Policy Analysis for Climate Change Unit, Nicholas Sitko, Stefanija Veljanoska, and Adriana Ignaciuk. The team would like to thank World Bank colleagues Willem Janssen (Lead Agriculture Economist), Joanne Gaskell (Senior Agriculture Economist), Carter Brandon (Lead Environmental Economist), as well as Phil Thornton (Flagship Leader and Principal Scientist, ILRI) for proving critical guidance and support during peer review process.

We would like to thank several colleagues who have taken time during preparation of the report to discuss and share their valuable insights and experience on the topic: William Sutton, Leah Germer, David Treguer, Tijen Arin, Stephen Hutton, Christopher Nelson and Klas Sanders from World Bank, and Erkan Ozcelik, Giacomo Branca, Jennifer Braun and Dino Francescutti from FAO.

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EXECUTIVE SUMMARY

Climate change poses a major threat to food systems and livelihoods all over the world. Climate-smart agriculture (CSA) addresses these challenges. CSA stands for including climate change into the planning and implementation of sustainable agricultural strategies. More specifically, CSA has three objectives to achieve these overarching goals: (1) sustainably increasing agricultural productivity to support equitable increases in incomes and food security; (2) adapting and building resilience to climate change from the farm to national levels; and (3) developing opportunities to reduce GHG emissions from agriculture (FAO 2013). The latter is important since the agriculture, forestry, and other land use (AFOLU) sectors are responsible for approximately 25 percent of anthropogenic GHG emissions, which stem mainly from deforestation and agricultural emission from livestock, soil and nutrient management (Tubiello et al. 2015). However, the relative importance of each objective, the potential synergies and trade-offs vary across time, scale, and context (Lipper et al. 2014).

Cost-benefit analyses (CBA) are one of the common tools to assess flows of benefits and cost of an intervention over a specific time period, as well as the trade-offs of climate-smart agriculture investments, from the perspective of the public and private sector, thereby supporting an efficient allocation of resources. CBA allows to determine the economic efficiency of an intervention, project or policy by comparing the net present value of the costs of planning, preparation and implementation to its expected quantified benefits. It answers questions of strategic importance for project appraisal - whether the investment is financially viable for beneficiaries and provides economic benefits for society- and highlights trade-offs between different interventions. CBAs are the corner stone for Economic and Financial Analyses (EFA) conducted during World Bank project preparation and appraisal. The report thus focuses on CBAs.

Given that CSA has multiple objectives, the question arises what is needed to conduct comprehensive economic and financial assessments of CSA interventions. We identify 10 salient features of CSA, which ay set it apart from traditional and other improved management practices. These features can affect CSA's benefit and cost streams and therefore impact the economic assessment. If these features are neglected, the resulting economic and financial indicators may reflect an incomplete picture, ultimately affecting project design or subsequent success of project implementation.

The report describes ten salient features of CSA based on literature review, assesses how they were addressed in recent World Bank projects, and which method an tools could be used in EFAs to incorporate the features better.

Ten features of CSA are expected to affect the results and quality of economic and financial analyses, specifically cost-benefit analyses. Not all of them are specific to the objectives of climate-smart agriculture of achieving productivity increases, resilience and adaptation to climate change and climate mitigation benefits, but are expected to be relevant, nevertheless:

- ✓ Climate change poses a major threat to food systems and livelihoods. A key objective of CSA is to address and **build resilience to climate change risks and uncertainty**. These aspects should be factored in explicitly into an economic analysis. The expected benefits of potential investments may be different when future climate change is considered, or climate risk and uncertainty are considered, and may lead to different results than in a "business-as-usual" case.

- ✓ Achieving **climate mitigation** is a dedicated goal of CSA and sets climate-smart agriculture practices apart from other improved agricultural practices. To ensure that the mitigation potential is correctly estimated, detailed data collection in the without and with project scenario and activities is crucial.
- ✓ CSA shows a high spatial interconnectedness. CSA practices are known to have spatial positive externalities and therefore, considering CSA within a **climate-smart landscape** is crucial. Adding on-site public benefits to an EFA would provide a more complete picture of CSA and should be explored.
- ✓ Several CSA practices are known to enhance benefits such as crop yield increases in the long-run but may not show yield increases in the short run. To ensure benefits are captured adequately in the economic analysis, a good understanding of **expected crop yield, which could be lower than under conventional practices in the onset, and delays in accrual of benefits**, and the possibility to have lower-crop yields than under conventional practices is also critical.
- ✓ CSA benefits are **context-specific and vary across biophysical conditions**. Yield increases under CSA management are known to by agroecological zone. Instead of considering average yield increases in an economic analysis, site-specific data should be considered to provide a realistic assessment of benefits and better support the project design.
- ✓ CSA tends to **increase production cost**, specifically labor cost in early phases of adoption. Labor cost, specifically family labor, should be carefully considered and costed in an EFA, to manage expectations about potential benefits of CSA and adoption rates.
- ✓ CSA has varied impacts **on different types of farmers, depending on their land size and income.** Thus, considering the heterogeneity of farmers and the distributional impacts of promoting CSA – within a landscape and community but also within a household – in economic are important and provides a complete picture of actual benefits of CSA to a community.
- ✓ Literature shows that CSA may **not be adopted on the entire farm**, but only on a share of the farming area. Adoption rates on-farm should be carefully assessed to avoid overestimating benefits, rather than assuming a normalized unit measurement of one hectare for the financial analysis.
- ✓ CSA is more than a single technology and farmers often adopt a **combination of practices**. Considering CSA as a combination of practices may provide insights about the financial viability of CSA as well as sensitivity to certain risks.
- ✓ To consider the **impact of CSA on livestock systems**, an understanding of the type of public and private benefits and cost is necessary as well as size and characteristics of the livestock herd.

We review project economic and financial analyses of 10 recent investment projects which have been assigned a high share of climate co-benefits to understand to which extent these features have been addressed. Three observations should be highlighted:

- Project economic analyses are **doing well in considering environmental externalities**, such as climate mitigation or on-site public good benefits from activities within a landscape. While climate mitigation benefits are always quantified - using a shadow price of carbon or a carbon market price – landscape-level benefits are frequently described qualitatively. In going forward project economists should enhance the quantification of environmental benefits.
- While climate change, uncertainty and risk are key challenges for food systems around the world, and one of the reasons why CSA practices are increasingly promoted, **only 50 percent of economic analyses in this report consider climate risks and changes explicitly**. Economic analyses often include

discrete sensitivity analyses which assume a decline in crop yields to demonstrate the robustness of the investment. These sensitivity analyses are rarely related to climate change scenarios or projections or risk analyses and may not provide an accurate picture of benefits of the investments.

- **Only one project economic analysis considers distributional impacts of CSA promotion** and whether heterogeneous farmer in a community benefit in the same way, even though this may affect the economic results. It is recommended that project economist increase efforts to obtain information about beneficiaries and address heterogeneity in the analyses and address potential distributional effects of promoting CSA in a community.

The report concludes with recommendations, which methods could be applied to strengthen some of CSA's typical features, such as climate change, risk and uncertainty, in a cost-benefit analysis. Most critical shortcoming to address is the consideration of climate change considerations. To better account for climate change in a sensitivity analysis: (i) Monte Carlo simulation could be considered to focus on the expected distribution of economic indicators, rather than on one expected mean value. Compared to other approaches Monte Carlo analyses is less data and resources intensive and open-software packages make the appraoch readily applicable; (ii) Scenario analysis could be considered which build on climate impact assessments, crop simulation models to design optimistic and pessimistic scenarios which can be considered for sensitivity analysis; (iii) to account for the value of waiting and understanding what the optimal portfolio of adaptation options looks like under climate change and risk, real option analysis and portfolio analysis could be considered. Both approaches are knowledge and data intensive and may be less suitable for an economic analysis of investment projects.

To enhance the inclusion and quantification of environmental externalities as well as distributional considerations in economic analysis several suggestions are made. The report reviews several greenhouse gas accounting (GHG) models which can support the quantification of climate mitigation benefits. In addition, remote sensing information and a range of biophysical indicators can be used to support the quantification of positive environmental externalities of CSA. To further support the inclusion of distributional consideration, economists should make a stronger effort to understand farmers heterogeneities in project communities and how differently they may benefit from project interventions. During project appraisal and data collection for the EFA, analysts should engage more with focus group discussions to verify data and get additional information about current practices in the community. Impact evaluations and or more extensive monitoring and evaluation arrangements in ongoing CSA projects, could provide lessons-learned for future economic analyses. Upon a thorough understanding of the project community, distributional effects could be addressed in an EFA as follows: (i) identifying and cataloguing how project related cost and benefits are distributed, and by (ii) assigning distributional weights to certain beneficiary groups. The latter is prone to criticism due to high level of subjectivity in the assessment and needs to be discussed and agreed on carefully with the client and task team.

1. Introduction

Background

1. **Climate change poses a major threat to food systems and livelihoods all over the world.** Agriculture is the key driver for climate change's impact on poverty (Hallegatte et al. 2016). Agriculture sector accounts for more than 30 percent of the Gross Domestic Products in many low-income countries, is the main source of livelihood for about 70 percent of the world's rural poor and is critical to food security (World Bank 2016). At the same time agriculture is most sensitive to climate change and related weather events both directly and through climate-dependent stressors (e.g., pests, diseases, and sea level rise). Despite of high level of uncertainties and large disparities between crops and agro-ecological conditions, there is agreement that crop production will be negatively affected by climate change in the longer term (IPCC 2014), affecting productivity and productive area. The biophysical impacts on crop yields could trigger changes in production and contribute to changes in food prices on local and global level. A rise in food prices tends to increase poverty rates in most countries, since the poorest households spend up to 70 percent of their total expenditure on food. Combined with future challenges of population growth and over-exploitation of natural resources, climate change puts food security and rural prosperity at risk (Hallegatte et al. 2016).

2. **At the same time, agriculture is a major contributor to greenhouse gas (GHG) emissions.** Increasing GHG levels and associated rises in temperature and climate variability pose major threats to agri-food systems across the globe (IPCC 2013). The agriculture, forestry, and other land use (AFOLU) sectors are responsible for approximately 25 percent of anthropogenic GHG emissions, which stem mainly from deforestation and agricultural emission from livestock, soil and nutrient management (Tubiello et al. 2015). Agriculture needs to limit emission by of ~1 Gigaton of carbon dioxide-equivalent emissions per year (GtCO2e/yr) by 2030 to limit warming in 2100 to 2°C above pre-industrial levels. Current agricultural development pathways deliver only 21 to 40 percent of needed mitigation, which indicates that more transformative technical and policy options will be needed, including how we produce, market, and consume.

3. **Climate-smart agriculture (CSA) addresses these challenges. CSA stands for including climate change into the planning and implementation of sustainable agricultural strategies**. Agriculture faces many biophysical and socioeconomic stressors, including climate change. CSA encompasses a set of agricultural technologies and practices. The concept CSA has emerged in 2009 and managed to raise awareness for supporting the transformation of food systems in the context of climate change (Sova et al. 2018). The aim of CSA is to support efforts from local to global level to support agricultural systems in achieving food and nutrition security and integrating necessary adaptation and mitigation measures (Lipper et al. 2014). More specifically, CSA has three objectives to achieve these overarching goals: (1) sustainably increasing agricultural productivity to support equitable increases in incomes and food

security; (2) adapting and building resilience to climate change from the farm to national levels; and (3) developing opportunities to reduce GHG emissions from agriculture (FAO 2013). However, the relative importance of each objective, the potential synergies and trade-offs vary across time, scale, and context (Lipper et al. 2014).

4. **Agricultural strategies to achieve CSA's three objectives are context-specific, may incur trade-offs and opportunities for synergies which show interdependencies across time and scale (Thornton et al. 2018).** CSA is not restricted to on-farm activities but relevant for the whole commodity value chain. This breadth of concerns involves options for sustainably producing production inputs as well as post-farm processes such as post-harvest handling, storage, processing, aggregating, packaging, and adding value. The main focus, and many examples presented in this report, however focus on land-based and on-farm activities, their specificities and trade-offs. For example, in integrated crop and livestock farm systems, an increase in biomass production can contribute to improved livestock feeding, increase livestock productivity and lower GHG emissions per unit of produce (Gerber et al. 2013). But utilizing crop residue for feeding rather than mulching can undermine long-term soil water retention capacity and jeopardizing resilience of the system (Giller et al. 2009). Also, benefits of yield growth and stabilization of CSA practices such as agroforestry can take years to accrue to farmers, while on-site public benefits, such erosion control and carbon sequestration, could accrue more quickly. The disconnect between potentially high upfront farm-level adoption cost, and delayed and uncertain private benefits for farmers, is an important factor which limits the adoption of CSA practices (Branca et al. 2011). Achieving CSA objectives entails a range of private and public good benefits and cost and needs tools to evaluate and prioritize investments (Thornton et al. 2018).

5. **Investment into CSA can be supported by the public sector, but the role of private sector investment to achieve key development goals becomes increasingly relevant.** Crowding-in private investment into the agriculture sector and agricultural value chains is key to achieving development goals including ending poverty and hunger, boosting shared prosperity through more and better jobs, and improving natural resources management. Increasing private sector finance plays a role for all stages along the value chain, including input suppliers, producers, processors and distributors and marketers. Thereby, farmers in low- and middle-income countries are by far the largest private investors in agriculture with on-farm investments more than three times as large as all other sources of public and private investment (public, ODA, and foreign direct investment). To stimulate investments in the agriculture sector, the public sector plays a critical role in providing a sound enabling environment, including the provision of public goods such as research and extension services, rural infrastructure, and secure and tenure (World Bank 2018). To ensure that climate-smart agriculture practices are sustainably adopted on the farm-level, and climate adaptation and mitigation pay a role along the value chain, the cost, benefits and trad-offs have to be carefully considered.

6. **Cost-benefit analyses (CBA) are one of the common tools to assess the trade-offs of climate-smart agriculture investments, from the perspective of the public and private sector, and support efficient allocation of resources.** There are several tools that could be used to assess trade-offs and set priorities for CSA interventions, including simulation modeling, mathematical programming, econometric

approaches, as well as cost-benefit analyses. Cost-benefit analysis is suitable to assess the relative profitability of CSA interventions by comparing flows of benefits and cost over a specific time period (Thornton et al. 2018, Crouch et al. 2017). CBA allows to determine the economic efficiency of an intervention, project or policy by comparing the net present value of the costs of planning, preparation and implementation to its expected quantified benefits. Thereby, it answers questions of strategic importance for project appraisal - whether the investment is financially viable for beneficiaries and provides economic benefits for society- and highlights trade-offs between different interventions. CBAs are the corner stone for Economic and Financial Analyses (EFA) conducted during World Bank project preparation and appraisal. The report thus focuses on CBAs.

7. **Given that CSA has multiple objectives, benefits streams and cost, the application of CBA may be challenging**. Thornton et al (2018) suggest that prioritization of CSA intervention could be challenging because cost and benefits need to be expressed in monetary units, and the choice of appropriate discount rates, and integration of risk and uncertainty may be challenging. This raises the questions what needs to be considered when conducting a comprehensive economic and financial assessments of CSA interventions. We argue that CSA has salient attributes (e.g., aiming to achieving resilience, mitigation benefits, context-specific, on-site benefits, …) which may set CSA apart from traditional and other improved agricultural management practices. These features can affect CSA's benefit and cost streams and impact the economic assessment. If these features are neglected, the resulting economic and financial indicators may reflect an incomplete picture, ultimately affecting project design or subsequent success of project implementation.

Guiding questions, approach, report structure

8. **This report addresses following questions**:

- What are the salient features of climate-smart agriculture which should be considered in an economic and financial analysis and specifically cost-benefits analyses?
- How have these features been considered in economic and financial analyses of World Bank agriculture projects recently? What are trends and lessons learned?
- Which techniques or approaches, in addition to a CBA or to enhance a CBA, could be employed to better address these salient features of CSA in economic and financial analysis? What are the challenges and constraints employing them?

9. **To answer these questions, we conducted a comprehensive literature review and review selected World bank agriculture projects' EFAs**. Based on a comprehensive literature review, we identify 10 features of climate-smart agriculture that are expected to influence the assessment of benefits and costs and thus become relevant in economic and financial analyses, as well as approaches that could be employed to complement current EFAs. We review EFAs of 10 recent agriculture lending projects, to understand whether and how the identified characteristics of CSA were addressed. The report does not assess the quality or results of EFAs in Agriculture GP and does not comment on process of conducting EFAs in Agriculture GP.

10. **The report does not provide a guide to project design of climate-smart agriculture projects, but recommendations for project economists to address CSA in their analyses.** The EFA is an important part of the project preparation process and has the potential to inform project design by emphasizing the most profitable activities for beneficiaries and the economy overall. The iterative nature of the project design process and identification of activities, and assessment of profitability of these activities, should be acknowledged. In the project preparation cycle, the EFA is meant to improve project design. This report provides recommendations for project economists which salient feature of climate-smart agriculture should be assessed and reflected in the economic analysis.

11. **The report is structured as follows**: The report starts with a brief overview of the framework for economic and financial analyses in section 2; section 3, provides an overview of benefit and cost categories that are relevant for CSA; section 4, provides descriptions of 10 salient features of CSA as may be relevant for EFAs; section 5, presents findings of the review of 10 EFAs of agriculture lending projects; section 6, provides a brief overview of techniques or tools that could support the presentation of CSA in EFAs; and section 7 concludes.

2. Overview: Economic and financial analyses

12. **Economic analyses support project design and selection of interventions that contribute to the welfare of a country.** Economic analyses should be conducted at in the early phases of the project cycle and contribute to the questions whether a proposed project is the best alternative for achieving certain objectives, whether some components perform better than others to achieve the objectives and who is expected to gain or lose from proposed project interventions. Economic analyses take for granted that a project is technically sound, socially acceptable, and institutional arrangements are adequate to ensure an effective implementation (Horstkotte-Wessler et al. 2000). Following a recent World Bank Guidance Note (2013), projects' economic analyses should answer three questions: (i) What is the project's development impact? (ii) Is public sector provision or financing the appropriate vehicle? (iii) What is the World Bank's value added? (World Bank 2013).

13. **A project's development impact is established if expected benefits justify the cost.** Benefits should include those that can be easily monetized and benefits which are more difficult to monetize or quantify. Expected benefits and costs are measured by comparing a situation with project, with a situation without project. The analysis should be able to compare plausible alternatives and show that the chosen project design maximizes net present value of expected benefits or is the least-cost alternative to achieve the project's objective. The form of the economic analysis depends on project context, time frame, degree to which benefits and costs can be quantified, and whether data is available. In determining the development impact questions on sustainability arise: (i) Financial sustainability, and whether participating in a project intervention is financially viable for the participating entity and participants will be able to self-finance the activity after the project has closed. (ii) Fiscal sustainability, to determine the project's impact on government budget; and (iii) environmental sustainability.

14. **The public rationale for an investment is given, if government actions aim to correct market failure, the incorporation of externalities or spillovers, distributional, and social and political concerns**. The choice where, on the spectrum between public and private investment, the project is located is context specific. To justify public sector involvement, the extent of market failure should be determined, whether there are any scenarios in which the private sector could provide the service, and whether there are any functions covered by the project which do not need to be performed by the government (World Bank 2013).

15. **Economic analyses should be tailored to the specific needs of the project, but two common approaches are cost-benefit analysis (CBA) and the cost-effectiveness analysis (CEA).** The CEA helps determine how cost of outputs provided by the project compare to other options which provide similar or the same outputs. CEA evaluates which option provides the desired result at the lowest cost. In contrast to the CBA, benefits do not need to be monetized, but the economist needs to ensure that the measure of cost-effectiveness is applied across alternatives providing comparable results. Cost-effectiveness analysis can be performed even if a full quantitative assessment of costs and benefits is not feasible (World Bank 2013).

16. **The CBA assesses whether the benefits of the project likely to outweigh its costs.** The CBA monetizes all benefits and costs associated with a project so that they can be directly compared with each other and to reasonable alternatives to the proposed project. This helps decisionmakers to identify and pursue the most valuable options. The CBA is concerned with assessing incremental cost and benefits of an intervention, that is, its contribution compared to the current situation. The analysis defines a "with project" and "without project" situation and assesses the incremental benefits which are expected to arise from project investment and operating cost. Compared to a CEA, a cost-benefit analysis is considered the most comprehensive approach (World Bank 2013). The CBA typically contains two complementary steps: an economic and financial analysis.

17. **The key difference between an economic and a financial analysis is their "perspective". The financial analysis assesses the investment from the viewpoint of an entity**, e.g., government, firm, farmers, and determines its financial viability. Financial analyses determine and compare expected revenue and expense streams from the point of view of the implementing entity. The corresponding financial indicators show the profitability and sustainability of the investment of the investment to the entity (World Bank 2013). The financial analysis uses market prices (current or expected) of the transaction as it is experienced, regardless of whether these prices represent the true cost to society. The cost of capital, land, activities, interventions are recorded prices of an accountant. Thus, the financial analysis evaluates how feasible and sustainable and financially attractive a project will be for the participants. Financial indicators can include: *gross and net margins; profit; incremental family income; return to labor; and increase in assets, as well as the financial internal rate of return (IRR)*.

18. **Economic analyses examine an investment from the point of view of society** and account for the range of externalities generated by the investment and its underlying opportunity costs. Economic analyses, therefore, place monetary values on a wide range of market and non-market costs and benefits, services and attributes. This entails the use shadow prices, which estimates prices that would prevail if all resources in the economy were optimally allocated, to quantify non-market costs and benefits. The economic analysis provides two main indicators: Economic *Net Present Value (NPV) and the Economic Internal Rate of Return (ERR)*, which allow for a direct comparison of different investments and are important decision-making tools.

19. **There are four main differences between economic and financial analyses**: (i) Economic analysis, focus on the impact of the project on society and takes a broader perspective. It does not use market prices, but shadow prices, which reflect the true social and economic value to society of the goods and services that the project utilizes to generate its benefits. Compared to markets prices, *adjustments for price distortions in non-traded items* or *traded items* are made. (ii) In the economic analysis taxes and subsidies are treated as *direct transfers payments* and need to be removed from the analysis. Income earned because of the project entails taxes, which are transferred to the government. Since the government acts on behalf of society, the taxes are not treated as costs. In the financial analysis taxes are treated as cost and a subsidy as return, any adjustments are unnecessary. (iii) In financial analyses the interest payments to an external lender are deducted from the analysis to derive the actual benefits

stream to the beneficiary. In the economic analysis interest on capital is not deducted from gross return because it is available to available to society as a whole (Gittinger 1982, Belli et al. 2001).

20. **The choice of an "'appropriate" discount rate can be guided by a descriptive or prescriptive approach.** The discount rate is a key element in calculating the NPV in economic analyses. Discounting is needed to compare benefits and costs occurring at different points in time, to express future costs and benefits at today's equivalent value. No agreement exists on what the correct discount rate is. Broadly, there are two approaches – the descriptive and prescriptive approach. The descriptive approach relies on determining the opportunity cost of capital as reflected in foregone returns when undertaking public investment. Opportunity cost of capital reflects the rate that would result if all capitals within an economy were invested in activities that pay the highest return. It reflects society's choice between present and future returns and indicates what society is willing to save. Authors favoring the descriptive approach typically suggest discount rates for developing countries in the range of 8-12 percent range (World Bank 2016).

21. **In contrast to relying on opportunity cost of capital, the prescriptive approach considers future growth as the key determining factor for choice of discount rate.** Drawbacks of this approach are that it is affected by market distortions or the short time horizon of market participants. The World Bank Guidance Note (2016) promotes a prescriptive approach and anchors the choice of discount rate in welfare economics: net benefits of a project at different points in time should be valued according to their marginal impact on welfare at the time they occur. If an economy is growing over time, the recipients of future benefits of a project will be richer, and future benefits are valued less than those that occur in the present, when recipients are less well-off. The choice of discount rate is based on assumptions about future growth and can also consider whether welfare of future project beneficiaries or current beneficiaries is more or less important. Higher or lower growth prospects imply a higher or lower discount rate. Relying on the standard Ramsey formula linking discount rates to growth rates, shows that a 3 percent per capita growth rate translates into a 6 percent discount rate, and per capita growth rates of 1-5 percent yield discount rates of 2-10 percent (World Bank 2016).

3. Cost-Benefits analyses - Benefit and cost categories

22. **Costs and benefits of adopting a CSA vary considerably** between households, across sub-regions, and at different scales. This section presents an overview the range of benefit and cost categories which become relevant for CSA investments and empirical examples. The value of climate-smart agriculture interventions can be classified as on-site private, on-site public and global (off-site) benefits. Private benefits accrue directly to individuals, households, or firms who adopt a practices; non-adopters can be excluded from receiving these benefits. Public on-site benefits are benefits which spillover to a certain geographical area. Public good benefits, on the other hand, typically accrue to society at large and are typically non-excludable (compare Cavatassi 2004).

23. **There is extensive literature in environmental economic which classifies the value of environment and natural resources including agricultural landscapes**. The total economic value is defined as sum of: direct use value and indirect use value, option value, and existence value. Where:

(i) *Use values*: directly related to agricultural production which generates income and other income generating activities which are tied to a multi-functional agricultural landscape, such as recreation, or tourism, which typically involve private benefits. Indirect use values refer to benefits that are derived indirectly through ecological functions performed by the agroecosystem, such as watershed protection, reduced soil erosion, carbon sequestration, conservation of agrobiodiversity, etc.

(ii) *Option value* refers to preserving the possibility of future direct or indirect use values, which can include agrobiodiversity and other regulating services of a healthy agroecosystem.

(iii) *Non-use values* are those benefits totally unrelated to the personal use of an agricultural landscape. This category includes: *Existence value*, which is the perceived value of a landscape, unrelated to current personal use, but through a valuation of its existence for e.g., biodiversity or soil carbon conservation. Or the *bequest value* accrues from the desire to conserve forests for the future generations.

3.1. Benefit categories

On-site private benefits

24. **On-site private benefits refer to benefits to the implementing agent obtained from the interventions.** On-site private benefits mainly include local private benefits tangible in the project area and accrue directly to the agent who undertakes an intervention. TEEB (2015) refer to them as "visible benefits". The Ecosystem services approach put forth by the Millennium Ecosystem Assessment refer to it as "*Provisioning services*". Examples of on-site private benefits include increases in income from productivity increases, resulting in increased production and sales, as well as benefits from employment.

25. **Increases in labor and land productivity and income because of adoption CSA, qualify as private benefits. When assessing these benefits a range of factors should to be considered.** Empirical evidence shows that CSA increases crop yield, but in many cases, there is a significant time lag between the adoption of a potential CSA practice and the accrual of productivity benefits. For example, minimum tillage, which is often promoted as climate-smart, frequently results in no yield improvement (Hernanz et al 2002) or in even a dramatic drop in yield relative to conventional tillage in the first years of adoption (Rusinamhodzi et al 2011; Raimbault and Vyn 1991; Paul et al 2013). While sustained adoption is often critical for achieving meaningful productivity gains, the delayed onset of productivity benefits often contributes to high levels of dis-adoption after project support is withdrawn (Arslan et al. 2014). Thus, there is an important time element to be considered when assessing productivity benefits. Increases in agricultural income are linked to productivity changes but are also influenced by the extent to which adoption of CSA contributes to a decline in the cost of production, for example through the replacement of commercial fertilizers with organic sources, stability of income or consumption resulting from production stabilization, through farm diversification, and labor savings. Pretty (1999) shows that farmers who adopted *mucuna* cover cropping benefited from increased maize yields as well as decreased labor cost for weeding.

26. **Benefits from on-farm or off-farm employment**: Some CSA investments produce spillover employment benefits that can be important. For example, in Burkina Faso, groups of young men have responded to local demand for *tassas* and *zai* planting pits, which were promoted to improve soil erosion management, by forming labor groups that specialize in the construction of these structures and move from village to village offering their services to local farmers (Pretty et al 2011). Consequently, more than 3 million hectares of degraded land in Burkina Faso has been rehabilitated, while significant off-farm employment opportunities have been created.

On-site public benefits

27. **On-site public benefits are externalities essentially related to the ecological function of a climate-smart landscape.** On-site public benefits refer to externalities and spillover effects which affect people living in, or close to, the project area. A healthy agro-ecosystem produces on-site effects as well as transboundary effects at a larger level (offsite). They are mainly represented by indirect use values or non-use values, which means that there are benefits reaped or costs borne by one agent despite the action being undertaken by another agent. These on-site benefits become relevant when CSA is conceptualized within a landscape approach. The importance of the functions of a healthy agroecosystem, to which adoption of CSA can contribute, is widely recognized. Among the most significant functions are the values of nutrient cycling, soil creation, genetic variability, moderation of extreme events, erosion prevention, pollination, water purification, pest control, decomposition, carbon fixation. These are also referred to as "invisible benefits" (TEEB 2015). At the same time there are "invisible cost" from traditional agricultural activities, which are expected to be reduced when certain CSA practices are adopted, such as habitat encroachment, loss of ecosystem complexity, species reduction or soil erosion. These services are also referred to as "*Regulating services*", "*Cultural services*" or "*Habitat services*" (TEEB 2015) or Other examples of on-site public benefits include cultural, aesthetic and spiritual values (see next sub-section).

28. **There is an area of overlap between private benefits and public on-site benefits.** A farmer can reap benefits of a healthy agro-ecosystem through different streams. These also accrue to farmers adopting conventional practices, which, arguably, inflict more invisible cost than benefits to the landscape. There is an area of overlap between private and public on-site benefits:

- *Benefits through better ecosystem functioning:* Products obtained from agroforestry activity are directly reaped at the private level. On the landscape level, an increase in agroforestry is expected to provide improved functioning and regulating services of the ecosystem, resulting in positive impacts on downstream farmers . Another example is that certain CSA practices can contribute to increased levels of soil organic carbon, which improve the water retention capacity of soil, and thus its capacity to provide water to crops in the case of drought, or reduced environmental contamination through reductions in harmful farm inputs. This can enhance resilience and increase yield stability for an individual farming household and can have positive spillover effect on downstream users.

- *Benefits from tourism:* The adoption of CSA within a landscape approach can enhance its cultural and touristic value. Brunori and Rossi (2000), describe the creation of a wine route in an area of Tuscany, Italy which created region-wide benefits beyond the farms themselves (e.g., created a new regional tourism industry), while creating numerous benefits at the farm level (Freemann 2015). Agricultural landscapes are considered regional cultural heritage. CSA practices may have a potential to enhance farming benefits and contribute to the maintenance of a cultural landscape. For instance, since the 1990s, terraced paddy fields have been considered a representative cultural landscape of Japan and conservation activities have been conducted to reverse the increasing abandonment of terraces. Tourists showed a clear preference for sustaining terraced paddy rice fields (Chen et al 2016). The resulting private benefit streams include increased income through additional market opportunities or increased prices for regionally-branded products, or off-farm employment opportunities in the tourism industry.

Global public benefits

29. **Global public good benefits refer to all benefits that accrue to members in local, national, and international communities.** They include: direct use values from the provision of genetic material and varieties for agriculture, indirect use values in the form of carbon sequestration, option values in the form of unknown genetic material which can be used for medical purpose in the future, and an existence value as agrobiodiversity conservation from the mere satisfaction of the existence of a healthy landscape (Andersen 1997). Reducing greenhouse gas emissions and enhancing soil carbon sequestration are the most commonly considered public good benefits of CSA. Also global public good services fall in the category of "*Regulating services*", "*Cultural services*" or "*Habitat services*" (TEEB 2015; see below), or "invisible benefits" (TEEB 2018).

3.2. Cost categories

30. **There are a range of cost-categories to consider:**

(i) *Investment cost* are associated with the adoption of a practices or technology and typically includes material, infrastructure, services, as well as labor.

(ii) *Production cost* include labor cost and cost of intermediate goods, i.e., water, energy, fertilizer, pesticides, and veterinary services. having information about these inputs is important, as there are significant differences between inputs across alternative climate-smart and conventional production systems even for the same commodity, and potential trade-offs between the use of purchased inputs versus reliance on natural ecosystem services. The latter may provide the same value at lower environmental and human costs, for example, for water (e.g., through direct rainfall), for fertilizers (e.g. through managed natural inputs such as compost) and for pesticides (e.g. through biological pest control) (McCarthy 2011).

(iii) *Opportunity cost* are associated with allocating factors of production to CSA instead of other uses, for instance crop residues. A household can use crop residues to improve soil quality instead of using it as livestock feed. Non-agricultural demand for land is likely to increase, particularly in proximity to rapidly growing urban areas. This raises the opportunity costs of dedicating land to agricultural purposes, and will likely lower the incentives to grow lower value food crops.

(iv) *Transaction cost* include costs associated with searching for information on particular CSA practices, costs associated with acquiring inputs or implements or the sale of farm output. Transportation cost are often valued as part of the production or operating cost of a system. However, while the cost of accessing information about new technologies, prices, and climate-smart agriculture practices, or coordinating a large group of small-scale farmers for value addition processes can hardly be quantified, it affects the incentive structure for private firms to invest in smallholder markets, due to reductions in the costs associated with reaching a large number of potential customers or suppliers of farm products.

(v) *Risk cost*: The adoption of new technologies or farm practices entails significant risks for farmers, due to uncertainty about their effects on production, consumption, and income. These risks are particularly acute where credit or insurance markets are imperfect or nonexistent. In semi-subsistence production systems, the risks associated with changing farm practices typically stem from the fact that production decisions are linked to consumption as well as income outcomes. In these cases, the risk that a new practice or technology will fail imperils future food security as well as income.

31. **In addition to quantifiable costs and benefits, perceptions and beliefs matter for shaping farm management decisions and technology adoption**. For example, three motivating factors were found for beef grazing farmers in Australia: 'economic or financial' motivation, 'conservation and lifestyle' motivation and 'social' motivation (Greiner and Gregg 2011). Farmers driven primarily by economic and financial motivation rate the opportunity cost (potential loss of production) of adopting "climate-friendly" measures as a more important consideration than farmers who are motivated by conservation and lifestyle or social factors (cited in Wreford et al 2017).

32. **While many of these costs are typically assessed at a household level, they are sensitive to the broader enabling environment**. This may include, cost of labor, which influence the opportunity cost of adopting labor-intensive farm management practice (Barrett et al. 2001), changes in transactions costs brought about by public investment in road infrastructure (Renkow et al. 2004), changes in investment cost for new technologies resulting from changes in import duties (Guerin and Guerin 1994); and, public investments in social safety nets that influence the risk costs of adopting new farm practices or technologies. Thus, when assessing costs and benefits with potential CSA investments, careful attention must be paid to the role of broad enabling environment factors in shaping the magnitude and distribution of these costs and benefits. Given high levels of farm-level heterogeneity, and its influence on the range of costs and benefits associated with changes in farm practices or technologies, reforms to the broader enabling environment may be more effective levers for promoting change than typical project-level activities.

4. Climate-smart agriculture - Salient features which should be considered in a cost-benefits analysis.

5. **In contrast to "brick and mortar" development investments, agriculture investment projects are complex**. For projects providing road infrastructure or electrification, it is relatively easy to assign monetary values to costs and benefits. According to Gittinger (1986) a renowned textbook on economic analyses for agriculture projects, economic and financial analyses of agricultural investments are complex because of the wide-range of potential risks to projected outcomes, including global input and output price risk and climate variability, complex impact pathways of investments, and challenges associated with monetizing costs and benefits at different scales.

6. **We argue that the assessment of climate-smart agriculture practices, which aims at achieving multiple social, environmental, and economic objectives and is defined according to the triple win-areas, i.e., productivity, resilience and mitigation, adds a layer of complexity to economic and financial analyses**. While opportunities exist to simultaneously achieve positive outcomes in each of these triple-win areas potential CSA actions may also entail trade-offs between objectives and across scales (e.g., household, landscape, national, global-levels). A common example of trade-offs of CSA is the case of conservation agriculture, which often entails substantial upfront costs to producers and causes crop yield to decline in the short-term but can achieve sizable mitigation benefit, which accrue to society as public good.

7. **In this section, we review literature to identify attributes of CSA that may need specific attention in economic and financial analyses** in order to provide an encompassing assessment of CSA. Our working hypothesis is that these features affect benefits and cost streams of CSA interventions and therefore directly impact the results of the economic assessment. If these features are neglected, the resulting economic and financial indicators may show an incomplete picture. These features include mitigation and resilience, but also risk and uncertainty, temporal and geographical scale, distribution of benefits and cost between private and public sector, gender.

8. **Some of the salient features may not be unique to CSA, and also apply to traditional and other improved agricultural practices**. Some of the presented features may also overlap and should not be viewed in isolation. However, this chapter aims is to portray the features individually and provide empirical examples from the literature. Feature that are considered specific to CSA or are known to affect the adoption of climate-smart agriculture, include: (1) CSA to strengthen climate resilience in light of climate change, risk and uncertainty; (2) mitigation and removal of greenhouse gas emissions; (3) climate-smart landscapes; (4) Slow onset of private benefits; (5) increase in production cost, specifically in initial phases of adoption. Several features are common in improved practices which do not necessarily qualify as climate-smart, such as: (6) context-specificity and consideration of site-specific data; (7) considering the heterogeneity of farmers and distributional implications of an intervention; (8) partial adoption of an improved practice; (9) using a combination of practices; (10) interventions for improved livestock management. Each feature is presented in subsequent subsections.

4.1. Resilience-building to climate change, risk, and uncertainty are key driver of CSA

Take away messages:
CSA is meant to address, build resilience to and support adaptation to climate change, risk and uncertainty. This demands for evaluating cost and benefits considering climate change, risk, and uncertainty. This can be implemented by considering CSA under certain climate-related scenarios and assigning probabilities to their occurrence, assigning probability distributions for key factors which are affected by climate change, or economically evaluate how the project reduces the risks and expected monetary losses associated with an uncertain adverse agricultural impact.

33. **Impacts from climate change on agriculture can be broken into three categories: changes in average climate conditions, climate variability, and climate uncertainty.** Since economic and financial analyses of agriculture projects typically consider a timeframe of 10-30 years, considerations of climate change, variability and risk, and uncertainty are of key importance. Thereby, *average climate conditions* relate to expected temperature and precipitation; shifts in averages and expected seasonal structural chnages are often gradual and involve adjustments such as chnages in crop rotations, planting times, fertilizer management, pest management, water management, and shifts in areas of production. *Climate variability* refers to variations from the mean and refers to increasingly frequent incidence of extreme weather events such as heat waves, droughts, and heavy precipitation. In addition, risk of pest and disease events may increase indirectly. *Climate uncertainty* is the degree to which we are unable to predict future climate. Climate models typically project annual averages rather than the implied risk of extreme events and incidences of pest and disease (Choudhary 2016). What distinguishes climate risk from uncertainty is the possibility of assigning probabilities to a possible event. From an analytical perspective, it is easier to deal with risk than uncertain since one can calculate summary statistics from the distribution (e.g., expected values, variance) (OECD 2018). However, naturally there is uncertainty about the projected the magnitude and timing of particular climatic extremes, thus about the probability and extent of climatic risk (ECA, 2009); it is expected that uncertainties will decline over time as more climatic and socio-economic data becomes available (UNFCCC 2010). The terms risk and uncertainty are frequently used interchangeably (OECD 2018). See Box 1.

1. **Climate change requires that agriculture adjusts to new average climatic conditions and more volatile weather with more frequent and intense extreme events in most locations. CSA is expected to play a key role in this transition.** Climate change alters agricultural production conditions and is expected to influence food production directly, through changes in agro-ecological conditions resulting in changes in yields, are for crop suitability, and occurrence of pests and diseases, and indirectly by affecting the growth and the distribution of incomes, and thus the demand for agricultural produce (Asfaw and Lipper 2016; Schmidhuber and Tubiello 2007). Since climate change affects average conditions and variability at each location differently, the impacts are heterogeneous and uncertain. At early stages of climate change,

adaptation to climate change may be incremental and consist of responses to changes in variability, including resilience-building (e.g., development and adoption of new technologies, learning and understanding), while at later stages transformational actions may be required (e.g., resettlement). New technologies and practices such as CSA, should follow a range of principles: They reflect No-regret strategies that address climate change and other pressing needs, and would be valuable even in the absence of climate change (e.g., improving water-use efficiency in areas that are already water-scarce due to on-climatic pressures), emphasis innovations that allow for more resilience-building in agriculture, balances short-term versus long-term consideration of climate change impacts (Zilberman 2018). CSA practices can play a key role in adjusting to new climatic conditions and can be considered long-term strategies to support resilience-building and mitigate climate-risks (Choudhary 2016), as well as no-regret strategies which yield benefits even in the absence of climate change (World Bank 2010).

Box 1. Climatic conditions and implications

Climate change requires that agriculture adjusts to new average climatic conditions and more volatile weather with more frequent and intense extreme events. Changes in average conditions, which is represented by shift 1(a), a mean shift from a historical average to a new average and are expected to impact the frequency of extreme events, which is represented by shift 1(b) in the tail of the distribution. In addition, climate change is expected to alter inherent climate variability, represented nu shift 2. The remaining uncertainty over future climate change will lead to more climatic uncertainty overall, as presented by point 3, which indicates potential upwards and sideward variations of the curve. Table a provides an explanation of the potential implications of the distributional shift.

Figure a.

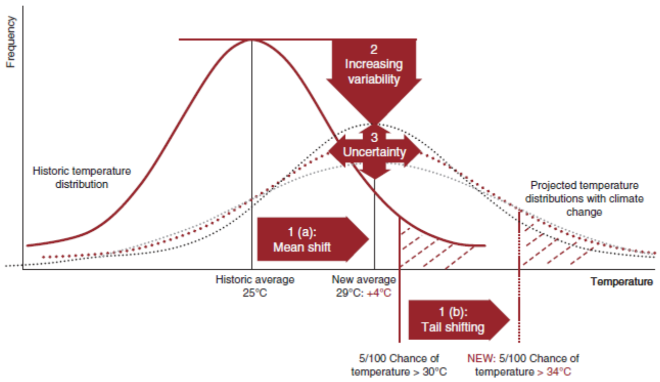


Table a.

ELEMENTS OF THE NEW NORMAL		TYPE	IMPLICATIONS
1. Distribution on the move	1.a) Mean/ Average	*APPROXIMATE KNOWNS*	Average/expected conditions change
	1.b) Tails		Redefinition of 'extreme events', in many locations likely: ▪ More extreme heat ▪ More extreme precipitation events (more/less volume, intensity change, type change) ▪ More pests & diseases ▪ Advent of types of climate and weather events without precedent in a given location (e.g., wildfires, floods)
2. Change in variability and volatility (most frequently: increase)		*KNOWN UNKNOWNS*	In the most frequent case of increasing variability: ▪ More extreme events ▪ Less predictability ▪ More pests & diseases
3. Increase in uncertainty (Projection confidence uncertainty over future emissions)		*UNKNOWN UNKNOWNS*	▪ Climate projections have limited precision, particularly at local scales ▪ Reduced predictability of future climate & weather conditions

Source: Choudhary 2016.

2. **Considering the different ways in which climate change is expected to manifest in the agriculture sector (Box1), the question remains how climate change is factored into cost-benefits analyses of investment projects.** At the same time the quetsion remains how and to which extent features of climate change impacts, such as variability and risk, scenario analysis and mean changes in weather variables are considered in assessing economic indicators for climate-smart agriculture investment and related investment projects. To evaluate the economic impacts of resilience-building strategies such as CSA to climate change at the project level faces the challenge of (i) being able to evaluate the potential

impact that climate change could have on agricultural productivity, and (ii) evaluating cost and benefits of the resilience building options in light of climate change, risk, and uncertainty. The latter usually takes the form of certain climate scenarios and assigning degrees of likelihood to their occurrence or assigning probability distributions for key variables which affected by climate change. For some interventions, specifically when the focus lies on climate extremes, it may be possible to economically evaluate how the project reduces the risks and expected monetary losses associated with an uncertain adverse agricultural impact. Thus, the understanding of a without project scenario is critical and how it may evolve under climate change and in the absence of resilience-building measures is important (World Bank 2010). From some recent publications of investment projects (e.g., IFAD 2017), or the assessment presented in Section 5, the extent to which climate change has been considered explicitly considered.

3. **Empirical examples show how critical it is to factor the impacts of climate change into a CBA for CSA, for instance by accounting for climate-induced changes in crop yields in a baseline, or 'without project", scenario.** Considering climate-induced risk and uncertainty surrounding agricultural interventions, several approaches are suggested which allow to factor in climate change, such as probabilistic modelling or scenario analysis, which consider risk assessments, future climate projections and assignment a probability to each scenario (see Section 6 for details). FAO (2018) demonstrates this with an example of Ugandan coffee plantations, for which climate change projections indicate a decrease in total annual rainfall and an increase of temperature, which might negatively affect coffee production. Soil and water conservation practices and agroforestry are introduced to help farmers deal with the climate variability. The projected impacts of climate change are factored into the baseline, or "without project" (WOP), scenario. It is assumed that coffee yields decline by 10-50 percent by 2050, with the mean loss at 30 percent by 2050, while with project, yield increases per tree are estimated to be 3.4-fold over the 15 years, compared to the WOP, resulting in an NPV of US$ 64 million compared to US$ 12 million in the WOP. The sensitivity analyses considered climate change scenarios and shows that profitability will drop under both WOP and WP scenarios, but remains higher in the WP scenario – even with climate change.

4. **Other examples show the relevance of factoring in risks and providing probability distributions of results, rather than a man expected value, by using a Monte Carlo simulation models.** Bizimana and Richardson (2019) use farm modelling combined with Monte Carlo simulations to assess five alternative production systems in Ethiopia. Monte Carlo simulation was used to analyses risk, by considering yields and prices as stochastic variables, and quantify the economic feasibility of alternative production systems. Instead of one value for the economic indicator, their farm model resulted in 500 values for each key output which allowed to define empirical probability distributions of results related to each intervention. To compare the benefits of adopting conservation agriculture compared to conventional practices, Lalani, Dorward and Holloway (2017) identify and rank certainty equivalents, that is, the amount of money where a decision maker is indifferent between the risky alternative induced by climate change, and receiving a certain amount, using the Stochastic Efficiency with Respect to a Function (SERF) tool. Even under extreme risk and uncertainty, the probability of achieving net returns above a threshold of US$353 are 41 percent for the adoption of conservation agriculture and maize-cowpea-sesame crop mixes and thus notably higher than for conventional maize-cassava mix.

4.2. Reduction and removal of greenhouse gas emissions is a dedicated goal of CSA

> **Take away messages:**
> There are several avenues through which climate mitigation impact can occur. To ensure that mitigation potential is correctly estimated, detailed data collection for a without and with project scenario and activities is indispensable. Including a climate benefits at a carbon price or shadow price of carbon in the economic analysis can have a sizable impact on economic indicators.

5. **Climate mitigation is a dedicated objective of climate-smart agriculture and sets the concept CSA apart from other improved or traditional practices**. According to the fifth assessment report of the IPCC, mitigation is defined as the "human intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC 2014b). This can be achieved through four avenues:

6. **First, climate-smart agriculture practices can reduce or avoid GHG emissions**. This category includes: improving water management of irrigated rice production and reducing methane emissions; improving soils management with conservation agriculture and reducing nitrous oxide emissions from soils or carbon dioxide emissions from residue burning; sustainable use of fertilizers and sustainable mechanization for crop production; improving manure management and introducing livestock feed additives in livestock production; using energy efficient aquaculture and reducing fossil fuel use by fishing fleets; sustainably managing soils and lands and avoiding degradation of wetlands (FAO 20xx).

7. **Second, Climate-smart agriculture can remove GHG from atmosphere, through carbon sequestration**. This category includes measures to increase carbon sequestration in standing biomass and soils. Agroecosystems, including forests, naturally remove CO_2 from the atmosphere through photosynthesis. The sequestered carbon is stored in biomass and soils, thereby acting as "sinks". Carbon capture in biomass and soils is generally cost-effective and with few or no associated direct risks. This type of greenhouse gas emission reductions is usually evaluated per area unit, e.g. tonnes of carbon sequestred (or removed from the atmosphere) per hectare per year. Management practices that specifically enhance soil carbon sequestration are those that increase the amount of organic matter that is added to the soil from plant sources and animal waste, as well as practices that reduce the decomposition of existing soil organic carbon stocks. Sustainably managed land can reverse past soil degradation and increase soil carbon levels until reaching a saturation point (FAO 2014).

8. **However, there have been few long-term studies of soil carbon dynamics or references to soil's initial carbon stock, particularly in developing countries**. Recent experimental evidence of the soil carbon sequestration impacts of several CSA practices in Zambia shows that they have a mitigation potential of between 0.2 and 1.1 tCO_2e emission/ha. This is higher than the average emission levels occurring with conventional maize systems (FAO 2014). An analysis for agroforestry systems in Zambia shows that alternative agroforestry systems (woodlots tree fallow, alley cropping, agri-silviculutre) have higher mitigation potential than improved crop management practices, due to their enhanced mitigation

potential through biomass growth and soil carbon sequestration. Mitigation impacts in Zambia were found to range between 5 and 15 tCO_2e emission per hectare but only reach full potential after 20 years (FAO 2014).

9. **Third, sustainable intensification through CSA can reduce land conversion for agricultural land.** In many African countries, agricultural land expansion is still the main avenue to increase production and satisfy the increasing and changing food demand. Achieving productivity increases could support the reduction of land expansion and reduce deforestation. However, a risk remains that with increasing productivity and profitability per hectare, land expansion becomes even more attractive. This points towards the need to adopt a holistic landscape approach which equally aims at including sustainable forest management.

10. **Fourth, climate-smart agriculture can help to reduce greenhouse gas outside the agriculture, forestry and land use sector**. This category includes interventions which affect the agriculture sectors as well as other sectors, i.e., energy, industry and waste. It includes activities such as reducing post-harvest loss, production of bioenergy, increasing energy-efficiency in irrigation, sustainably harvested wood for manufacturing and construction and proper disposal of agriculture residues (FAO e-Sourcebook).

11. **For economic analyses of CSA, there are a range of tools (Section 6) which allow to assess the GHG emission reduction potential for a project compared to a baseline.** The mitigation benefits of selected project activities should be assessed against a quantified baseline scenario, or without project scenario. The project's net carbon balance, as difference between gross emissions without and with project will be reported. The quality of the assessment will depend on (i) the emissions coefficients used – for which usually Tier 1 default values are used, as well (ii) activity data. Tier 1 emission coefficients[1] should be interpreted with caution, because they are highly aggregated and do not consider country-specific characteristics for soil carbon sequestration. To improve coefficients for changes in soil organic carbon (SOC) stock and storage, disaggregated and area-specific information on previous land use, SOC stocks or SOC content and bulk densities for both the previous and current land use, soil depth, and time span since conversion are needed (Cardinael et al. 2018). Activity data includes information about current land use and management practices as well as size of hectare area under CSA practices, energy and fuel use in value chain projects, or impacts on deforestation even outside the project area. At least the latter, i.e., documenting current activities in project areas as well as expected project activities and their expected externalities, can be controlled by the analyst to ensure that estimates are credible.

12. **Valuing climate mitigation benefits and incorporating them in project economic analyses is increasingly common and can notably affect economic indicators**. A study in El Salvador uses satellite imagery to map aboveground woody biomass carbon stocks at the landscape level. Depending on carbon prices they would range from \$38,270 to \$354,000 yr^{-1} for the study area, or about \$13 to \$124 per hectare and per year. While relying solely on direct carbon payments to farmers may not lead to widespread CSA adoption at the farm scale, it may affect profitability and incentive to adopt of the

[1] As provided by the Intergovernmental Panel on Climate Change (IPCC) 2006 and 2007 Guidelines.

practice (Kearny et al. 2017). A study in Zambia showed that considering climate mitigation benefits could increase the NPV of an intervention to scale-up CSA to 50 percent of rural households from US$170 million to US$204 million if a carbon price of US$5 per tCO2equivalent emission reduction considered, to up to US$751 if a high shadow price of carbon is considered (see section 5 for an explanation of shadow price of carbon); or from an internal rate of return of 34 percent to an IRR of 37 percent or 70 percent, respectively (World Bank 2019).

4.3. CSA benefits and cost exhibit spatial and temporal dependencies

13. **The size and nature of the benefits and costs of CSA adoption may have both scale and temporal dependencies**. Scale dependence may arise in relation to the aggregated regional impacts of the adoption of an intervention on production and prices. Temporal dependence may arise as a consequence of the relationship between the three pillars of CSA – short: productivity, resilience, and climate mitigation - through time; for instance, interventions that improve soil health and enhance soil organic matter may translate into substantial production, carbon sequestration, climate resilience and income benefits several years into the future, but come at a cost in the short term (McCarthy et al. 2018 in Thornton et al. 2018).

4.3.1. Spatial: Climate-smart landscapes enhance positive environmental externalities of CSA

Take away messages:

- Many examples document, quantify and monetize the positive externalities of adopting CSA at a landscape level.
- Adding on-site public benefits to an EFA provides a more complete picture of CSA and support stakeholder dialogue for adopting different financing mechanisms (e.g. that allow to compensate farmers for adopting CSA at early stages).

14. **There is broad acknowledgment that CSA should be viewed within a landscape rather than only on the field level.** For agriculture to achieve climate-smart objectives, the focus should be increasingly on ‘climate-smart landscapes’. Climate-smart landscapes operate on the principles of integrated landscape management, and consider CSA at the field and farm scale, diversity of land use across the landscape to provide resilience, and management of land use interactions at landscape scale to achieve social, economic and ecological impacts (Scherr et al. 2012). In this context, CSA provides *regulating ecosystem services* and externalities across geographic scale and time, including biological pest control, pollination services, improving water quality and quantity, reducing evapotranspiration and retaining high level of soil moisture enhancing soil structure and fertility, and climate mitigation (Power 2010).

15. **A vast number of integrated agricultural landscape initiatives, which exemplify the benefits of CSA in a landscape, have been documented worldwide**. For instance, Banca et al. (2011) documented the adoption of sustainable landscape management practices in the upstream catchment area of the Ruvu river to reduce soil erosion and land degradation and enhancing downstream water quality in Tanzania. Farmers participated in a payment for ecosystem services scheme and received between US$8 and US$48 for adoption of SLM practices. Downstream beneficiaries are the public water utility and a private water

bottling company for whom it was estimated that the resulting reduction in sediment load in Ruvu River, could reduce annual water treatment costs by 10 percent (i.e., US$200,000/year); including avoided costs from worsening watershed conditions, savings could increase to more than US$ 400,000/year. On-site, farmers observed an improvement of soil characteristics, an increase in moisture levels from 0.3 percent to 1.6 percent, and a tripling of maize and beans yields (Branca et al. 2011). In Nicaragua Dryland corridor, Sain et al (2016) estimated the value of CSA practices on reducing negative externalities in the form of water pollution from sediments and agrochemicals by valuing their opportunity costs. The estimated value of soil loss by erosion to inhabitants of the catchment area was assumed to be US$ 0.008/t (Tobías and Duro, 2013); the potential to reduce erosion estimated at by 91.1 t/0.7ha/year (FAO 2006), resulting in values of US$ 7/ha for agroforestry and US$1.04/ha for conservation agriculture with mulching.

9. **The question also arises whether CSA practices such as agroforestry also provides negative environmental impacts through the increased N availability in the soil.** Rosenstock et al. (2014) summarize findings on the agroecological footprint of legume-based agroforestry, whether these systems catalyze the release of N into the surrounding environment, in particular nitrous oxide (N_2O), which is a potent greenhouse gas. However, it appears that a relative similarity among fluxes arising from soils planted with N_2-fixing trees and those fertilized with mineral N exists and that the potential for being a net sink for greenhouse gases biomass and soil carbon sequestration would outweigh this effect.

4.3.2. Temporal: Delay in onset of private benefits of CSA remains critical in EFAs

Take away messages:

- CSA enhances soil health and yield increases may only occur several seasons after CSA adoption. Response. This time-lag needs to be factored into the analysis.
- Yield increases should not be overestimated and situations considered where yield increase under CSA are just moderately higher or not higher than under conventional practices.

16. **In many cases, there is a significant time lag between the adoption of CSA and yield increases**, **and a risk that crop yields decline compared to conventional practices in the initial years of adoption**. CSA includes practices which aim at sustainably strengthening ecosystem services such as soil quality, reduce erosion and improve water availability and quality, which affect crop yields (Kagabo et al. 2013). Depending on the initial level of soil degradation and other biophysical factors, yield response could take a considerably long time (Sain et al. 2016). In some cases, minimum tillage leads to a dramatic drop in yield relative to conventional tillage in the first years of adoption (Rusinamhodzi et al. 2011; Raimbault and Vyn 1991; Paul et al. 2013), or to no yield improvement at all (Hernanz et al 2002). When residue retention is combined with minimum soil disturbance, yields typically decline relative to conventional practices and then begin to increase, typically exceeding conventional yields after a decade (Pannell et al. 2014; Fowler and Rockstrom 2001; Baudron et al. 2012). Govaerts et al (2005) estimate that it takes 5 years for the benefits of minimum tillage, combined with crop residue retention, to become evident. For agroforestry, it was estimated to take approximately 10 years from the time of planting of *faidherbia albida,* a commonly promoted agroforestry tree in Africa, to see a measurable effect on crop yields and

yield stability (Franzel et al. 2004). Given the high discount rates of smallholder farmers, delayed benefits are likely a major barrier to adoption, or contribute to high levels of disadoption once project support is withdrawn (Arslan et al. 2014).

17. **If crop yields under CSA are lower than under conventional practices, the consideration of by-products could ensure the financial profitability of a CSA practice compared to some conventional production systems.** Certain agroforestry trees have the capacity to support microbial N2 fixation and increase soil nitrogen (N) availability. Thereby they improve soil fertility, crop yields, and sustainable natural resources management, and reduce production for fertilizer cost. Despite slow onset of yield increases, agroforestry systems generated income streams from by-products such as firewood or fruit. In Zambia this generated a discounted NPV of between US$233 and US$309/ha, which compares favorably with an NPV of US$130/ ha for unfertilized maize production. However, continuous, fertilized maize cultivation without and with fertilizer subsidies are still 13 percent, or 61 percent respectively, more profitable than agroforestry (Ajayi et al. 2009). This example highlights the necessity of considering by-products in economic and financial analyses.

4.4. Agroecological and site-specific context determine CSA's benefits and cost

Take away message: CSA benefits vary across biophysical conditions., which should be considered to provide a realistic assessment of benefits and better support project design.

10. **There is broad acknowledgement that the accrual of benefits of climate-smart agriculture is highly context specific.** Sova et al. (2018) reviewed several CSA technologies across Africa, Asia and Latin America and show that technologies which are considered climate-smart by experts vary considerably across regions, reflecting the context-specificity of opportunities, constraints, vulnerabilities of the agricultural sector. The "smartness" of a given CSA technology varies considerably between production systems and locations and key factors that influence the success of CSA technologies in a production system must be assessed carefully.

18. **Natural endowments specifically precipitation levels and soil quality affect the success of CSA.** For instance, Dutilly-Diane et al. (2003) found that farmers in semi-arid northeastern Burkina Faso who had invested in stone bunds had lower yields in high rainfall years, due to water logging. Herwig and Ludi (1999) found similar disadvantages to waterlogging in sub-humid regions of Ethiopia and Eritrea (cited in McCarthy et al. 2011). Barriers to adoption of residue retention practices in Zambia are highly context specific and evidence from field trials and simulation models suggests considerable variability in yields (Baudron et al. 2012, Probert 2007): Residue retention appears to support higher soil moisture levels in the first year after its installment, with beneficial effects on yields under dry conditions. However, yields were found to decline under high rainfall conditions (Rusinamhodzi et al. 2011).

11. **Adopting CSA practices provides widely different results across agroecological zones**. **Crop yields under CSA are sensitive to precipitation and lower in relatively wet regions.** The Zambia Climate-

Smart Agriculture Investment Plan (World Bank 2019) uses data from a unique household-level dataset on cost and benefits of CSA adoption.[2] Detailed data was reported for 1,264 fields in two agroecological zones (AEZ): AEZ III with high amount of average precipitation and AEZ IIa which is considered the most productive zone in Zambia. The analysis assessed the incremental net benefits of adopting minimum soil disturbance, crop rotation, mulching, intercropping, use of cover crops or agroforestry, compared to conventional practices where farmers cultivate maize under a ploughing regime (soil tillage method). The descriptive analysis showed that yields of CSA practices were higher in low and medium rainfall areas (AEZ I, IIa, IIb) (Table 1a). In areas with high rainfall (AEZ III), CSA led to lower increases (e.g., for beans, cassava, cowpeas, groundnuts) compared conventional practices and for maize conventional practices led to higher yields. Yield differences also arise between CSA practices, as evident in AEZ IIa where detailed data was available (Table 1b).

12. **Due to high production cost, net incremental benefits of adopting certain CSA practices for certain crops are lower than for conventional practices in certain agroecological zones. Raising questions about the financial viability of adopting CSA.** The same analysis, presented in the Zambia Climate-Smart Investment Plan, shows that certain CSA practices led to higher production cost (World Bank 2019). Production cost were higher for farmers using minimum soil disturbance than for farmers using conventional practices: Minimum soil disturbance required more herbicides and fertilizer; higher cost for hired labor, as well as higher cost for those practices that required animal power, that is, ploughing with oxen under conventional systems or and ripping with oxen under a CSA system. The analysis finds that for maize, cassava, beans and cotton, the net incremental benefits of CSA is negative in at least in one AEZ. So, CSA is not only context specific, but adoption not always financially viable.

13. **The need to consider the biophysical context in an economic and financial analysis, points towards challenges in obtaining data for different agroecological zones within a country.** The empirical evidence cautions that data about several agroecological zones is needed to properly assess the impact on CSA practices. However, robust data may not be easily available. Available data about the effect of agricultural practices is often controversial as they may derive from on-farm or on-station trials or demo plots with high variability. In addition, climate-smart agriculture practices are often composed of a set of different practices and their effect may differ by crop and AEZ. To understand the cumulative effect of all practices and/or incremental effect of each practice poses challenges to socio-economic data collection (Branca, forthcoming).

Table 1a: Crop yields (kg/ha) under conventional and CSA practices across AEZ in Zambia

Crop	AEZ I	AEZ IIa	AEZ IIb	AEZ III	AEZ I	AEZ IIa	AEZ IIb	AEZ III	AEZ I	AEZ IIa	AEZ IIb	AEZ III
	Conventional				CSA				% difference			
Beans	586	497	601	539	821	696	842	680	40	40	40	26
Cassava	1,912	5,214	2,575	6,993	2,231	6,083	3,004	8,100	17	17	17	16
Cotton	1,037	992	999	-	-	684	-	-	-	-31	-	-

[2] The dataset was collected by an FAO-EC project in season 2012/13 season. Detailed data was reported for 1,264 fields in two agroecological zones.

Cowpeas	490	616	383	400	930	1,170	728	700	90	90	90	75
Groundnuts	356	430	852	730	509	615	1,219	900	43	43	43	23
Maize	1,654	1,933	1,217	3,575	1,930	2,475	1,420	2,200	17	28	17	-38
Rice	1,891	1,771	1,510	1,386	3,045	2,852	2,431	2,231	61	61	61	61
Soybeans	1,820	894	196	831	2,639	1,296	285	1,204	45	45	45	45

Source: World Bank 2019.
Note: The information is based on a FAO-CSA (season 2012-3) and RALS 2015 datasets, personal interviews and focus group discussions

Table 1b: Maize yields (kg/ha) under conventional and variation of CSA practices in AEZ IIa.

Crop	Conventional		CSA				
	Conventional hand hoe/ridging	Ploughing with oxen	Planting basins/potholes	Ripping with oxen	MSD and agroforestry	MSD and crop rotation with legumes	MSD and Residue retention
Maize	1,933	1,618	2,139	2,229	2,644	2,893	2,134

Source: World Bank 2019.
Note: The information is based on a FAO-CSA (season 2012-3) and RALS 2015 datasets, personal interviews and focus group discussions

Table 2: Annual net margins and incremental benefits for each crop and AEZ in US$/ha

Crop	AEZ I	AEZ IIa	AEZ IIb	AEZ III	AEZ I	AEZ IIa	AEZ IIb	AEZ III	AEZ I	AEZ IIa	AEZ IIb	AEZ III
	Conventional				CSA/MSD				Net incremental benefits			
Beans	-71	-100	-67	-87	-62	-101	-65	-110	10	0	2	-24
Cassava	24	392	98	590	13	443	89	664	-11	51	-9	74
Cotton	39	28	30			-21			0	-49	0	0
Cowpeas	23	39	10	12	88	94	96	68	65	55	87	56
Groundnuts	31	60	224	177	78	133	357	240	47	73	132	63
Maize	21	48	-22	132	51	86	1	53	30	38	23	-79
Rice	242	218	165	140	441	404	305	271	199	186	140	131
Soybeans	108	-11	-100	-19	238	90	-39	78	130	101	61	97

Source: World Bank 2019.
Note: The information is based on a FAO-CSA (season 2012-3) and RALS 2015 datasets, personal interviews and focus group discussions. The net incremental benefits for maize in AEZ IIa presents the average across practices.

4.5. CSA tends to increase production cost, specifically in the initial phases of adoption

Take away messages:

- In the initial phases of CSA adoption, labor cost, but also other investment costs, are high, affect financial profitability, and pose a barrier to adoption. This suggest a need to model cash-flows of benefits over a long period of time to understand impact of CSA adoption on financial viability and adoption of CSA.
- Labor cost, specifically family labor, should be carefully considered in an EFA, to better manage expectations about household benefits and adoption rates. Considering the increase in labor

time, valuing family labor in the financial analysis remains critical, as otherwise profitability and the likelihood of adoption of a CSA practice may be overestimated.

- Poor households may need to spend more labor time on CSA to compensate for inputs they cannot afford. This raises concerns whether CSA benefits wealthy and poor households in the same way or exacerbates inequalities in a community.
- Transaction cost to learn a practice may affect viability of adoption and should be considered in an analysis id possible.

14. **Total labor time and cost are an important production input and need to be diligently addressed in the economic and financial analyses.** Changes in labor time and cost as a result of the adoption of CSA vary by biophysical context, agricultural seasons, and along the production cycle. Some studies show that total labor requirements for CSA is lower than for traditional practices. Considering land preparation, planting, weeding, and harvesting, Boahen et al. (2007) found that CSA demanded 48 working days per growing season, notably less compared to slash-and-burn agriculture which required 83 working days. The greatest labor savings in CSA were those associated with weeding and the collection and burning of slash. Another example in Tanzania, shows that time required for land preparation, planting, and weeding was 50- 75 percent lower in CSA than in conventional agriculture (Shetto and Owenya 2007). Others show that are higher. In a study among Zambian smallholder farmers showed that minimum soil disturbance proved to be more labor intensive than conventional practices, due to a combination of land clearing and digging planting basins.

15. **Labor requirements for CSA adoption vary over time, with high labor requirements in the initial years and lower requirements in subsequent years. Changing benefit streams over time should be modelled carefully in an economic analysis. T**he establishment of planting basins which requires more labor relative to conventional practices in the first year of adoption, but once the basins are established, labor demand is less than for conventional practices (Haggblade and Tembo 2003). USAID (2016) conducted a comprehensive study in Burkina Faso and Kenya to assess constraints to CSA adoption which shows that initial cost, such as equipment, inputs and services, were considered the key adoption barriers by 68 percent of farmers. Long-term costs were also cited as barriers but not considered to be a key constraint, possibly because long-term costs are indeed lower, or survey respondents were most concerned with the more immediate cost. Overall, the increased labor cost in early years of adoption constitutes a critical barrier for the adoption of climate-smart agriculture practices, and therefore need to be modelled with caution in a cost-benefit analysis.

16. **Increased labor requirements can be substituted by other production inputs, if farmers can afford it. This can imply, that CSA adoption is easier for wealthier farmers.** Labor requirements for minimum soil disturbance can be reduced if herbicides are used, thus production cost increase. Field trial data from eastern and southern Africa shows a 50 percent reduction in labor demand for minimum soil disturbance, but a 30 percent increase in weeding demand. For cotton production systems under CSA in Zambia, Haggblade and Tembo (2003) found that the number of workdays for weeding nearly doubled (from 45 to 80), and the number of days for land preparation increased nearly tenfold (from 7 to 66) compared to production systems under conventional agriculture. Instead of manual weeding, farmers can use herbicides. This increases production cost compared to production systems under conventional practices where ploughing is used to suppress weeds (D’Emden et al. 2008, Erenstein et al. 2012, Wall

2007, Giller et al. 2009). For many smallholder producers, herbicide use is not an option, due to unavailability, lack of financial resources, and knowledge. This implies that it may be easier for wealthier farmers to adopt CSA, because they can afford production inputs – hired labor or herbicides. For project economist, an understanding of farmer types in the area is thus important. In addition, the use of herbicides inflicts negative environmental externalities and thus increase societal cost of using CSA.

17. **Other costs, such as opportunity cost and transaction cost should be considered as well. Besides an increase in total cost, higher labor demand has several implications on production risk.** The increased labor requirement for CSA can increase the production risk especially in the in peak planting season, when labor is on high demand and there may be challenges to hire sufficient labor force in a timely manner (World Bank 2019). If possible, farmers can utilize counter seasonal labor by preparing land in the dry season, the off-peak season; this is another way to spread labor demand across season and lower costs. With respect to opportunity cost studies show that crop residues are often used for mulching or livestock feeds. In areas where open grazing is the norm, the ability to fence fields is thus essential for managing residues. This entail high costs of fencing – which also requires more secure land tenure-, but also opportunity cost for buying livestock feed. These are limiting factors for adoption of mulching for smallholder farmers. Ignoring such cost might over-estimate the benefits associated with mulching. Another study emphasized transaction cost which cover the time and non-physical resources spent by farmers on activities such as attending extension trainings, farm group meetings, management committees, or extra time and travel associated with marketing, which are often neglected in economic and socio-economic assessments of CSA. Unsurprisingly, transaction cost seemed most significant for the adoption of CSA approaches farmers were unfamiliar with, such as Payment for Environmental Services approach (USAID, 2016).

4.6. Considering heterogeneity of farmers and the distribution o benefits of CSA can be critical for a CBA

Take away messages:

- Land size and income are important determinants of whether and which type of CSA practices are adopted and whether farmers will reap enough benefits from CSA.
- To reflect the benefits and cost of CSA adoption to society, the distribution of benefits and can make a distinct impact on NPV of a project. The distributional aspect of net benefits can be addressed by applying weighting coefficient to benefits of important target groups.
- Introduction of new technologies, which have specific time and cost requirements, can affect intra-household dynamics. Increased labor times also raises questions about intra-household dynamics and women's increased burden.
- Technologies and practices are introduced into existing and unequal power relations. Factoring in the potential costs of CSA adoption for certain groups within a community can affect an economic analysis.
- Neglecting the heterogeneities between farm types, or the varied impact that CSA adoption can have within a community or within a household, can lead to an overestimation of economic benefits and lead to an incomplete picture of the practice.

19. **To reflect the benefits and cost of CSA adoption to society, not only the net impacts benefits should be considered but also distribution of benefits. The distributional aspect of net benefits can be addressed in several ways.** Climate change impacts disproportionally affect vulnerable populations, many of whom are poor. It is therefore important to consider the distribution of the costs and benefits of CSA, and not only the net benefits of the intervention. Thus, can be addressed in several ways: (i) to give weights to different costs and benefits according to who receives the benefits and who bears the cost; for instance, by doubling the benefits for poor people, and halving that for the rich. The difficulty with applying such weights is that there is a subjective aspect to choosing where the thresholds between vulnerable and wealthy household lies and what the coefficients for weighting should be. (ii) Alternatively, the distributional impacts of CSA options can be presented alongside the aggregate costs (UNFCCC, 2010).

20. **Considering the heterogeneity among farmers should be acknowledged and is expected to impact economic indicators of a project.** The relationship between land size and the adoption of CSA practices has important implications for distributional impacts of CSA investments. Land size is often closely associated with socio-economic status, where poverty is concentrated among small landholders. In EFAs the unit for analysis is typically an average farmer, with an average farm size, and/or a uniform one-hectare unit is assumed to assess the yield potential and production cost of CSA. The question arises whether this assumption masks potential negative distributional impacts of promoting CSA in a community. IFAD (2017) conducted economic assessment of recent agricultural projects. Considering a homogenous population and adoption rate of 70 percent, the NPV of the intervention is US$109 million. However, if a more realistic heterogenous farm population is considered the NPV could be smaller since not all farmers would adopt CSA practice sin the same extent. The economic NPV may be approximately US$70 million than when assuming a homogenous farm population.

21. **Land size and income are important determinants of whether and which type of CSA practices are adopted and whether farmers will reap enough benefits from CSA. Ignoring these disparities between farm types can lead to an overestimation of economic benefits.** Lan et al. 2018 show that the attractiveness of CSA practices varies among farmers in Vietnam depending on their income groups and land sizes, with varying profitability per hectare. The planting of sugarcane and coconuts in areas which are no longer suitable for irrigated rice due to water scarcity or high salinity, was mainly suitable for farmers in higher income groups. The initial investment cost only constituted 14 -26 percent, while initial investment for farmer sin low-income groups constituted about 67 percent of their annual income respectively. The new practices may seem less attractive for higher-income farmers since their dependency on rice is a lot less than lower-income framers. A study in Northeastern Ghana showed that farmer typologies are reflective of household opportunities and constraints for an intervention (Kuivanan et al 2016). In a five-country study on adoption of conservation farming in eastern and southern Africa, Corbeels et al. (2013) show that the capacity to retain crop residues on small farms is substantially less than on larger farmers due to higher levels of competition, and associated opportunity costs, for crop residues on small farms. Similarly, Kamanga et al. (2010) show that in Malawi, despite the long-term benefits of adopting crop rotations, production risk and costs for low-income households is higher for

legume-maize rotations than legume-maize intercropping, in part due to limited land availability and the opportunity costs of diverting land away from staple food production. Rapid population growth, particularly in rural Africa, is placing considerable pressure on land availability and further constraining access to land by poorer households (Jayne et al. 2003). Understanding farm typologies is instrumental for the success of the intervention, but also for an understanding of true benefits and cost of CSA.

22. **New technologies are introduced into an existing landscape of unequal power relations. Without considering existing social relations, there is a risk that the CSA technologies could exacerbate inequalities.** Within a landscape the promotion of certain practices could have negative externalities and enhance vulnerability of poor population who often live in marginal areas (Cervigni and Morris, 2017). Cervigni and Morris (2017) propose several examples how certain interventions can benefit one community while negatively impacting another, thereby with a potential to manifest existing power relations, specifically in drylands. For instance, expanding irrigation schemes into previously uncultivated land benefits farmers who gain access to irrigation services, but harms pastoralists who had been able to take advantage of feed resources on the previously uncultivated land. Improving veterinary services to reduce animal mortality rates benefits the livestock keepers but could harm the farmers who subsequently experience more frequent invasions of their fields by free-roaming animals. Neglecting these interrelations and subsequent negative externalities of CSA in an economic analysis could lead to an overestimation of benefits.

23. **Within households, new technologies have the potential to increase labor requirements on women.** The gender and intra-household dimension of division of labor are equally important and help an analyst to understand whether potential benefit and cost of CSA are distributed equitably within a household. Even if total labor requirements are less under CSA, labor requirements for women may be greater (Milder et al. 2011). Women are seen to have a higher opportunity cost of time than men and may have to devote time to activities within the household such as having to look after children, fetching water/firewood and caring for the sick etc (Lalani et al.). Women may feel discouraged from adopting CSA even though labor requirements decrease in the long-term (see subsection 4.5.). For example, CSA reduces the need for ploughing, which may be traditionally done by men, but may increase labor requirements for women associated with land preparation (e.g., digging of planting basins) and weeding (Silisi 2010). In other countries, CSA could also reduce labor requirements and be beneficial for women. For instance, in Ghana, the most time-consuming activities in conventional slash-and-burn agriculture are uprooting grass and de-stumping. As these tasks are mostly done by women and children, a transition to CSA was found to increase the time available for other household activities (Boahen et al. 2007 in Banard et al. 2016). Similarly, in Zambia, a switch to CSA allowed women and children to carry out lighter and more diversified tasks (Baudron, et al. 2007 in Banard et al. 2016).

4.7. Understanding how CSA practices are adopted affects an economic assessment.

4.7.1. CSA may not be adopted on the entire farm, but only partially

Take away messages:
The EFA should factor in that CSA adoption on a farm may occurs only partially, on a small share of the entire agricultural land; this may affect assumptions about adoption rates and assessment of benefits in a project area.

24. **The scope of adoption of CSA practices on a farm or within production system vary.** In many cases, adoption of a potential CSA practice or technology is not a binary choice but occurring along a continuum between no adoption to full adoption, and partial adoption occurring in between. For example, Corbeel et al. (2013) show in a 5-country study on conservation farming, that farmers who adopt one or more conservation farming practices do so on 30-40 percent of their available land, and frequently do not apply the full suite of conservation farming practices. This is corroborated by recent studies about the drivers of crop diversification in Zambia and Malawi, which show that probability of adoption increases with increasing land size. The authors conclude that farmers remain cultivation of traditional staple crops on the majority of their land and adopt CSA when additional land is, or becomes, available (World Bank 2019; Mofya-Mukuka and Hichambwaa 2016). Similarly, a study in Bihar, India, shows that large plot size and proximity to the homestead correlates positively with the intensity of CSA adoption. Plots farther from the homestead received fewer climate-smart agriculture practices (Aryal et al. 2017). This implies that CSA is hardly adopted on the entire farm/plot. The EFA should factor in that CSA adoption occurs only partially, which may affect assumptions about adoption rates and assessment of benefits in a project area.

25. **Certain CSA practices entail high trade-offs so that full adoption on a farm is not beneficial. A common example is the trade-off between using crop residues for mulching or as livestock feed.** Mulching involves retention of crop residues on the field, thereby conserving and enhancing soil moisture and reducing surface runoff and erosion, providing soil organic matter and a carbon sink while increasing soil fertility. Despite these ecosystem services, mulching present potential trade-offs. Several studies have documented the trade-off between using crop residues for mulching or livestock feed (Shikulu et al. 2016). For instance, Valbuena et al. (2012) study mixed crop-livestock systems in 9 countries in Sub-Saharan Africa and South Asia and find that in areas with high population density, biomass production may be sufficiently high to support livestock systems and leave residues for mulching. However, in medium to low density areas, where biomass production is low, the opportunities cost of mulching are too high and the CSA practice is abandoned (or never adopted). Baudron et al (2014) analyzed this trade-off on the plot, farm and territory level in Zimbabwe and find that the optimal fraction of residue retention depends on the number cattle (e.g., for farmers with up to 2 heads of cattle residues retention on 80% of their plot was optimal, with 2–3 heads between 60–80%, and with 4 or more heads between 40–60% of their plot), and conclude that retention of all crop residue as mulch appears unrealistic and undesirable in farming systems that rely on livestock for traction. The relationship between mulching and livestock feed is further complicated in the dry season, when the demand for crop residues is high for animal feed, but also mulching becomes more beneficial to households (Barnard et al. 2015).

4.7.2. CSA is more than a technology but a combination of practices

Take away messages:
Adoption of single versus combinations of practices could be assessed as they may provide insights about the actual financial viability of certain practices as well as sensitivity to certain risks.

26. **The combination of practices or technologies often affects the expected yield, income, adaptation, and/or mitigation effect; few farm-level activities produce large benefits when practiced in isolation**. For example, Yamoah et al. (2002) show that while residue retention applied in isolation can raise pearl millet yields 1.2 times, when combined with inorganic fertilizer the yield effect is as much as 4-fold, double the effect of applying fertilizer alone. Similar results were found in Subbarao et al. (2000), Buerkert et al. (2000), and Rebafka et al. (1994). In Kenya, crop yields for maize and beans were substantially improved by crop residue retention in combination inorganic fertilizer application. When residues were removed and without external inputs, maize yields of 1.4 metric tons/ha were achieved; when straw was retained, and fertilizer and manure applied, yields of 6 metric tons/ha were achieved (Kapkiyai et al. 1999). When combined with minimum tillage practices, mulching and/or residue retention are routinely shown to increase yields relative to conventional practices of residue removal and conventional ploughing (Triplett et al. 1968, Verhulst et al. 2011, Paul et al. 2013).

27. **However, the effect may not be linear, and it is important to understand the relation between production cost and yield increases when CSA practices are combined.** Khatri-Chhetri et al. (2016) show improved seed as a stand-alone technology high net returns. However, a combination of improved seeds with zero tillage yields nearly the same net revenue but, overall, affects input cost less i.e., zero tillage reduced input costs due to a reduction in land preparation cost, and may thus reduce farmers' dependency and sensitivity to markets and risks (Table 3).

Table 3: Impacts of CSA on production, cost and income in rice–wheat system in India.

CSA intervention	% change in total production	% change in total input cost	Change in yield (t/ha)	Change in input cost (INR ha)	Net return (INR ha)
Improved seeds (IS)	19	52	1.03	1,402	15,712
Laser land levelling (LLL)	10	9.5	0.33	3,037	8,119
Zero tillage (ZT)	6	−41	0.36	−1,577	6,951
IS + LLL	17	63	0.87	1,752	14,194
IS + ZT	16	6	0.94	234	15,303

Source: Khatri-Chhetri et al. 2016

4.8. CSA livestock interventions require understanding of range of benefits and cost

Take away messages:
To consider the impact of CSA on livestock systems, an understanding of the type of public and private benefits and cost is necessary as well as size and characteristics of the livestock herd

28. In low- or middle-income countries livestock is typically kept for a range of purposes, and therefore have a range of benefits, costs and externalities which can potentially play a role in the economic analysis. Benefits on livestock systems usually value physical production, such as meat, manure, wool, blood and milk, or animal power are valued at market prices, and other benefits and functions of livestock are neglected. For instance, in low-productive systems where cattle and goats graze on communal land, livestock keepers may be less concerned about productivity but keep livestock generating savings, security or assets. This implies that a standard cost-benefit analysis may over or underestimate the value of holding cattle, in a way that is not reflective of farmers' decision-making. Farmers' choices may deviate from optimal production methods as suggested by the outcome of a financial analysis (Moll 2005).

29. Private benefits of livestock systems can be derived from a sum of alternative functions and values which stretch over time. Moll (2005) provides an elaborate framework for assessing private benefits of livestock holding. He distinguishes between: (i) Recurrent production and embodied production to deal with regular and irregular income streams. Recurrent production becomes available according to the type and sex of the livestock and season and include milk, wool, manure or animal power. Embodied production is not consumed but kept in the animal as investment and future recurrent production and is often valued at the sales price of the animal. (ii) Market and non-market values, where non-market values may be consumed, exchanged, or invested; and (iii) recognition and estimation of the services that livestock provides such as insurance, financing, status display. The relevance of these indicators may vary by household characteristics and type of livestock system.

30. **The description of benefits and cost in livestock systems is extended to include social and health benefits.** Salmon et al. (2018) provide an overview of the different benefits and functions of livestock, which include: services and resources including nutrition and ecosystem support. For instance, in some societies, women have more opportunities to keep livestock as asset, e.g., acquired through gifts, inheritance or market purchases, than to purchase land, access finance or other physical assets (Kristjanson et al. 2014, Rubin et al. 2010, in Salmon et al. 2018). Improving women's asset status has further positive household benefits such as food security, nutrition and education outcomes in children. In general, keeping livestock provides essential micro-nutrients and a core component to daily dietary energy intake (Allen 2002, Murphy and Allen 2003; Fielding et al. 2000 in Salmon et al. 2018).

31. **In addition, environmental externalities and ecological functions of livestock can be valued. Ecological functions include regulating services and habitat services.** In many grazing systems livestock can have a positive effect on the composition of vegetation and biodiversity. It can increase land cover and plant productivity and biodiversity, which can have a positive effect on water infiltration and filtering, reduces soil erosion and can increase soil carbon sequestration. Livestock can play a role in maintaining firebreaks, and control of weeds and invasive species as well as distribute nutrients in dung and urine across landscapes. Many grasslands are biodiversity-rich areas where livestock grazing can be vital in maintaining habitats for plants and animals, thus providing habitat services (FAO 2016). Livestock also generates a range of negative environmental externalities and a cost to society. Some of these can be mitigated by adopting climate-smart management practices. The externalities include: (i) greenhouse gas emissions from land use and land use change for grazing and feed crop production, energy and input use, methane emission from digestion; (ii) land degradation including expansion in natural habitat, overgrazing

and soil erosion due to intensive feed production; (iii) water depletion and pollution including the alteration of water cycles, pollutions with nutrients, pathogens and drug residues water depletion and pollution, and (iv) biodiversity, including habitat destruction, pollution or loss of genetic diversity. These positive and negative effects manifest differently across livestock system, such as extensive grazing and intensive systems for ruminants, or, traditional or industrial systems for monogastric (FAO, 20xx).

32. **To consider the impact of CSA on livestock systems, an understanding of the type of public and private benefits and cost is necessary as well as size and characteristics of the livestock herd.** This understanding should go beyond the number of livestock heads targeted by the project, but also how the herd is expected to evolve over time which is determined by current and projected mortality rates, morbidity rates, calving intervals, or destocking and restocking rates. This is critical if it is expected that the extent of herd size, rather than productivity per head, are driving benefits or costs of the intervention. For instance, with respect to calculating and valuing the project's net carbon balance, the herd size will be an important channel of impact.

33. **Empirical examples factor in environmental cost and benefits and show that upfront cost for sustainable management practices are a sizable share of cost, but the potential to generate environmental benefits is high.** An economic assessment for the transition from extensive livestock to sustainable intensification systems and considered the adoption of good agriculture practices, pasture maintenance/restoration, and restoration of environmental liabilities, with the aim of reducing deforestation of the Amazon. The authors assessed 13 pilot farms and found that half of the upfront cost were associated with environmental restoration. Returns of the operation exceeded investment, thus ensuring the viability of the transition to a sustainable intensification approach, except for farms with less than 150 ha of pasture. The analysis also quantified, but did not monetize, avoided emission reduction by avoiding 5,148 hectares deforestation, which results in 1.9 MtCO_2e emission, carbon sequestration from land restoration, 0.36 MtCO_2e emissions and increased emission from methane emission from enteric fermentation, which results in carbon source of 1.69 MtCO_2e emission (Garcia et al 2017).

Summary

34. In summary, most of the characteristics of CSA seem to affect the calculation of private benefits, rather than on-site or global public benefits. These benefits and costs will require detailed level of information on household and community level which is rarely available (Table 4). Table 4 also indicates which features appear more specific to CSA, than for other improved or conventional agricultural practices.

Table 4: Summary of salient features compared to type of benefit category.

Salient features of CSA	Specific to CSA	Onsite private benefits	On-site public benefits	Global benefits
1. Considering climate change, risk, and uncertainty	✓	+++	++	

2. GHG emission reduction and carbon sequestration	✓	+	++	+++
3.1. Spatial effects: Climate-smart landscapes	✓	+++	+++	+++
3.2. Temporal effects: Slow onset of private benefits	✓	+++		
4. Agroecological and site-specific context		+++	++	++
5. Increased production cost	✓	+++		
6. Heterogeneity of farmers and distributional effects		+++	++	
7.1. Partial adoption of CSA		+++		
7.2. Adopting a combination of practices		+++	+	
8. Livestock management		+++	++	++

Notes: (+++)strong impact; (++) medium impact; and (+) low impacts; blank cells imply that effect is unclear.

5. Review of financial and economic analyses of recent World Bank agriculture projects

35. **How are projects addressing the salient features of CSA?** We explore to which extent selected agriculture lending projects form Fiscal Year (FY) 16-18 have addressed these features of CSA in project economic and financial analyses. We selected 10 projects with the highest total share of climate finance out of total project finance[3] approved between FY16 and FY18. Annex 1 provides a summary of each project, key information about the economic and financial analysis, and key indicators. The projects are scored qualitatively, according to which extent they have address the specificity of CSA. We develop two scores: a CSA-total score, referring to the sum of CSA scores in 10 categories; and the CSA-intensity score, whether those elements that were addressed were strongly addressed.

36. **A positive correlation appears between the share of climate finance and the CSA-score.** Four projects with the highest climate finance score (P154784, P153420, P163444, P158522) have a CSA-score above one, indicating that they have addressed more than half of the CSA categories. Projects with the lowest climate finance score also addressed the lowest number of categories. P158522 Tamil Nadu Irrigated Agriculture Modernization Project had the highest CSA-intensity score and average score, a composite out of number of categories addressed and whether they have been addressed strongly.

37. **Projects tends to consider environmental externalities: The CSA-features climate-smart landscape and valuing mitigating co-benefits are most frequently mentioned.** Conducing GHG accounting analyses is a mandatory requirement for lending projects since June 2014; projects approved after July 2017 include a valuation of net carbon balance in their economic analysis. 70 percent of projects have applied the shadow price of carbon. Another 70 percent of projects mentioned the spatial interconnectedness of benefits and cost of CSA interventions in their EFA, but only 3 out of these 7 projects quantified these benefits, while 4 projects described them qualitatively. While there is awareness of these benefits, economists may lack time, data, or resources to quantify these positive on-site public benefits or cost.

38. **Projects hardly consider distributional impacts of CSA: The category heterogeneity of farmers and distributional concern was only addressed once**. While task teams seem to look at environmental dynamics in a landscape/watershed, it appears more difficult to assess the social dynamics. It appears that task teams have little information or data about the characteristics of the type of potential project beneficiaries ex-ante, and therefore difficulties to provide a more differentiated analysis. One aspect of distributional impacts of adopting CSA are intra-household dynamics: these could be approximated by

[3] In the scope of the multilateral development banks (MDB) methodology, climate finance refers to the amounts committed by MDBs to finance climate change mitigation and adaptation activities in development projects. The methodology provides guidance to track adaptation finance and mitigation finance. In agriculture lending projects, both adaptation and mitigation finance are often related to the promotion of CSA practices that explicitly aim at enhancing productivity and resilience and reducing/removing GHG emissions.

measuring the burden of labor and transaction cost which often women must bear. This shortcoming could possibly be addressed by combining the development of gender assessments and studies with data collection for the economic analysis.

39. **All projects conduct discrete sensitivity analyses, other than that climate risks and resilience are rarely considered quantitatively.** No project considered probabilistic approaches or simulation models to capture sensitivity to climate change, climate resilience or and other challenges. The impact of climate change, risk and resilience building is more often qualitatively described than quantitatively assessed. While 50 percent of projects address climate change explicitly; 3 out of 5 projects quantify resilience benefits, while the remaining 2 refer to resilience in a qualitative way.

40. **The fact that CSA is frequently adopted partially, but not on the entire farm, and the effect of combination of technologies, scored relatively low**. Partial adoption refers to the observation that adoption is not a binary choice and farmers may not choose to adopt CSA on the entire farm. This was considered by 30 percent of projects. The common assumption that farmers adopt CSA on their average farm size of, for instance, 1 hectare land, and could indicate that project benefits have a tendency to be overestimated. While 60 percent of projects assume the adoption of more than one CSA practice, the attribution of benefits and cost to each practice is not clear and may make it more difficult to assess the "true" benefit and cost of a CSA practices and understand the likelihood for adoption.

41. **Financial analyses always indicate financial profitability of adopting CSA**. The CSA-literature emphasizes that CSA adoption has high initial cost, which poses barriers to adoption (e.g., section 4.5). While the practice becomes profitable in the long-run, farmers need more support in early stages. While 40 percent of project addressed the question of increasing production cost, the financial analyses do not appear to reflect that potential of financial losses in early stages of adoption. Rather, the adoption of CSA seems throughout profitable. This raises the question whether a too optimistic financial assessment masks the difficulties of adopting CSA, specifically for poor farmers, and gives a distorted impression of CSA, leading to a too optimistic assessment to inform project design. When CSA practices are profitable, this raises the questions which counterfactual, "without project" scenario was chosen and whether this is reflective of realities in the ground.

42. **The score "not clear" should be interpreted with caution**. This assessment relies on written Annex of the EFAs. Some features such as phasing of crop yields, or increased production cost, which are quite commonly addressed, may have been considered in the calculation but not documented in the text. Thus, the CSA score may be underestimated for certain categories. For other projects, the CSA feature may just not be applicable, for instance for a project focused on strengthening agriculture research and development with a focus on one crop, landscape features may be less relevant. Also, not all projects are supporting livestock interventions.

Table 5: List of approved agriculture lending projects, ranked by size of total climate finance.

FY	Project code and Country	Project Name	Total Climate Co-Benefits Over Total IDA/IBRD	Total Climate Finance (USD million)
FY17	P154784 Kenya	Climate-Smart Agriculture Project	100%	250
FY16	P153420 Niger	Climate-Smart Agriculture Support Project	100%	111
FY18	P163444 Uruguay	AF- Sustainable Management of Natural Resources and Climate Change	98.5%	41.4
FY18	P158522 India	Tamil Nadu Irrigated Agriculture Modernization Project	95.8%	304.8
FY18	P160408 India	Maharashtra Project on Climate Resilient Agriculture	94.2%	395.7
FY18	P157736 Pakistan	Additional Financing for Punjab Irrigated Agriculture Productivity Program Project	92.2%	119.8
FY17	P153349 Kenya	National Agriculture and Rural Inclusive Growth Project	89.6%	179.1
FY18	P162908 Haiti	Resilient Productive Landscapes	80.4%	12
FY16	P125728 Tanzania	Southern Agricultural Growth Corridor of Tanzania Investment	79.2%	55.4
FY16	P158265 WAAPP/Senegal	2A - Support to Groundnut Value Chain in Senegal	78.2%	15.6

Table 6: Summary of results of scoring projects by category.

Projects/ Features of CSA	P154784 Kenya	P153420 Niger	P163444 Uruguay	P158522 India	P160408 India	P157736 Pakistan	P153349 Kenya	P162908 Haiti	P125728 Tanzania	P158265 WAAPP/Senegal	Project addressing feature
Resilience-building to/and climate change	+	++	+	++	++	nc	nc	nc	nc	nc	50%
GHG emission reduction and carbon sequestration	++	++	++	++	++	+	++	nc	nc	nc	70%
Climate-smart landscapes	+	+	++	++	++	nc	+	+	nc	nc	70%
Delay in onset of benefits	nc	++	++	++	nc	nc	nc	nc	++	nc	40%
Agroecological and site-specific context	++	++	++	nc	nc	++	++	++	nc	nc	60%
Increased production cost of CSA	++	nc	nc	++	++	nc	++	nc	nc	nc	40%
Heterogeneity of farmers	nc	nc	nc	nc	nc	++	nc	nc	nc	nc	10%
Partial adoption of CSA	++	nc	++	nc	nc	nc	nc	nc	nc	++	30%
Combination of practices	+	+	nc	nc	+	nc	+	+	nc	+	60%
Livestock (information	++	++	++	++	nc	nc	nc	nc	nc	nc	40%

on benefits and herd development)											
TOTAL CSA - Score	**1.30**	**1.20**	**1.30**	**1.20**	**0.90**	**0.50**	**0.80**	**0.40**	**0.20**	**0.30**	
CSA-Intensity Score	**1.3**	**1.4**	**1.7**	**2.0**	**1.6**	**1.3**	**1.0**	**0.5**	**2.0**	**1.0**	
Average	**1.28**	**1.31**	**1.51**	**1.60**	**1.25**	**0.92**	**0.90**	**0.45**	**1.10**	**0.65**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description or the feature doesn't apply; Total CSA-score: average across 10 categories; CSA- Intensity: average across all pluses and normalized between 1 and 2, where 2 indicates the highest score.

6. Approaches for addressing salient features of CSA in cost-benefit analyses

54. **We introduce approaches, tools, and techniques that could help address salient features of CSA in EFAs**. The previous section showed that out of those features that were identified to be key for CSA-features (see section 4.9, or table below), 70 percent of project EFAs had addressed GHG emission reduction and carbon sequestration and climate-smart landscapes; 50 percent of projects had addressed climate change, risk and uncertainty and resilience building; 60 percent the combination of CSA practices; and 40 percent addressed increased production cost and delay in onset of benefits explicitly in the analysis. Of those features which are important across improved and traditional technologies, not only CSA practices, following features were addressed: 60 percent of projects had addressed context-location specificity; 40 percent included a comprehensive assessment of livestock cost and benefits; 30 percent of projects addressed a partial adoption of CSA; and 10 percent of projects addressed heterogeneity of farmers and distribution effects of CSA.

55. We thus suggest seven approaches (Table 7): To address climate change risk and uncertainty we suggest probabilistic appraoch (6.1.1), scenario analysis (6.1.2), and real option and portfolio analyses (6.1.3); improving GHG Accounting assessments (6.2); improving household survey data and focus group discussions to better understand changes in production cost and heterogeneity of farmers (6.3); the use of distributional weight in cost-benefits analyses, to account for distributional effects of CSA in EFAs (6.4); and the use of remotes sensing data to better track environmental externalities (6.5). While the tools are presented individually, they are not mutually exclusive. However, many of these methods are resource intensive and technically complex, and this is likely to constrain their application during investment project appraisal.

Table 7. Summary of approaches, methods and tools to address features of Climate-Smart Agriculture

Salient features of CSA	**Specific to CSA**	**Approaches, methods, data sources**
Considering climate change, risk, and uncertainty	✓	▪ Probabilistic appraoch – Monte Carlo Analysis ○ considering variances rather than mean economic indicators ▪ Scenario analysis using climate change projections and crop simulation models, and ○ considering dynamic without project scenario ▪ Real option and portfolio analysis
GHG emission reduction and carbon sequestration	✓	▪ GHG Accounting Models ▪ Shadow price of carbon and carbon pricing ▪ Crop simulation models which consider a range of biophysical variables

Spatial effects: Climate-smart landscapes	✓	▪ Remote sensing and landscape level agroecological indicators
Agroecological and site-specific context		
Temporal effects: Slow onset of private benefits	✓	▪ Field experiments (a) ▪ Household or beneficiary survey
Adopting a combination of practices		
Increased production cost	✓	▪ Household or beneficiary survey
Livestock management		
Partial adoption of CSA		
Heterogeneity of farmers and distributional effects		▪ Household or beneficiary survey ▪ Poverty assessments (a) ▪ Applying weighting coefficients

Notes: (a) These approaches, methods, data sources are not covered in this report

6.1. Including climate change, risks, and uncertainty in an economic analysis

56. **Climate change associated risk will strongly influence the benefits and cost associated with CSA practices. While several projects referred to climate change, resilience and risk, only few quantified it.** As discussed in section 5, most EFAs consider production risk and climate-related risk in the form of a discrete sensitivity analysis in their economic analysis. The sensitivity analysis is usually composed of assumptions of declining crop yields, or declining benefits or increases in cost by, for instance, 10, 20 and 30 percent. These sensitivity analyses are usually not related to climate change projections or distribution of risk. This section summarizes key approaches to analyze climate change and risk in a cost-benefits analysis, and their potential use, as well as their key strength and weaknesses.

57. **The incorporation of uncertainty adds complexity to the economic approach as well as to the interpretation and use of its results**. However, uncertainty should be incorporated even given the danger that the results of using the approaches will be less concrete and not necessarily straightforward. If uncertainty is not taken into account, decision-making based on such analyses may not be robust enough. Assessing and managing climate risks and uncertainty, beyond a sensitivity analysis, usually involves a number of steps: (1) describing and obtaining information, quantitatively model the expected climate change projections and related risk; (2) describing the production system and understanding its vulnerabilities; (3) understanding to which extent climate-related events may affect the functioning of the system; (4) quantitatively analyzing the projected impacts, using so of the presented approaches in this section, and carrying out the decision making (or deliberative) process (ECONADAPT 2017). There is no one-size-fits-all solution on how to include climate change considerations into CBA, and the suitability for these methods should be considered carefully.

6.1.1. Monte Carlo analysis: Probabilistic appraoch to sensitivity analyses

Take away message:

- Monte Carlo simulation can be used for sensitivity analysis in CBA. The allow to generate probability distribution for key economic and financial indicators, thereby approximating climate-induced risk to the project and provide an indication about the financial and economic robustness of the intervention under climate change.
- Monte Carlo analysis allows to shift the focus on expected variance of economic indicators, rather than only one expected value.
- To design a probability distribution of an uncertain input variable to the CBA (e.g. crop yields, discount rates, cost), historical data, climate models, or exert opinions can be used. Obtaining a reasonable approximation can constitute a challenge for projects.
- To employ this probabilistic appraoch for a sensitivity analysis, open source software is easily available.

58. **Monte Carlo simulation is a risk modeling technique that uses statistical sampling and probability distributions to simulate the effects of uncertain variables on model outcomes.** Monte Carlo analysis uses estimates of the probability distribution of costs and benefits, and other parameters used in the CBA and thus allows to undertake probabilistic analysis of economic indicators such as NPV and IRR. The probability distribution provides information on the likelihood of different scenario emerging and uses this information to provide a probability distribution of the NPV and IRR. Box 2 shows the steps to Monte Carlo analysis. Monte Carlo simulations allow to analyses a large quantity of scenarios (e.g., more than 10,000). In this sensitivity analysis technique random numbers in a predefined range of parameters (e.g., costs, benefits, interest rate, and probabilities) generate a multitude of scenarios (OECD 2018, GIZ 2013). The results of these scenarios are summarized and visualized in a distribution function. Monte Carlo simulation provides a more comprehensive view of potential outcomes and allows to assess whether economic indicators are still robust, despite accounting for high level of risk.

Box 2. Steps to Monte Carlo analysis to include climate change considerations into a cost-benefits analysis

1. Understand which parameters will be most affected by climate change in the production system, and are expected to affect the economic indicators, e.g. crop yields, or discount rate to model time preference
2. Estimate the probability distribution for parameters of interest. Where parameters are correlated the joint probability, distribution is estimated. When estimating a probability distribution of e.g., crop yields, the results of a crop simulation model, or climate impact model can be used to inform the probability distribution. One can also use historical data, expert opinion or experimental evidence. For instance, Liu et al. (2016) obtained the minimum, most likely, and maximum of each variable and used a triangular distribution for those variables where they had all three values; when the most likely estimate was not available, they used a uniform distribution, where all values within the range defined by the minimum and the maximum had an equal chance of occurring.
3. Take a random draw of the parameters of sample size n.
4. Estimate the NPV, or other economic indicators, n-times using the parameters drawn.
5. Calculate the mean NPV across n-values and store the value.
6. Repeat m-times until the probability distribution of the mean NPV condition on the uncertain parameters with sample size n, with m repetitions, can be plotted.
7. Evaluate the likelihood of a positive or negative NPV.

Various software programs are available to assist in conducting Monte Carlo simulations, such as @Risk or RiskAMP which work with Microsoft Excel, or Crystal Ball software.

Source: OECD, 2018

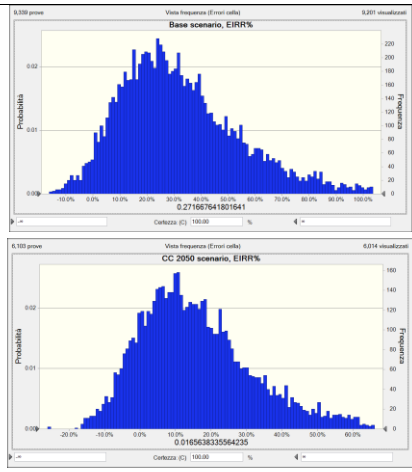
59. **Risk analysis typically involves the choice of several variables which are varied simultaneously, as returns are generally subject to more than one source of risk**. The Monte Carlo technique provides a systematic assessment of the combined effect of multiple sources of risk in key variables This allows accounting for risks stemming from the biophysical, context-specific conditions of the project area. By combining the distributions and randomly selecting values, it recalculates the simulated model many times and generates a probability distribution. It is categorized as a sampling method because the inputs are randomly generated from probability distributions to simulate the process of sampling from an actual population. The Monte Carlo simulation can be useful for determining risks and factors that affect forecasted variables and, therefore, can lead to more useful predictions.

Box 3. Example of Monte Carlo simulation for climate-smart agriculture investment in Zambia.

The example stems from an unpublished background paper for the Zambia Climate-Smart Agriculture Investment Plan (World Bank 2019) and refers to a situation where 50 percent of Zambian household are supported to adopt CSA practices for 8 crop commodities until 2050. Climate change impacts on the agriculture sector were modelled with the GLOBIOM model (Havlik et al. 2014; see World bank 2019 for details on the model) which uses five general circulation models for climate change projections in Zambia and two biophysical process simulation models to model the impact on crops. Using the Crystal Ball software, values for crop yields are sampled randomly from the crop simulation models without and with climate change projections, using a normal distribution. These figures are used to calculate an estimate of the EIRR and NPV. This process is repeated 10,000 times, and an average (or "expected") NPV and EIRR are produced together with the associated probability distribution, estimates of standard deviation, minimum and maximum values. To analysis is conducted for a situation without and with climate change. Figure a and Table b present the results.
The Monte Carlo simulations provide useful information about the changes the variability of the CSA investment profitability as effect of the expected climate change in 2050. In the '2050 scenario' the volatility of the CSA investment plan is expected to decrease: indeed, the variance and the standard deviation are lower in the '2050 scenario' than in the base case scenario. This is confirmed by the value of the Kurtosis which is higher in the base case scenario than in the '2050 scenario'. Therefore, even if in the '2050 scenario' the profitability of the investment plan will be much lower than in the base case, its variability will be lower, i.e. it will be relatively more certain that the investors will gain low benefits in the future.

Figure a. Economic internal rate of return for a case without climate change (above); and with climate change (below)

Table b. description of results of the economic rate of return.



	Business-as-usual without climate change	With climate change; 2050 scenario
Number of iterations	9,339	6,103
Average EIRR	33.3%	16.6%
Median	29.0%	13.8%
Standard deviation	25.1%	17.7%
Variance	6.3%	3.1%
Kurtosis	14.00	7.84
Coefficient of variation	0.7525	1.06
Min	-16.2%	-26.0%
Max	388.3%	211.6%
Interval	404.4%	237.6%
Standard error	0.3%	0.2%

6.1.2. Scenario analysis: Using climate impact models and biophysical simulation models to develop scenarios for CBA

Take away messages:

- Scenario analysis combines climate impact models and crop simulation models which simulate yields and other biophysical variables for a range of conditions to provide a climate-informed sensitivity analysis for a CBA.
- In addition to the sensitivity analysis, the model linkage can be useful to inform the design of dynamic "without project" and "with project" scenarios, where without project scenario may incorporate increasing yield losses.
- Given the multitude of possible model/scenario-combinations, the choice of scenarios can be based on most optimistic/pessimistic climate scenarios.
- While the usefulness for EFAs is high, as it provides detailed information, the availability of models may be a challenge for a project-level EFA, unless the information is readily available.

60. To perform a climate sensitivity analysis for agriculture sector investment, results of climate impact models can be paired with crop simulation models to develop scenarios. There are many types of crop simulation models which can be applied to assess CSA at different levels, from the field to national scale. Crop simulation models are biophysical representations of crop production simulating the relevant soil plant-atmospheric interactions that that determine plant growth and yield and can be used to assess the impacts of climate change on agricultural productivity or yield losses and other biophysical variables (e.g., soil carbon stock, water use, greenhouse gas emissions) and assess the impact of CSA practices. Several models can account for practice such as planting and harvesting methods, fertilization, timing and amount of irrigation, change of crops. The impacts can often be assessed for seasonal dynamics and inter-annual variability, or even flood extremes, as well as long-term crop production under conditions of

increased climate variability (i.e., more frequent dry spell or more intense rainfall). Common biophysical crop system models are DSSAT, APSIM, EPIC, LPJmL for crops, and NUANCES-FARMSIM for livestock.[4]

61. **When combined with climate change models, crop simulation models enable to simulate future crop and livestock productivity under various climate change scenarios and socio-economic conditions**. Crop simulation models are frequently part of an integrated model linkage and combined with climate models, hydrological models or economic models (World Bank 2010, Jones et al. 2007). This allows to conduct analyses controlling for diverse agro-ecological and climate uncertainty conditions including Representative Concentration Pathways (RCPs), Global Circulation Models (GCMs), and Shared Socioeconomic Pathways (SSPs). However, the detailed analysis requires a larger amount of input data and time for model calibration and evaluation than studies of global yield potential. In a next step, these models have been linked to household economic models which can combine both biophysical and economic aspects of farming and allow for trade-off analyses between crop and livestock systems (Robertson et al. 2012 in Thornton et al. 2018).

62. **Thereby crop simulation models help to inform the development of without and with project scenarios. However, the models have several advantages and disadvantages**. An advantage of using crop simulation models for project-level assessment is that they are calibrated using historical relationships between independent variables (i.e., soil profile, climate data, management practices) and production outputs. There is a risk that the models overstate the longer-term impacts of climate change, since they do not adequately allow for autonomous adaptation. Using crop simulation models, allows economists to develop not only a “with project” scenario, but also a dynamic “without project scenario”, which shows losses in productivity and yields due to lacking adoption of adaptation or resilience building measures. However, “without-project” scenarios also damages run risk of being underestimated because they cannot incorporate the effects of future technological change. Box 4 summarizes the advantages and limitations of using crop simulation models.

Box 4: Benefits and limitations of crop simulation models

Using cropping system models as source of input data for socio-economic assessments can be characterized as providing the following benefits:

- *Coverage of a comprehensive sets of climate-smart agricultural management and technology options* at field level without the necessity that information of technology adoptions is available from large or representative household datasets. A limited set of observation from agronomic experimental trials is however obligatory for model calibration and evaluation, particularly in the case of analyzes at the national level.
- *Explicit consideration of future climate change:* Cropping system models provide a clear and straight forward methodological strategy to explicitly consider future climate change.
- *High degree and location specificity:* If adequate data is procured at the national level, cropping system models can provide estimates at a high resolution (e.g. 0.5-0.1 decimal degrees) and explicitly take into

[4] Agricultural Production Systems sIMulator (APSIM) – Keating et al. (2003); Environmental Policy Integrated Climate (EPIC) model – Williams (1990); Decision Support System for Agrotechnology Transfer (DSSAT) – Jones et al. (2003); Lund-Potsdam-Jena managed Land (LPJmL) model – Bondeau et al. (2007); Nutrient Use in Animal and Cropping systems – Efficiencies and Scales FARM SIMulator (NUANCES–FARMSIM) – van Wijk et al. (2009).

account a high set of location specific information (soil properties, rainfall, temperature, land-use history, etc.).

- *Integrated climate change adaptation and mitigation assessments:* Several, but not all, crop models can provide estimates of climate change adaptation and mitigation impacts in an integrated manner.

Crop simulation models are associated with certain limitations:

- *Data requirements* (i.e., soil profile data, weather data, local management information, etc.) can be demanding for these models, especially for project-level applications. The investment of time and resources to benchmark and run a model may also be considerable. While the usefulness of these models is high for a climate-informed CBA for projects, the practicability may be low, unless the data is readily available.
- *Consideration of static adaptation options:* Most models uses currently available agricultural practices and technologies in order to estimate their suitability as vehicle for climate change adaptation (or mitigation). Practices and technologies are expected to evolve in the future, as a response to specific stressors from climate change. These are however not currently represented in cropping system models.
- *Limited consideration of pest management:* Crop simulation models are limited regarding their ability to consider current impacts of agricultural pests on yields and the moderating impact of management practices.
- *Deterministic model set-up:* Most models are set-up as deterministic models that provide a single estimate as output. Stochastic approaches that provide yield probability distributions are rare.

63. **In addition, or instead of conducting a CBA, a global economic models or household economic models can be used to translate estimated yield changes into socio-economic impacts**. Household economic models have also been used to estimate climate change impacts on household welfare (Rigolot et al. 2017, Antle and Valdivia 2006). Commonly computable general equilibrium models (AIM, ENVISAGE, FARM, MAGNET) and partial equilibrium models (GCAM, GLOBIOM, IMPACT, MAgPIE[5]) have been applied to estimate and compare future global economic and food security outcomes under climate change. Internationally, the Agriculture Model Intercomparison and Improvement Project (AgMIP) and the Modeling European Agriculture with Climate Change for food Security (MACSUR) are examples of research programs that employ and compare combined approaches of cropping system models in combination with economic methods for analyzing the future economic and food security situation under climate change (e.g., Rosenzweig et al. 2014).

64. **However, the question remains how to select climate scenarios for sensitivity analysis? Thereby the question how and which probabilities to assign o scenario occurrence remains a challenge.** Given the multitude of available models and combination, the quetsion arises which scenarios should be used for the sensitivity analysis. In some cased, subjective probabilities can be assigned to scenarios, based on beliefs determined by actual knowledge. In that case, the “best” intervention is expected to maximize the expected net present value, weighted by the occurrence probabilities for every scenario. Knowing probabilities is a key challenge, as is often the case with climate change, a scenario-by-scenario approach can be taken which looks for interventions that are acceptable within a maximum number of scenarios. Benefits are no longer maximized within a given scenario (or within the average of a set of scenarios) but,

[5] Asia-Pacific Integrated Model (AIM), Environmental Impact and Sustainability Applied General Equilibrium model (ENVISAGE), Future Agricultural Resources Model (FARM),Global Change Assessment Model (GCAM), Global Biosphere Optimization Model (GLOBIOM),Global Trade and Environment Model (GTEM), International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT),Modular Applied General Equilibrium Tool (MAGNET), Model of Agricultural Production and its Impact on the Environment (MAgPIE). For a comparison of global climate change modelling results please refer to Nelson et al. (2014a, b).

instead, remain above the acceptable level of benefits for the set of scenarios (or for as many scenarios as possible). Another, preferable option, is to use at least two, an "optimistic" and "pessimistic" scenario to which subjective probabilities are attributed. The optimistic climate scenario assumes ambitious climate policies at the international level and a low-level response to GHGs; and the pessimistic scenario assumes the absence of ambitious measures to limit global warming and a strong climate response. When big impacts and long adaptation times are expected, it may be reasonable to focus on the most pessimistic scenario, even though the likelihood of occurrence is low. If the expected impact is limited, it can be considered to take the most likely scenario (Hallegatte et al. 2011).

65. **Given the high uncertainty surrounding climate change, it remains important to consider several climate change scenarios to evaluate the robustness of CSA.** In fact, the choice of CSA and other adaptation measures is expected to depend, to a large extent, on the choice of climate scenarios and the question of the scenario selection is therefore extremely important. Designing an adaptation strategy based on a single climate scenario could lead to major maladaptation and be worse than no action at all. It should be noted that there is a high level of uncertainty about the local manifestation of climate change, and different models can lead to different regional patterns. Therefore, it may be necessary to use as many models as possible, but in practice it may be enough to use the most contrasted models. Considering the context of uncertainty, the analysis would only be able to provide a response contingent on a set of beliefs about the future and an attitude in relation to risk (Hallegatte et al. 2011).

6.1.3. Real option analysis and portfolio analysis: Investment decisions under climate uncertainty and risk

Take away messages:

- Real option analysis allows the consideration of the value of learning and waiting for more information about climate uncertainty to become available. Portfolio analysis allows the passements of agricultural practices which are robust against climate change risk.
- Both methods result in economic indicator, but considering climate risk an uncertainty which can be compared with a ‘standard” economic appraisal.
- Both methods are quite knowledge and data intensive ad require information about climate projections and potential effect of management practices under climate scenarios. Thus they may not be readily applicable for project economic and financial a.

66. **In contrast to previous approaches, real option analysis allows for learning and postponing decisions until more information which reduces climate uncertainty, becomes available**. The probabilistic appraoch and scenario appraoch have drawbacks: probabilities are often assumed as given and neglect the purpose of adaptation or resilience building measures of actually reducing risks; and lastly, they do not incorporate the possibility of learning and decision making as new information becomes available. Approaches such as real option analysis consider that there is an economic value in waiting, which may be larger than the net present value obtained via scenario analysis. This is specifically relevant for large investments, where scarce resources are committed in an irreversible way under uncertainty.

The analysis values an option of undertaking the investment now or waiting. A real option can be defined as the ability to undertake a future economic action or project and thus values the flexibility of future learning. It provides insight into the optimal timing of investment and the risks associated with investing in physical assets to early or late (World Bank 2010).

67. **Standard economic appraisal normally assesses the performance of a project over its whole lifecycle and results into one NPV. Real option analysis recognizes that projects are more complex and dependent on status of climate change in the future and provides an "extended NPV".** The methodology is thus useful when uncertainty is high and the value of the investment depends critically on the future state of the climate, which is not known at time of project appraisal; evaluating investment decisions which, if not undertaken, lead to irreversible damage, or the investment as such is irreversible because it locks-in a large amount of capital; when investment decisions are phased and project design thus allows for learning (Econadapt 2017, World Bank 2010). The economic value of the project is calculated by adding the value of the options created by the project, that is, the option to adapt, to abandon, to scale up an investment and subtracting the options which are destroyed by the project, that is the option to wait or make an alternative investment, to the standard NPV, resulting in an "extended NPV" (Knudsen and Scandizzo 2004 in World Bank 2010). While the real options methodology allows for incorporating the economic value of learning and waiting, the key drawback is that it is linked to a complex methodology, which typically requires high volumes of data and resources (Econadapt 2017; World Bank 2010). Box 5 provides a step-wise approach to conducting the analysis.

Box 5. Steps to conduct a real option analysis.

The real options analysis is considered complex and requiring a high level of data and resources. Conducting the analysis can be summarized in three steps:

1. *Identification of options:* The expected project impact should be determined such as higher capacity to deal with climate change, or new opportunities ad new technologies that are introduced. This is usually done through stakeholder involvement to identify the capabilities and options.
2. *Analyzing the options: (*i) conducting a cost-benefits analysis and determine the project's expected NPV; (ii) assess the opportunities and threats from climate change and assign probabilities to future outcomes; (iii) applying the options algorithm to calculate the option value. In some cases a decision-tree methodology is used where each branch presents varying development in the design of the adaptation option and probabilities are assigned; then costs and benefits of each option are calculated and multiplied with probability distribution.
3. *Evaluate the opportunity:* of acting now or exercising the option to wait. The option to wait may dominate if the project does not provide any benefits in the present state, or that a better-informed decision (e.g. building of a dam in case climate becomes drier) can be taken in the future (e.g. when more information is available as to whether that climate is rather dry than wet and the value of the dam high). The value of an option shows the difference between the expected value of postponing the investment – or preserving the option and implementing the investment (e.g. constructing the dam) straight away (Leary 1999). The assessment should include a sensitivity analysis to test the sensitivity of the option value to parameter estimates.

Source: World Bank 2010; Econadapt 2017

67. Portfolio analysis is another methodology to consider for evaluating a diverse set, or portfolio, of adaptation options, as opposed to relying on a single strategy. It is based on the idea that diversification is an important risk management response. The benefits of a portfolio of measures and climate-smart agricultural practices are likely higher than of an adaptation strategy that relies on a single measure. By considering a portfolio of options, the risk of failure is minimized as the loss associated with one measure is compensated by the better performance of another. Portfolio analysis allows to compare multiple portfolios of options against the uncertainties of future conditions and is specifically suitable where different measure may be complementary (e.g., see section 4.7.2) (Econadapt 2017).

68. Portfolio analysis allows to assess trade-offs that can be expected between risks and benefits of various portfolios but the appraoch has drawbacks. Risk preferences often relate to the uncertainty of future climate scenarios and the preference that selected strategies perform well over a range of plausible futures. Portfolio analysis identifies a group of strategies which are effective adaptation measures over a range of possible future climate scenarios. which match that preference, instead of providing one option for one future. On the downside, the methodology is resource intensive, requiring a high degree of expert knowledge and data. The methodology requires benefits to be expressed in quantitative terms and requires information about climate scenarios and related uncertainties. Box 6 provides a stepwise guide as to how to conduct a portfolio analysis (Econadapt 2017).

69. Due to the high data and resources intensity the appraoch is most often used in agriculture economics research, which has many examples of farmers technology choice, or optimal allocation of water, impact of policies under various climate scenarios and under ecological constraints (e.g., Robert et al. 2018). Portfolio analyses techniques help select a combination of practices, "robust" against risks and help developing portfolios of combination of CSA options, which allow to minimize risk, while maximizing returns. (Mitter et al. 2015; Strauss et al 2011). The resulting combination can be compared with a business as usual, or "without project scenario". The potential value for an economist lies in the ability to derive economic indicators of "optimal" decisions while considering uncertainty and risk.

Box 6. Steps to conduct a portfolio analysis:

Econadapt (2017, page 38) present following steps to conduct a portfolio analysis*:*

1. Defining a number of adaptation options and constructing possible adaptation strategies which represent a combination of options.
2. For each option, evaluating the expected benefits of each option, and their variance over a given range of future climate scenarios.
3. For each strategy, calculating the expected benefits and its variance, by multiplying the expected benefits of each option in the strategy by the proportion (of cost) of each option in the strategy
4. Plotting benefit data against variance and identifying strategies which either maximize benefits for a given level of variance (risk) or minimize variance (risk) for a given level of variance

6.2. GHG Accounting tools and valuation of carbon: Improving mitigation benefits calculation

Take away messages:

- Including the valuation of a project's net carbon balance in the economic analysis is a common way to account for global public good benefits.
- The usefulness and practicability of GHG Accounting tools is high.
- The quality of results needs to be ensured by using activity data that reflects project activities.

68. **Agriculture, Forestry, and Other Land Use (AFOLU) sector is unique among economic sectors with high mitigation potential** which derives from both an enhancement of removals of GHGs and a reduction of emissions through management of land and livestock. There are several Accounting tools to quantify that, which were assessed and compared by a recent study (Toudert et al. 2018): Carbon Benefits Project Simple and Detailed Assessment tools developed by the GEF-funded 'Carbon Benefits Project' (CBP SA and DA); Agence Française de Développement Carbon Footprint Tool (AFD-CFT); Forest Carbon Calculator (U.S. Agency for International Development [USAID] and Agriculture, Forestry, and Other Land Use [AFOLU] Carbon Calculator; Carbon Assessment Tool for Afforestation and Reforestation (CAT-AR); Carbon Assessment Tool for Sustainable Forest Management (CAT-SFM); Climate Change, Agriculture, and Food Security Mitigation Options Tool (CCAFSMOT); Cool Farm Tool (CFT); DeNitrification-DeComposition Model (DNDC); Ex-Ante Carbon-Balance Tool (EX-ACT); Tool for Afforestation and Reforestation Approved Methodologies (TARAM).

69. **Many advanced tools have been developed, however the methodologies applied by the tools follow IPCC guidelines and are relatively similar. However, the scope of the tools, i.e., number and type of GHGs, as well as coverage of subsectors, varies**. The tools are moderately data, skills, and time-demanding and several of them offer many additional functions including carbon footprint, socioeconomic analysis, and multiple area analysis. The methodologies on which the tools are based are transparent and detailed in guidance documents. However, not all tools account for the same number of activities. For instance the study found that CBP and EX-ACT are the most versatile tools, addressing a range of emissions from sub-sectors agriculture, livestock and forestry, while CAT-AR, CAT-SFM and TARAM are least versatile and specific t the forestry sector (Table 8).

Table 8: Activity scope of GHG tools, results of a comprehensive comparison

No.	Tool	Temperate crops	Tropical crops	Rice cultivation	Grassland	Livestock	Field trees, hedges, agroforestry	Perennial production (orchards, vineyards)	Forest	Wetlands	Settlements [2]	Other land[3]	Score (%)	Assessment Ratings
1	CBP	x	x	x	x	x	x	x	x	x	x	no	91	++++
2	AFD-CFT	x	x	no	x	x	no	no	x	no	x	x	73	+++
3	AFOLU	x	x	x	x	x	x	x	x	no	no	no	73	+++
4	CAT-AR	no	no	no	no	no	no	no	x	no	no	no	9	+
5	CAT-SFM	no	no	no	no	no	no	no	x	no	no	no	9	+
6	CCAFS	x	x	x	x	x	x	x	no	no	no	no	64	+++
7	CFT	x	x	x	no	x	x	x	no	no	no	no	55	+++
8	DNDC	x	x	x	x	x	no	x	no	no	no	no	55	+++
9	EX-ACT	x	x	x	x	x	x	x	x	x	x	x	100	++++
10	TARAM	no	no	no	no	no	no	no	x	no	no	no	9	+

Source: Toudert et al (2018); Notes: x means the tool meets the criterion; no means the tool does not. Score is the number of activities out of 11 for which a tool is suitable, expressed in percent.

70. **The IPCC has published guidelines and good practice references for GHG accounting (IPCC 2006).** GHG accounting using the IPCC methodology can be carried out at three levels: (i) Tier 1 emission factors are highly aggregated and corresponds to accounting for large areas, with average emission factors provided for large ecoregions of the world. (ii) Tier 2 emission factors uses state- or region-specific data, and are more accurate with carbon stock changes when available. (iii) Tier 3 is very detailed, applying biophysical models of GHG processes that were developed at the country or regional.

71. **Emission factors are multiplied with activity data about project interventions**. For emissions of CO2 from energy consumption and all nitrous oxide (N2O) and methane (CH4) emissions, the generic approach considers multiplying an activity data (which can be land area, animal numbers, mass unit, or fuel quantity) by its specific EF for each source. For non-energy-related CO2 emissions or removals, most calculations, except otherwise specified, use an approach with a stock difference method. The stock difference method calculates emissions or removals as the change over time of carbon stocks for the different pools. The IPCC methods are based on five carbon pools—above-ground biomass, below-ground biomass, litter, deadwood, and soil carbon. Six out of the seven tools account for aboveground and soil carbon, but EX-ACT is the only tool accounting for all five carbon pools.

72. **Activity data for GHG appraisals are typically sourced during project identification up to appraisal and are key to ensure quality of estimation.** At plot scale and farm scale, technical data are easily available and can be provided directly by farmers and technical experts who are involved in the project design. At the regional scale, data inventory often needs to be obtained from statistical databases or expert knowledge leading to an increase in uncertainties. The accuracy of the GHG results depends mainly on the activity data that feed into it.

73. **Since 2014, Agriculture GP uses mainly EX-ACT tool to assess a project's net carbon balance** (i.e., the difference between gross emissions in a without and with project scenario). EX-ACT has a tremendous advantage of being user-friendly and enabling analysist to enter a range of activities from all AFOLU

sectors. However, the quality of the analysis is depended on the activity data. While EX-ACT allows to account for livestock activities, there are more specific tools which also include Tier 2 emission factors which can be used for more accurate analyses (see Section XX) .

74. **Since 2017, World Bank recommends to value project's net carbon balance at a low and high shadow price of carbon** to account for the marginal abatement cost of the effort to reduce carbon emissions. The High-Level Commission on Carbon Prices, led by Joseph Stiglitz and Nicholas Stern, concluded based on an extensive review that a range of US$40-80 per ton of CO_2e in 2020, rising to US$50-100 per ton of CO_2e by 2030, is consistent with achieving the core objective of the Paris Agreement of keeping temperature rise below 2 degrees, provided a supportive policy environment is in place.[6] Beyond 2030, the low and high values on carbon prices are extrapolated from 2030 to 2050 using the same growth rate of 2.25% per year that is implicit between the 2020 and 2030, leading to values of US$78 and $156 by 2050.[7]

6.3. Household-level analysis: Gaining better understanding of CSA cost and benefits

Take away message:

- Household survey data has shortcomings in assessing CSA impact. Their usefulness is high to receive general information about project area and beneficiaries, moderate for understanding the impacts of CSA adoption, and low for obtaining sufficiently detailed information to conduct a CBA. The practicability is high if data and additional reports are available.
- To obtain better data for CBAs, the following could be considered: targeted project monitoring and evaluation surveys, making existing surveys available across projects in the agriculture sector, conducting focus group discussion with beneficiaries during project appraisal, or CSA-focused impact evaluations.

75. **Household survey data can be used for CBAs, but may not always provide sufficient detailed information.** Household survey data may be relevant for CBAs if they provide information about production cost and benefits of CSA. This level of detail is not always be available, though survey may provide information about household income from agriculture and other sources, they may not sufficiently disaggregate the source of income. Surveys may include information about the adoption of improved agricultural practices such as irrigation but may not always provide enough detail about the adoption of distinct CSA practices (e.g. zero tillage, conservation agriculture, agro-forestry). Even then, the impact of CSA adoption – e.g. yield increases, income increases – cannot always be understood if only

[6] Carbon Pricing Leadership Coalition 2017. Report of the High-Level Commission on Carbon Pricing, Commission chairs: Stiglitz, J.E. and Stern, N., supported by World Bank Group, ADEME, French Ministry for the Ecological and Inclusive Transition. https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/59244eed17bffc0ac256cf16/1495551740633/CarbonPricing_Final_May29.pdf

[7] This is a conservative assumption reflecting a very optimistic forecast of early mitigation action and rapid cost decline of low-carbon technologies

one survey-year is available and due to long recall period for farmers (that is, recalling which management practice has led to a change in productivity under consideration that yields increase several years after CSA practice is adopted) which may impact data validity. Some of the projects presented in Section 5 have indicated to have used survey reports as data source. Specifically, additional finance projects have used results of field surveys conducted in the project area.

76. **Household survey data is frequently used to assess drivers and impacts of technology adoption, to inform agricultural policy and investment decisions**. Rather than for CBAs, household survey data is used for analyses of drivers and impacts of adoption of CSA practices and its impacts (yield, income, and/or food security outcomes), and, to an extent, distributional effects. Analyses of adoption frequently use binary adoption variables as the dependent variable and assess the conditional correlations between adoption and on a range of socio-economic, human capital, and geographic/agro-ecological variables. However, there are often strong correlations between socio-economic variables of interest for CSA impact analysis and unobserved household variables, which limits the utility of cross-sectional analysis for identifying determinants of adoption or response (Arslan et al. 2015).

77. **However, to assess the impact of CSA adoption, a one-time household survey or evaluation survey may not always be suitable.** The income, food security, or productivity impact of adopting CSA practices is contingent on the duration of adoption, the intensity of adoption, and the simultaneous adoption of complementary activities. This raises significant challenges in terms of analysis and data collection. Major weaknesses of all survey data approaches to understanding CSA impact include: 1) difficulty identifying partial adoption practices, even when field level data are collected. At a field level, farmers typically only adoption a practice on 30-40 percent of available land. Capturing partial adoption practices is difficult and most surveys focus on the household's primary activity; 2) long respondent recall requirements to effectively estimate adoption response. Because of the slow accrual of benefits of many CSA activities, it is often necessary to ask respondents to recall management practices at a field level, such as residue management, tillage, fertilizer application, etc…, over a multi-year period. This adds substantial levels of uncertainty in terms of data validity; 3) Because of challenges associated with long recall, many surveys do not capture practices and activities outside of the survey reference period. This confounds analyses of determinants of adoption or response, because the costs and benefits of one CSA practices are often influenced by actions taken prior to the reference period. For example, without information on previous field level practices, such as inorganic fertilizer application, tillage method, residue retention practices, and yields (proxy for biomass), it is difficult to accurately estimate current impacts of adoption; 4) intra-household dynamics, such as gendered division of labor and resources resulting from CSA adoption, are critical for understanding the distributional effects of a CSA action, but are often difficult to capture with household survey data.

78. **Panel data analysis is preferred for understanding the relationships between key explanatory variables and the impact variable of interest**. **For a CBA it may provide insights about the achievement of benefits because of CSA adoption.** However, while panel data analysis provides more empirically robust analysis, disadvantages include the cost of collecting panel data compared to cross sectional data, the timeline for analysis, and data availability. In situations where panel data are not available, but

repeated cross sections have been carried out, such as annual crop forecast surveys, pooling data to a useful unit of analysis, such as district, can be effective (Ngoma et al. 2015).

79. **Despite these short-comings, the use of household survey data to assess CSA impacts, if available, remains useful**. Household survey data is relatively widespread, in part due to long-term investments in Livelihood Standard and Measurement Survey (LSMS) data collection. This allows for relatively low costs analysis of agricultural interventions. Whether CSA practices are sufficiently or at all captured remains a challenge. The survey data could, however, provide more information about the composition of larger communities and which allows to assess the potential distributional and equity impacts of CSA interventions. Moreover, analyses using survey data can be aggregated upward to answer questions at various scales. Being cognizant of the short-comings and addressing these methodically or through the data collection process, can improve the accuracy of household survey data approaches for answer CSA investment impacts.

80. **Following steps could be considered in ongoing projects to enhance information and data gathering for future EFAs: (i) impact evaluations; (ii) targeted monitoring and evaluation (M&E) indicators that in support information base for future EFAs; (iii) focus group discussion with beneficiaries during appraisal.** Several projects with CSA-focus (e.g., Kenya Climate-Smart Agriculture Project; Kenya National Agriculture and Rural Inclusive Growth Project; Niger Climate-Smart Agriculture Project) have included impact evaluation to assess the drivers and expected impacts of CSA adoption, or detailed monitoring and evaluation arrangements in project design. Such information will constitute an important source of information for future EFAs. The M&E indicators and related surveys could collect information about production cost and labor requirements, and the type and scope of CSA practices applied. Governments of community of Development Partners should be encouraged to collect and make M&E across different projects centrally available. The promotion of CSA data is increasingly common among development partners and together a comprehensive information base about CSA may be available, but is currently fragmented. Well-thought through monitoring and evaluation arrangements and surveys, as well as an information management system that allows to easily access this information, could be a relevant source of data and information serving project teams in the future. Other project assessments, during appraisal or implementation, for instance gender and social impact assessments, which may rely on focus group discussion and expert interviews, could be relevant to approximate intra-household impacts of CSA adoption. Focus group discussions with potential project beneficiaries, not only technical government counterparts, to collect data for the economic analysis should be considered within project appraisal process.

6.4. Distributional weights: to assess whether CSA benefits are equitable

Take away message: The promotion of CSA often affects different actors in a community in a different way. To ensure that CSA investment benefits the most vulnerable groups, the project could identify and report how benefits and cost are distributed across groups; or assign distributional weights to the analysis.

81. **Distributional weights can be applied to emphasize the benefits and costs of vulnerable groups in project area**. The review in section 4.6. shows how critical it is to consider distributional effects of CSA adoption, but the assessment in section 5 shows that distributional impacts and equity considerations are rarely considered in economic and financial analysis. The assumption of average, homogenous farmers is most common and easy to implement. To understand the heterogeneity of beneficiaries, household survey data can be used or social and gender assessments which are conducted by, for instance, social safeguard expert. To consider heterogeneity and the subsequent distribution effects in the economic analysis, OECD (2018) suggests a range of practices: (1) identifying and cataloguing how project related cost and benefits are distributed, in physical units and in monetary terms. (2) calculate implicit distributional weights. For instance, if a project generates a net aggregate loss but net gains are enjoyed by a vulnerable group in society, the eights could be assigned to show that the investment has a positive social value. (3) re-calculating the project's et benefit based or assigning explicit distributional weights to the benefit and cost incurred by different societal groups. Steps 2 and 3 imply that a subjective judgement must be made about societal groups and their degree of vulnerability. It is thus suggested to at least provide step 1, to provide useful information about the distribution of benefits and costs (Kristoem 2005 in OECD 2018)

6.5. Considering landscape-level: Remote sensing data

Take away messages. Earth observation data provides data in several areas of application. By using observations from the past (e.g. crop yields, soil moisture, land use changes which overlap with household survey data to understand areas of high vulnerability, spatial interconnectedness in a landscape) the analysts can derive projections for a with or without project scenario. Unless information is readily available, interpreting the data accordingly and make it suitable for an economic analysis, requires additional software, analysis, skills and time. this may not be feasible within the project appraisal period.

82. **Satellite derived measurements are essential inputs for improved agricultural management and can provide data and information that can inform the inclusion of public good benefits in economic analyses**. There is vast availability and numerous areas of application for remotely sensed data. Areas of application include biomass and yield estimations; vegetation vigor and drought stress monitoring; assessment of crop phenological development; crop acreage estimation and cropland mapping; mapping of land cover and land use change, or soil moisture estimations and assessment of crop damage (Atzberger 2013). For assessing on-site and global public benefits, this stream of data and related historical observations could be helpful.

7. Conclusion

83. **Based on a comprehensive literature review, we identify ten features that are expected to affect the results and quality of economic and financial analyses, specifically cost-benefit analyses, of climate-smart agriculture**. Not all of them are specific to the objectives of climate-smart agriculture of achieving productivity increases, resilience and adaptation to climate change and climate mitigation benefits, but could be relevant nevertheless:

- ✓ Climate change poses a major threat to food systems and livelihoods. A key objective of CSA is to address and **build resilience to climate change risks and uncertainty**. These aspects should be factored in explicitly into an economic analysis. The expected benefits of potential investments may be different when future climate change is considered, or climate risk and uncertainty are considered, and may lead to different results than in a "business-as-usual" case.
- ✓ Achieving **climate mitigation** is a dedicated goal of CSA and sets climate-smart agriculture practices apart from other improved agricultural practices. To ensure that the mitigation potential is correctly estimated, detailed data collection in the without and with project scenario and activities is crucial.
- ✓ CSA shows a high spatial interconnectedness. CSA practices are known to have spatial positive externalities and therefore, considering CSA within a **climate-smart landscape** is crucial. Adding on-site public benefits to an EFA would provide a more complete picture of CSA and should be explored.
- ✓ Several CSA practices are known to enhance benefits such as crop yield increases in the long-run but may not show yield increases in the short run. To ensure benefits are captured adequately in the economic analysis, a good understanding of **expected crop yield, which could be lower than under conventional practices in the onset, and delays in accrual of benefits**, and the possibility to have lower-crop yields than under conventional practices is also critical.
- ✓ CSA benefits are **context-specific and vary across biophysical conditions**. Yield increases under CSA management are known to by agroecological zone. Instead of considering average yield increases in an economic analysis, site-specific data should be considered to provide a realistic assessment of benefits and better support the project design.
- ✓ CSA tends to **increase production cost**, specifically labor cost in early phases of adoption. Labor cost, specifically family labor, should be carefully considered and costed in an EFA, to manage expectations about potential benefits of CSA and adoption rates.
- ✓ CSA has varied impacts **on different types of farmers, depending on their land size and income.** Thus, considering the heterogeneity of farmers and the distributional impacts of promoting CSA – within a landscape and community but also within a household – in economic are important and provides a complete picture of actual benefits of CSA to a community.
- ✓ Literature shows that CSA may **not be adopted on the entire farm**, but only on a share of the farming area. Adoption rates on-farm should be carefully assessed to avoid overestimating benefits, rather than assuming a normalized unit measurement of one hectare for the financial analysis.
- ✓ CSA is more than a single technology and farmers often adopt a **combination of practices**. Considering CSA as a combination of practices may provide insights about the financial viability of CSA as well as sensitivity to certain risks.
- ✓ To consider the **impact of CSA on livestock systems**, an understanding of the type of public and private benefits and cost is necessary as well as size and characteristics of the livestock herd.

84. We review a range of economic and financial analyses of recent investment projects which have been assigned a high share of climate co-benefits to understand to which extent these features have been addressed. We want to highlight three findings:

- Project economic analyses are **doing well in considering environmental externalities**, such as climate mitigation or on-site public good benefits from activities within a landscape. While climate mitigation benefits are always quantified - using a shadow price of carbon or a carbon market price – landscape-level benefits are frequently described qualitatively. In going forward project economists should enhance the quantification of environmental benefits.
- While climate change, uncertainty and risk are key challenges for food systems around the world, and one of the reasons why CSA practices are increasingly promoted, **only 50 percent of economic analyses in this report consider climate risks and changes explicitly**. Economic analyses often include discrete sensitivity analyses which assume a decline in crop yields to demonstrate the robustness of the investment. These sensitivity analyses are rarely related to climate change scenarios or projections or risk analyses and may not provide an accurate picture of benefits of the investments.
- **Only one project economic analysis considers distributional impacts of CSA promotion** and whether heterogeneous farmer in a community benefit in the same way, even though this may affect the economic results. It is recommended that project economist increase efforts to obtain information about beneficiaries and address heterogeneity in the analyses and address potential distributional effects of promoting CSA in a community.

85. **The report concludes with recommendations, which methods could be applied to strengthen some of CSA's typical features, such as climate change, risk and uncertainty, in a cost-benefit analysis**. Most critical shortcoming to address is the consideration of climate change considerations. To better account for climate change in a sensitivity analysis: (i) Monte Carlo simulation could be considered to focus on the expected distribution of economic indicators, rather than on one expected mean value. Compared to other approaches Monte Carlo analyses is less data and resources intensive and open-software packages make the appraoch readily applicable; (ii) Scenario analysis could be considered which build on climate impact assessments, crop simulation models to design optimistic and pessimistic scenarios which can be considered for sensitivity analysis; (iii) to account for the value of waiting and understanding what the optimal portfolio of adaptation options looks like under climate change and risk, real option analysis and portfolio analysis could be considered. Both approaches are knowledge and data intensive and may be less suitable for an economic analysis of investment projects.

86. **To enhance the inclusion and quantification of environmental externalities as well as distributional considerations in economic analysis several suggestions are made.** The report reviews several greenhouse gas accounting (GHG) models which can support the quantification of climate mitigation benefits. In addition, remote sensing information and a range of biophysical indicators can be used to support the quantification of positive environmental externalities of CSA. To further support the inclusion of distributional consideration, economists should make a stronger effort to understand farmers heterogeneities in project communities and how differently they may benefit from project interventions. During project appraisal and data collection for the EFA, analysts should engage more with focus group discussions to verify data and get additional information about current practices in the community. Impact evaluations and or more extensive monitoring and evaluation arrangements in ongoing CSA projects, could provide lessons-learned for future economic analyses. Upon a thorough understanding of

the project community, distributional effects could be addressed in an EFA as follows: (i) identifying and cataloguing how project related cost and benefits are distributed, and by (ii) assigning distributional weights to certain beneficiary groups. The latter is prone to criticism due to high level of subjectivity in the assessment and needs to be discussed and agreed on carefully with the client and task team.

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ANNEX A. SUMMARY AND EVALUATION OF PROJECTS

P154784: Kenya-Climate Smart Agriculture Project

1. The proposed project development objective is "to increase agricultural productivity and build resilience to climate change risks in the targeted smallholder farming and pastoral communities in Kenya, and in the event of an Eligible Crisis or Emergency, to provide immediate and effective response." Components in Table X.

Table: Project components

Component 1	Upscaling Climate-Smart Agricultural Practices
Component 2	Strengthening Climate-Smart Agricultural Research and Seed Systems
Component 3	Supporting Agro-weather, Market, Climate, and Advisory Services
Component 4	Project Coordination and Management
Component 5	Contingency Emergency Response

1. **Approach of the EFA:** The detailed EFA analysis has three parts. The **first** part is an **overview** of tangible and intangible benefits, including tangible benefits from productivity and income increases, intangible benefits such as community benefits, project governance benefits by CDD approaches, environmental benefits, and benefits from improving nutrition. The **second** part is the **financial analysis**, comparing "with project" and "without project" scenarios at the farm level to estimate the financial viability of adopting CSA Technologies, Innovations, and Management Practices (TIMPs) for 11 commodities identified as climate-smart priority commodities in the 24 participating counties with about 521,500 households as direct beneficiaries. The financial analysis shows positive incremental net benefits for adopting CSA TIMPs, including improved seed and animal breeds; and improved agronomic, animal, and tree husbandry practices. The **third** part is the **economic analysis**. It evaluates the project's benefits and costs to the national economy. The economic analysis aggregates net incremental benefits from adopting CSA TIMPs (valued in economic terms) and monetized environmental benefits expected to accrue from reduced GHG emissions and increased carbon sequestration.

2. Economic and financial indicators are listed in Tables X-X below.

Table X: Results, i.e., financial indicators of the project financial analysis, for each commodity/CSA practice.

Commodities	***CSA practices***	***Benefits-costs ratio WP***	***Switching values cost WP***	***Switchin g values benefits WP***	***NPV increm ental net benefit***
Cassava/beans	Intercropping with beans to improve soil productivity, optimal spacing, drought and disease tolerant varieties, increase in manure application	1.40	0.40	-0.29	2,523
Sorghum/green grams	Improved seed, fertilizer, and soil management practices	1.79	0.79	-0.44	794

Finger millet	Drought-tolerant and high-yielding varieties, improved crop management practices such as improved sowing techniques and fertilizer application	1.45	0.45	-0.31	403
Pigeon peas	Adoption of adapted (drought-tolerant) varieties, a more timely planting date, improved plant population density and spacing, fertilizer application at the beginning of the season, and optimal application of chemicals for pest/disease control	2.08	1.08	-0.52	672
Bananas	Adoption of TCB, soil testing, improved fertilizer application, and mulching	5.34	4.34	-0.81	5,803
Tomatoes	Improved weeding and disease control, improved seed, soil analysis to allow fertilizer application, and mulching	5.20	4.20	-0.81	7,983
Irish potatoes	Introduction of clean, certified seed, soil testing, improved timing of planting, and improved fertilizer type and application	1.69	0.69	-0.41	2,202
Dairy	Preventive health checks, improved hygiene to reduce risk of mastitis, establishment of pastures, adoption of feed conservation practices, and improved feed formulation and quantity of supplementary feed	2.52	0.28	-0.60	4,085
Local poultry	Improved indigenous chickens, hens are vaccinated and receive supplementary feeding	2.54	1.54	-0.61	707
Apiculture	A local honey refinery facilitating the adoption of modern Langstroth beehives among community members	5.56	4.56	-0.82	12,413
Cattle	Improved market information, pastoralism integrating livestock husbandry with other activities	1.72	0.72	-0.42	643

Table: Key economic and financial indicators

Key project indicators:	
Beneficiaries	108,900 households will have adopted at least one CSA TIMP
Total investment costs	US$279.7 million
Timeframe	20 years
Economic indicators:	
Economic discount rate	6.0 %
ENPV	US$304 million
EIRR	16.7 %
Financial indicators:	
Financial discount rate	12.0 %
FNPV	range from US$403 for millet to US$12,413 for honey
Financial Benefit-cost ratios	range from 1.40 for cassava-bean to 5.56 for honey
Lowest switching value across all commodities	-28 for the reduced benefits; 29 percent for increased costs

3. **Sensitivity analyses** for key variables demonstrate the robustness of the results (Table below). The NPV is positive for all proposed changes, and the EIRR is above 6%, the opportunity cost of capital. The analysis thus supports the public investment decision (Table X). Table X provides a **ranking, for each CSA-specific area.**

Table X: Sensitivity analysis

Changes	NPV (US$)	EIRR (%)	Changes	NPV (US$)	EIRR (%)
Base case					
	303,984,720	16.7			
Change in adoption rate			Change in project cost		
-10%	250,832,014	15.2	+10%	280,133,777	15.3
-20%	197,679,308	13.6	+20%	256,282,833	14.1
-30%	144,526,601	11.9	+30%	232,431,890	13.0
+10%	357,137,426	18.1	-10%	327,835,664	18.3
+20%	410,290,133	19.4	-20%	351,686,607	20.1
+30%	463,442,839	20.6	-30%	375,537,551	22.2
Change in incremental net benefits			Area on which TIMPs are adopted		
-10%	249,735,305	15.2	2 acre	228,934,696	14.6
-20%	195,485,889	13.6	1.5 acre	153,884,672	12.2
-30%	141,236,474	11.8	1 acre	78,834,648	9.4
+10%	358,234,136	18.1	3 acre	379,034,744	18.7
+20%	412,483,551	19.5	3.5 acre	454,084,768	20.5
+30%	466,732,967	20.7	4 acre	529,134,792	22.1
Change in social value of carbon			Delay of project benefits by 1 year		
0 USD/tCO_2e	293,017,628	16.3	1 year	252,719,289	14.5
30 US$/t$CO_2$e	325,918,905	17.5			

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Score	Explanation
Context-specificity (location)	++	County-specific information; but not site-specific information.
Increased production cost; family labor valued	++	Changes in production inputs for each commodity are described
Phasing of crop yields	nc	Not clearly described in the text
Climate adaptation and resilience	+	The analysis mentions that CSA can reduce production losses and enhance resilience; the effect is not quantified.
GHG emission reduction and carbon sequestration	++	Environmental benefits/public good benefits quantified and included at a shadow price of carbon in the analysis
Heterogeneity of farmers	nc	“analysis treats farmers as homogeneous entities and assumes average values”
Partial adoption of CSA	++	Sensitivity analyses of the financial analysis accounts for decline in area where TIMPs are adopted
Climate-smart landscapes	+	On-site public benefits are qualitatively described, but not quantified
Combination of practices	+	Several technologies were assumed in crop budgets; but no assessment made what the impact of single vs multiple technologies is
Livestock (information on benefits and herd development)	++	Strongly comply: dairy, pastoralist system, honey and eggs are assessed and described. Herd-dynamics are modelled with DYNOMOD.
Equity	nc	no mentioned
TOTAL CSA - SCORE	**1.18**	

CSA – Intensity	**1.62**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses.

P153420: Niger – Climate-Smart Agriculture Project

4. **The project development objective** is: (i) to enhance adaptation to climate risks, (ii) to improve agricultural productivity among the Targeted Communities and (iii) in the event of an Eligible Crisis or Emergency, to provide immediate and effective response to said Eligible Crisis or Emergency.

Table: Project components

Component 1	Investments for scaling up climate-smart agriculture
Component 2	Innovative practices and improved service delivery for mainstreaming CSA
Component 3	Contingency Emergency Response
Component 4	Project coordination and management

5. **Project description:** The project supports a demand-driven and integrated approach focusing on activities that will: (i) improve the utilization rate of selected and drought-tolerant seeds; (ii) increase the number of farmers using irrigation; (iii) increase the use of agroforestry and conservation agriculture techniques to minimize climate risks and enhance food security; (iv) promote the reclamation of degraded agro-pastoral land; (v) protect the watershed from erosion and secure irrigation potential; (vi) promote livestock and other high potential value chains (dairy, poultry, crops, vegetables, aquaculture, fruits trees, animal feeds and mechanization); and (vii) improve market access.

6. **Approach of the EFA:** The Project activities are expected to generate three main benefit streams: (i) farmers-, community- and commune-level benefits, such as increased crop yields, increased animal productivity, increased revenues, resilience to climate change risks, together with more intangible social benefits such as improved nutrition, human capital strengthening and women empowerment, (ii) public benefits, such as capacity development and institutional support to decentralized authorities to promote CSA interventions and mainstream them into communal investment plans; and (iii) more global benefits, such as natural resources protection and reduced GHG emissions which also contributes to migration benefits. In addition, the analysis of adaptation activities has been modeled dynamically, more particularly for rain-fed systems that are more vulnerable to weather's vagaries to calculate adaptation benefits. The **economic analysis** assesses the overall project's net impact on economic welfare. To calculate the total incremental benefit stream resulting from the project, the analysis aggregated benefits arising from (i) sustainable increase of agricultural production (irrigated and rain-fed systems), (ii) sustainable increase of livestock production, (iii) increased carbon sequestration in soils and biomass (mitigation co-benefits) and, (iv) public infrastructures, such as rural roads.

Table: Key economic indicators

Key project indicators	
Beneficiaries	500,000 farmers and agro pastoralists
Investment costs	US$117.8 Million
Timeframe	20 years
Economic discount rate / OCC	6.0 %
Economic indicators:	

ENPV	US$98,155,000
EIRR	16.4 %

7. The **financial analysis** focuses on a wide sample of sub-projects (rain-fed and irrigated systems). Cereals include millet (mono-cropped), millet (in association), and sorghum (in association); pulses include cowpea (in association) and groundnuts (in association); irrigated crops (drip irrigation) include tomatoes, cabbages, sweet potatoes, sugar cane, and onion. For rainfed crops, CSA techniques as below could be applied: (i) the use of selected drought-tolerant and short cycle seeds, (ii) the integration of micro-doses of mineral fertilizer with organic fertilizer/manure, (iii) the assisted natural regeneration (ANR), (iv) the construction of rain water harvesting soil bunds coupled with organic manure. In addition, there are aggregated benefits from livestock interventions (vaccination campaigns, improved management of pasture lands) calculated with herd dynamics models.

Table: Financial analysis of sub-projects (rainfed systems)

Commodities	CSA investment	IRR %	NPV @ 8%
Millet/cowpea	ANR, Zaï/Tassa, animal traction, tools, living hedges etc.	15.2	110,514
Millet/sorghum/cowpea		20.3	190,816
Millet/groundnut		22.5	222,402
Millet		10.2	33,607

Table: Financial analysis of sub-projects (irrigated systems)

Commodities	CSA investment	Gross margin/ha (CFA)	Gross margin/ beneficiary (1 HH operates on 0.25ha)	IRR % (10 years)	NPV @ 8% (10 years, '000 FCFA)
Onions	About 3,8 million CFAF/ha, inc. wells, pumps, drip irrigation, farming tools, living hedges, livestock units	1,435,480	358,870	37.5	4,628.0
Tomatoes		1,228,572	307,143	28.8	3,103.8
Cabbage		1,160,347	290,087	21.5	2,096.6
Sweet potatoes		1,399,016	349,754	32.8	3,791.6
Sugar cane		1,023,129	255,782	19.1	1,651.3

8. The **sensitivity analysis** was performed using variables as table shows below. Results remain robust against changes in these variables, with positive NPVs and IRR above the opportunity cost of capital.

Table: Sensitivity analysis

Modeling scenario	EIRR %
Base scenario	16.4
With yield decreases…	
…by 10%	14.0
…by 20%	12.7
With output price decreases…	
…by 10%	14.5
…by 20%	12.5
With decrease in the social price of carbon…	
…by 30%	15.5
…by 40%	15.2
With a drought every 5 years, reducing benefits…	
…by 50%	15.4

…by 70%	15.0
With a reduction of the adoption rates…	
…by 10%	14.2
…by 20%	12.2
With a total reduction of the benefit stream…	
…benefits reduced by 10%	14.5
…benefits reduced by 20%	12.5

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Score	Explanation
Context-specificity (location)	++	Information from community action plan
Increased production cost; family labor	nc	Not described in the PAD
Phasing of crop yields	++	Phasing of benefits is clearly described
Climate adaptation and resilience	++	Qualitatively described and models shocks/drought frequency and impact
GHG emission reduction and carbon sequestration	++	Mitigation benefits from increased carbon sequestration in soils and biomass
Heterogeneity of farmers	nc	
Partial adoption of CSA	nc	The sensitivity analyses considers changes in adoption rates, but no changes in hectare area.
Climate-smart landscapes	+	On-site public benefits are qualitatively described, but not quantified
Combination of practices	+	Crop rotation is assumed; otherwise not clear whether technologies were assessed in combination
Livestock (information on benefits and herd development)	++	ECORUM interface of the Livestock Sector Investment Policy toolkit (LSIPT) was used
Equity	nc	
TOTAL CSA - SCORE	**1.09**	
CSA – Intensity	**1.71**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses.

P163444: Uruguay - Sustainable Management of Natural Resources and Climate Change Project

9. **The development objective** of the project is to support Uruguay's efforts to promote farmer adoption of climate smart agricultural and livestock practices, and improved natural resource management practices in project areas.

Table: Project components

1	Agricultural Information and Decision Support System
2	Territorial Interventions and On Farm Investments for CSA and Livestock Management
3	Capacity Building and Training
4	Project Management and the M&E system

10. **Approach of EFA**. With the scale-up of investments in irrigation subprojects, the enhancement of benefits under National Agricultural Information and Decision Support System (SNIA), and further strengthening of OPYPA, the pattern of benefits generated by the Project has changed. In addition, with the injection of the AF resources and Government counterpart financing, the costs of the Project have also changed. The AF uses the cost-benefit methodology to capture the new estimation of economic benefits from the Project. The costs considered were the AF, Government counterpart financing and beneficiary contribution, and the benefits were analyzed from the perspective of direct, indirect and co-benefits. The project is expected to generate three types of benefits. First, direct benefits will be derived from productive improvements in the beneficiary farms that can be completely appropriated by the beneficiaries through the market system. Second, indirect benefits will derive in the form of increased adaptive capacity to climate change and shocks. Third, environmental co-benefits will be derived from the restitution of ecosystem services, understood as goods, products or services provided or regulated by ecosystems for global benefit. The following analysis quantifies all three of these benefit types (Table XX- XX).

Table: Estimated benefits of Component 1

Parameter	Value	Unit
Family cattle ranchers	15,900	Establishments
Total area covered by ranchers	1,280,000	190,816ha
Average production	80	222,402kg/ha
Use of Ag info	48%	Ratio
Estimated adoption of info	**10%**	**Producers**
Output of info	0.25	Kg/ha
Contribution of SNIA	0.25	
Estimated price of meat	**1.7**	**USD/kg**
Benefits	**572,416**	**USD/yr**

Table: Estimated benefits of increased milk production in Component 2

Parameter	Value	Unit
Total milk impact	7.5%	Ratio
Total milk impact	7,900,000	liters
Milk price	0.3	USD/lt
Investments APA 1	3,000,000	USD
Investments APA 2	3,450,000	USD
Coverage of the APA 2 producers	713	
Ration of milk / beef producers	100%	Ratio
Benefits	**2,725,500**	**USD/yr**

Table: Estimated benefits of increased meat production in Component 2

Parameter	Value	Unit
Meat production without project	80	Kg
Impact in kg of meat	7.6	
Production of meat with project	87.6	Kg
Price	1.7	USD
Area	210	Ha
Coverage of GFCC 1	1,100	Sub-proyectos
Individual cost of GFCC 1	7,300	USD

Investment in projects	7,300,000	USD
Benefits	**2,745,120**	**USD/yr**

Table: Estimated benefits of GHG avoided in Component 2

Parameter	Value	Unit
Actual coverage	4	Cm
Additional coverage	1	Cm
Gain	0.2	Ton C/ha/yr
Sequestration of CO2	0.733	Ton C/ha/yr
Grass height	10	Cm
Area of grass	172,964	Ha
Carbon price	5	USD/ton
Co-Benefits	**317,100**	**USD/yr**

Table: Estimated benefits in Component 3

No.	Part	Value
1	Support for generating relevant information	Included in the estimated value of other components
2	Consolidation of soil	Using a discount rate of 4%, the NPV would be US$174,000,808
3	Consolidation of the water area	Expressed through the interventions related to water availability described in Component 2
4	Consolidation of the natural pasture area	Included in the provision of information and coordination of natural field- based livestock interventions included in Component 2

Table: Key economic and financial indicators

Key project indicators		
Beneficiaries	3,900	
Total investment costs	US$47.2 million	
Timeframe	20 years	
Financial indicators:		
Economic discount rate	4.7 %	
FIRR	25-42 %	
Economic indicators:		
	Base (component 2)	**All components (1,2,3)**
Value of benefits (USD)	67,993,600	81,826,621
Value of costs (USD)	37,760,842	37,760,842
ENPV (USD)	30,232,758	44,065,778
EIRR	12.7 %	17.5%

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Score	Explanation
Context-specificity (location)	++	Uses data from impact assessment in similar area
Increased production cost;	nc	Not described

family labor		
Phasing of crop yields	++	Model a decline in crop yields due to erosion.
Climate adaptation and resilience	+	For one model, production model data from a Family Cattle and Climate Change (GFCC) program was used; but no sensitivity analysis of models
GHG emission reduction and carbon sequestration	++	Mitigation benefits quantified and valued.
Heterogeneity of farmers	nc	"sub-projects with similar characteristics"
Partial adoption of CSA	++	"beneficiaries are expected to irrigate 3% of the area of their farm."
Climate-smart landscapes	++	Evaluate a Subproject "improved water management"
Combination of practices	nc	Not described
Livestock (information on benefits and herd development)	++	Strongly comply: livestock producers use SNIA information to make better productive decisions; development of livestock Insurance is also included; promoting the sustainable adoption of technology and good productive practices
Equity	nc	
TOTAL CSA - SCORE	**1.18**	
CSA – Intensity	**1.85**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses.

P158522: India – Tamil Nadu irrigated Agriculture Modernization Project

11. **The Project Development Objective (PDO)** is to enhance productivity and climate resilience of irrigated agriculture, improve water management, and increase market opportunities for farmers and agroentrepreneurs in selected sub-basin areas of Tamil Nadu.

Table: Project components

Component 1	Irrigation and Water Management
Component 2	Agriculture Productivity Enhancement, Diversification, Improved Livelihoods, Marketing, and Value Addition
Component 3	Project Management Support
Component 4	Contingency Response

12. **Approach of EFA.** The financial analysis has been carried out for the 7 agricultural crops (paddy, maize, finger millet, minor millets, pulses, groundnut, and sugarcane), 15 horticultural crops (e.g. brinjal, bhendi, tomato, green chilies, gourds, TCB, tuberose, mango, guava, pomegranate), and fodder crops, as well as for the livestock and fisheries interventions. The main economic benefits of the proposed project are expected to come from (a) increase in area under production and productivity increases associated with improved irrigation systems; (b) diversification from food grains into high-value agriculture and livestock and fisheries activities; and (c) improved marketing, postharvest management, and value addition. In addition to the increases in productivity and production of higher-value crops, it is expected that establishing the CGs and FPOs and facilitating PPPs will lead to increased incomes of beneficiaries due to (a) higher prices for the agricultural produce through better aggregation and new market channels, also resulting from improved market information; (b) potentially reduced input prices resulting from procurement by the FPOs in bulk; and (c) increased value addition through Farmer Common Service Centers

(FCSCs) created by the FPOs for postharvest activities, including cleaning, grading, sorting, and processing. Furthermore, the project will support productive postharvest management infrastructure.

13. In addition, there will be significant benefits coming from improved resilience to climate change and positive nutritional effects associated with the diversification of production systems toward high-value agriculture crops and livestock and fisheries activities. Major potential economic benefits also accrue through flood protection with regard to avoided losses and damages associated with the failure of tanks that may be affected without rehabilitation. The **economic analysis** attempts to quantify the economic benefits resulting from part of subcomponents, which are a precondition for the effective implementation of the project. However, the economic costs of all subcomponents have been included in the economic analysis. Given the uncertainties with estimating the potential benefits from flood protection, these were not included in the economic analysis.

14. The results of the **sensitivity analysis** show that the project remains economically viable also in the case of adverse changes in project costs and benefits. Additionally, expected reduction in GHG emissions will increase the overall economic benefits.

Table: Key economic indicators and sensitivity analysis

Beneficiaries			**500,000**	
Total investment costs			**US$ 455.8 million**	
Economic discount rate			**10 %**	
Scenario			**EIRR (%)**	**ENPV (US$,000)**
Base Case			25.4	363,841
Base Case (GHG)[a]			27.0	476,080
Changes (Base Case without GHG)			—	—
Project Costs	**Incremental Benefits**	**Benefits Delayed**	**—**	**—**
+20%	—	—	20.6	289,014
+40%	—	—	17.1	214,188
	−20	—	19.7	216,246
	−40	—	13.3	68,652
+20%	−20	—	15.5	141,420
+40%	−40	—	6.9	−81,001
Base Case		1 year	19.7	20.2%
		2 years	16.3	16.7%
		3 years	13.6	13.9%
		1 year	12.5	69,314
+20%	−20	2 years	10.1	3,764
		3 years	8.1	−55,828
Scenario			**EIRR (%)**	**ENPV (US$,000)**
Switching values[b]			**—**	**—**
Costs	+	97%	—	—
Benefits	−	49%	—	—

a. GHG mitigation benefits valued at US$30/$tCO_2e$. b. Percentage change in cost and/or benefit streams to obtain an EIRR of 9 percent, that is, economic viability threshold.

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Grade	Explanation
Context-specificity (location)	nc	Not clearly described in the text
Increased production cost; family labor	++	Assess return to family labor

Phasing of crop yields	++	Accounted for
Climate adaptation and resilience	++	Climate resilience is mentioned, and assessed in e.g., climate-resilient fish production systems.
GHG emission reduction and carbon sequestration	++	Mitigation potential quantified and included in analysis
Heterogeneity of farmers	nc	Not described
Partial adoption of CSA	nc	Not clearly described in the text
Climate-smart landscapes	++	Potential water shed level benefits are mentioned, but not quantified: "downstream benefits through avoided flood damage"
Combination of practices	nc	Not clearly described in the text
Livestock (information on benefits and herd development)	++	Consider several benefits; but no herd dynamics model.
Equity	nc	Not clearly described in the text
TOTAL CSA - SCORE	**1.09**	
CSA – Intensity	**2**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses.

P160408: India - MAHARASHTRA PROJECT ON CLIMATE RESILIENT AGRICULTURE

15. **The project development objective** is to develop and/or promote agricultural production systems that are able to cope with changing climatic conditions, while enhancing farm productivity and facilitating the participation of small and marginal farmers in agricultural value chains.

Table: Project components

1	Promoting Climate-resilient Agricultural Systems
2	Post-harvest Management and Value Chain Promotion
3	Institutional Development, Knowledge and Policies for a Climate- resilient Agriculture
4	Project Management

16. **Approach of EFA.** The main project benefits for the targeted smallholder farmers are expected to come from: (i) improved stability in agricultural output and increased productivity of traditional crops through farmers' adoption of climate-resilient agriculture technologies and agronomic practices; (ii) diversification into new, suitably adapted, higher-value, climate resilient agriculture; (iii) improved post-harvest management and value-addition; (iv) a reduction in GHG emissions through on-farm carbon sequestration and the adoption of green technologies in agri-food processing. Most benefits will be derived from farm output stability and increased productivity (of at least 20 percent above baseline) due to project interventions on rain-fed land which represents about 80 percent of the 2.9 million hectares that constitute the project area. The remaining 20 percent of the land will benefit from drip and sprinkler irrigation, alongside the project's suite of interventions, with a projected impact on productivity of at least 50 percent. The cropping intensity in the project area is projected to stabilize at about 120 percent.

17. A series of crop and farm budgets were developed for “With-Project” and “Without-Project” scenarios. In order to derive economic prices from financial prices, fertilizer prices were adjusted to remove subsidies, commodity prices were adjusted to remove protective import duties where applicable, and a standard conversion factor of 0.9 was used on non-tradable goods. Table below summarizes key indicators.

Table: Key economic and financial indicators

Key project indicators	
Beneficiaries	1.7 million
Total investment costs	US$ 599.55 million
Timeframe	15 years
Economic discount rate/OCC	6 %
Financial indicators	
IRR	23 %
NPV (USD)	461 million
Economic indicators	
ERR	22 %
ENPV (USD)	415 million

18. **Sensitivity analyses** results show that the return on the project’s investment would remain above the opportunity cost of capital in the simulated scenarios (Table X).

Table X: Sensitivity analysis

	Benefits down by 30 %	Investment costs up by 30 %	Benefits down and Investment costs up by 30 % each
IRR	13%	16%	7%
NPV US$ mill.	184	322	45
ERR	12%	14%	6%
ENPV US$ mill.	152	276	413

19. **Mitigation benefits.** An analysis was also conducted incorporating the social value of carbon. On the basis of a net balance of -1.9 tCO_2-eq per hectare and a social value of carbon starting at US$ 34.4 in 2018, the ERR was estimated at 85 percent. Taking into account the sensitivity scenarios from the GHG accounting, the ERR reduces to 76 percent and 68 percent when the net GHG balance drops to -1.7 and -1.5 tCO_2-eq/ha/year respectively.

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Grade	Explanation
Context-specificity (location)	nc	Not clearly described
Increased production cost; family labor	++	Increases in labor time considered
Phasing of crop yields	nc	Not clearly described
Climate adaptation and resilience	++	Resilience benefits are explicitly mentioned; “benefits […] expected to come from: (a) improved stability in agricultural output and increased productivity of traditional crops through farmers’ adoption of climate-resilient agriculture technologies and agronomic practices”

GHG emission reduction and carbon sequestration	++	Mitigation benefits included in EFA
Heterogeneity of farmers	nc	Not described
Partial adoption of CSA	nc	Not described
Climate-smart landscapes	++	Landscape interventions explicitly considered and quantified
Combination of practices	+	Combinations of CSA practices applied; but difference between single and combination not tested.
Livestock (information on benefits and herd development)	nc	Livestock is considered in GHG analysis, but not in EFA, hardly information provided.
Equity	nc	Not described
TOTAL CSA - SCORE	**0.81**	
CSA – Intensity	**1.8**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply 9if an explanation is given as well; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses, to show whether project comply moderately; or strongly.

P157736: Pakistan - Additional Financing For Punjab Irrigated Agriculture Productivity Improvement Program Project

20. **The original PDO** is the projects development objective is to improve the productivity of water use in irrigated agriculture. The parent PDO will remain as is under the proposed AF. Project component are presented in Table X.

Table: Project components

Component 1	Installation of High Efficiency Irrigation Systems
Component 2	Upgrading of Community Irrigation Systems
Component 3	Improvement of Agricultural Technology and Practices, and Monitoring and Evaluation of Project and Environmental and Social Management Plan
Component 4	Project Management, Independent Project Supervision, Strategic Studies, and Technical Assistance to Project Implementing Entity

21. Under the AF project, another activity—constructing rainwater harvesting ponds—has been added to component A. Economic analysis has also been carried for this part of the component, separately as a subcomponent. The analysis estimates the overall IRR of the activity as 24%.

22. **Approach of the EFA.** In economic analysis, the data are drawn to include activities under original project components as below.

- Component A1: Improving Water Productivity (HEIS)
- Component A2: Laser Land Leveling
- Component B1: Improvement of Unimproved Canal Irrigated Watercourses
- Component B2: Completion of Partially Improved Watercourses
- Component B3: Rehabilitation of Irrigation Conveyance System in non-canal command area

23. Crops under HEIS include cucumber, tomato, hot pepper, capsicum, potato, wheat, cotton, sugarcane, maize, potato, kinno, lemon, guava, and mango. Crops under improved W/Cs farms include wheat, potato, cotton, maize, sugarcane, rice (fine), and rice (coarse). In the **results**, the **IRR** has been estimated for various project interventions to establish the economic viability of different sizes of farms and of each different source of irrigation.

Table: IRR (Percent) of HEIS for Various Crops and Farms

Sr.	Crops	At Appraisal				Based on Actual Data March 2016			
		Farm Size (Acres)				Farm Size (Acres)			
		3	5	10	15	3	5	10	15
A.	Drip Installation								
A.1	Existing Orchards								
i	Citrus	38.9	41.1	50.2	55.6	22.4	27.9	33.3	38.0
ii	Guava	31.7	33.3	40.6	48.4	13.8	17.9	21.8	25.1
iii	Mango	40.7	42.8	51.2	58.0	32.1	39.4	46.6	53.0
A.2	New Orchards								
i	Citrus	22.1	23.7	27.9	30.9	n/a	n/a	n/a	n/a
ii	Guava	21.4	22.0	26.3	31.4	n/a	n/a	n/a	n/a
iii	Mango	22.1	22.7	25.7	28.6	n/a	n/a	n/a	n/a
iv	Citrus + Vegetable	27.5	32.1	37.3	43.7	n/a	n/a	n/a	n/a
iv	Others (Grapes & Olives)	n/a	n/a	n/a	n/a	47.8	58.4	68.9	78.2
A.3	Vegetables								
	- Tomato	18.1	26.8	32.6	36.0	14.4	18.1	18.5	19.4
	- Potato	21.2	27.3	33.6	37.5	33.8	41.5	44.7	52.0
	- Chilies	20.9	28.4	34.0	38.3	n/a	n/a	n/a	n/a
	- Vegetables (Overall)	n/a	n/a	n/a	n/a	25.3	28.3	29.3	30.5
A.4	Other Crops								
i	Sugarcane	13.7	18.1	24.9	26.7	17.6	27.0	29.2	33.0
ii	Cotton	22.0	33.4	35.9	37.4	5.2	11.0	12.3	14.4
iii	Flower Roses	22.5	31.7	38.0	42.8	25.3	37.5	40.4	45.5
B.	Sprinkler								
i	Wheat Canal Command	15.8	19.6	30.5	31.0	6.5	10.0	13.8	16.6
ii	Wheat Barani Area	17.5	21.7	33.6	34.7	10.0	14.0	18.3	21.6
iii	Pulses	16.2	21.2	27.4	31.6	12.0	16.3	21.0	24.6
v	Maize	n/a	n/a	n/a	n/a	16.7	21.8	27.6	32.1

Table: Key economic indicators

Key project indicators:	
Beneficiaries	Not specified
Total investment costs	US$ 206 million
Timeframe	20 years
Economic indicators	
Economic discount rate/OCC	12 %
EIRR	30.2%

24. **Project costs** include investment costs and operation and maintenance costs. Strong ownership of these investments is confirmed by the very high demand and by users' substantial financial and in-kind contributions toward the investment cost. Using a similar approach as adopted at appraisal, the ERR has been estimated based on actual data for various project interventions to establish the economic viability of different sizes of farms and for each different source of irrigation. Key economic indicators are shown above. **Sensitivity analysis** also proves the robustness of the IRR; therefore, the investment of the AF project may be made without any substantial risk. Furthermore, the project has greenhouse gas (GHG) reduction co-benefits.

Table: Sensitivity Analysis: IRR Response %

Project intervention	PAD (Feb 2012)	Updated (Mar 2016)
Base case	32.6	30.2
Cost increased by 20%	25.7	25.6
Benefits reduced by 20%	24.2	22.2
Cost increased and benefit reduced simultaneously by 20%	18.5	18.7
Benefits delayed by two years	19.6	18.5

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Score	Explanation
Context-specificity (location)	++	Field surveys were performed and sampled data used
Increased production cost; family labor	nc	Not explicitly mentioned in EFA
Phasing of crop yields	nc	Not explicitly mentioned in EFA
Climate adaptation and resilience	nc	Not explicitly mentioned in EFA
GHG emission reduction and carbon sequestration	+	GHG Accounting applied, but value not included in EFA.
Heterogeneity of farmers	++	Conducted for different farm sizes.
Partial adoption of CSA	nc	Not explicitly mentioned in EFA
Climate-smart landscapes	nc	The project deals with irrigation, the EFA does not mention potential negative externalities on groundwater
Combination of practices	nc	Not explicitly mentioned in EFA
Livestock (information on benefits and herd development)	Not applicable	
Equity	nc	Not explicitly mentioned in EFA
TOTAL CSA - SCORE	**0.5**	
CSA – Intensity	**1.6**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses.

P153349: Kenya - National Agricultural And Rural Inclusive Growth Project

25. **The project development objective is** that the project will contribute to GoK's high-level objective, which aims at transforming smallholder subsistence agriculture into an innovative, commercially oriented, and modern sector by: (i) increasing the productivity, commercialization, and competitiveness of selected agricultural commodities; and (ii) developing and managing key factors of production, particularly land, water, and rural finance.

Table: Project components

Component 1	Supporting Community-Driven Development

Component 2	Strengthening Producer Organizations and Value Chain Development
Component 3	Supporting County Community-Led Development
Component 4	Project Coordination and Management

26. **Approach of the EFA.** The financial analysis uses "indicative enterprise models" or "farm budgets" to assess the financial and economic viability of **eight** selected VCs as table shows below. The financial analysis compares the "with project" to the "without project" scenario. The results show that NARIGP-supported activities would bring positive net present values (NPVs) for each enterprise. The NPVs range from US$577 for intercropped maize and beans to US$12,142 for TCB production.

Table: Commodities and financial indicators identified in the EFA

Commodities	NPV (in US$)	BCR	Switching value benefits	Switching values cost	IRR
Horticulture					
Tissue-culture banana – by kg	12,142	13.1	-92%	1208%	
Mango	1,626	2.0	-51%	102%	
Tomato	2,146	4.4	-77%	343%	
Cereals and pulses					
Maize-beans intercropped	577	1.49	-33%	49%	
Sorghum and green grams	692	1.34	-25%	34%	
Livestock					
Dairy: Semi-intensive grazing	1,098	1.4	-30%	43%	
Dairy: Milk cooler business	79,099	-	-	-	36%
Apiculture: 10 hives	5,268	3.8	-74%	280%	
Apiculture: 3 hives	950	2.7	-64%	174%	
Local poultry	8,227	1.89	-47%	89%	

Table: Commodities and CSA interventions identified in the EFA

Region	Value chain/activity	WOP situation	WP project situation (CSA practices)	No. of beneficiaries
Nyanza	Banana	Traditional banana production	TCB production	21,000
Coast	Mango	Traditional mango varieties	Integrated pest management	5,600
Western	Tomatoes	No input use, low productivity	Improved variety, input use, and improved productivity	19,600
Nyanza	Maize-green beans	No input use, low productivity	Input use, improved seed, and increased productivity	19,600
Eastern	Green grams-sorghum	No input use, low productivity	Input use and increased productivity	12,600
Rift Valley	Milk production	Free-range pasture system	Semi-intensification, improved breeding and feeding practices	53,200
	Dairy – post-	-	Milk cooler business	
Western	Apiculture	Maize-green bean cultivation without inputs	10 Langstroth beehives	8,400
Eastern	Poultry	Local poultry	Hybrid chicken breeds, improved feeding, intensification of	36,400

27. The economic analysis aggregates the incremental benefits of the above crop and livestock VCs and the incremental benefits related to potential reductions in GHG emissions.

Table: Key economic and financial indicators

Project key indicators	
Beneficiaries	176,400 participate in SLM and VC interventions
Total investment costs	US$219 million
Recurrent costs	US$14.3 million
Timeframe	20 years
Economic discount rate	5.0 %
Economic indicators	
ENPV	US$827.482 million
EIRR	21.8 %
Financial indicators	
Financial discount rate	12.0 %
FNPV	US$707 million
FIRR	20.9 %
Benefit-cost ratios	range from 1.3 for intercropped sorghum and green grams to 13.1 for TCB

28. Sensitivity analyses performed for the economic analysis demonstrate that the project is capable of absorbing substantial negative impacts and still generating an IRR of at least 14 percent, which is above the opportunity cost of capital and thus supports the investment decision.

Table: Sensitivity analysis

Changes	NPV (US$)	EIRR (%)
Base case		
	827	21.8
Change in adoption rate of improved agricultural practices		
-30%	519	17
-50%	313	13.6
Change in total project cost		
+30%	763	18
+50%	721	17
-30%	891	27
-50%	933	32
Change in incremental net benefits		
-30%	515	17
-50%	307	14
Change in social value of carbon		
0 USD/tCO2e	815	21.6
30 US$/tCO2e	852	22.2

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Score	Explanation

Context-specificity (location)	++	EFA uses county-specific data.
Increased production cost; family labor	++	Production cost described and family labour included and valued
Phasing of crop yields	nc	Not clearly described
Climate adaptation and resilience	nc	Not clearly described
GHG emission reduction and carbon sequestration	++	Mitigation benefits quantified and included in the economic analysis
Heterogeneity of farmers	nc	Not clearly described
Partial adoption of CSA	nc	Not clearly described
Climate-smart landscapes	+	On-site public benefits are mentioned qualitatively, not quantified
Combination of practices	+	Combination of practices used, but the effect between single and combination is not assessed.
Livestock (information on benefits and herd development)	nc	A livestock model is used, but the benefits streams and herd dynamics not described,
Equity	+	The impact on women and nutrtion is mentioned qualitatively.
TOTAL CSA - SCORE	**0.81**	
CSA – Intensity	**1.5**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses.

P162908: Haiti - Resilient Productive Landscapes Project

29. **The Project Development Objectives** are: (i) to improve the adoption of resilience-enhancing agricultural and landscape management practices in selected sub-watersheds11; and (ii) to enable the Government to respond promptly and effectively to an eligible emergency.

Table: Project components

Component 1	Strengthening of institutional and organizational capacity for landscape level interventions
Component 2	Investments to strengthen resilient agricultural production and practices
Component 3	Project coordination, monitoring and evaluation
Component 4	Contingency Emergency Response Component

30. **Approach of economic analysis**. The EFA taking into account the projected outreach to beneficiaries, hectares, returns from improved productivity, post-harvest handling, processing and marketing in the selected crops, and projected cost streams associated with the interventions. It has been undertaken taking into account the activities of Component 2 only. On the cost side both Components 2 and 3 have been included. Benefits are expected from increased production; improved productivity; increased marketed production; reduced imports of selected crops; increased processed capacity of primary agriculture products; reduced post-harvest losses; and improvements in food security. In addition, there are also major institutional benefits and social benefits.

Table: Commodities and project interventions including CSA practices identified in the EFA

Zone	Commodities	Interventions including CSA practices

Altitude>600m	Vegetable production with or without irrigation. Main crops: Cabbage; bean; yam	Post-harvest intervention: stocking; processing; marketing. Services: mechanization; vulgarization
Altitude 400-600m	Mixed cropping: Jardin Créole (fruit trees; vegetables; food crops); peanuts	Trees intensification for soil protection; cropping pattern adjustments; Post-harvest intervention: stocking; processing; marketing. Services: mechanization; vulgarization
Altitude 100-400m	Dry forest; maize; Congo Peas	Improved seeds; introduction of new varieties; Post-harvest intervention: stocking; processing; marketing. Services: mechanization; vulgarization
Altitude 0-100m	Scenario A) Rainfed agriculture: maize- sorghum; sorgo-pois; Congo-sweet potatoes	Improvement of existing crops: improved seeds; introduction of new varieties; Post-harvest intervention: stocking; processing; marketing. Services: mechanization; vulgarization.
	Scenario B) Small irrigation schemes: winter peas; vegetables; fruit trees	Improvement of existing crops: improved seeds; introduction of new varieties; Post-harvest intervention: stocking; processing; marketing. Services: mechanization; vulgarization.
	Scenario C) Rice	Improvement of existing crops: improved seeds; introduction of new varieties; Post-harvest intervention: stocking; processing; marketing. Services: mechanization; vulgarization.

Table: Financial indicators in processing activities

Activity	IRR %	NPV (USD)
Fruit Processing	21	46,000
Cocoa Processing	78	36,000
Yam Processing	30	24,900
Compost	64	63,700

31. The **financial analysis** for the processing and marketing activities mentioned in the table above foresees positive returns and cash flows. This underlines that using matching grants to encourage producers to adopt new technologies provides them with additional financial space, particularly during the first years when they are working their way further along the technology adoption learning curve. Furthermore, economic values of targeted crops have been converted from financial ones using the following conversion factor: 0.9. Table below shows key economic and financial indicators.

Table: Key economic and financial indicators

Project key indicators	
Beneficiaries	4,000 organized small-size farmers and processing entrepreneurs
Total investment costs	US$ 26.21 million
Timeframe	20 years
Economic discount rate	12%
Economic indicators	

ENPV	USD 7.5 million
EIRR	20.8%
Financial indicators	
FIRR	21 – 78%

32. The **sensitivity analysis** shows robustness to both decreases in benefits and increases in costs. The Project is more sensitive to changes in benefits and adoption rates. If the adoption rate were to fall to 45 percent or below (e.g. lower/no yields increases or hectares without production), then the EIRR would fall below the 12 percent threshold level and NPV would be negative. Decreases in expected benefits by more than 30 percent also lead to unsatisfactory economic indicators.

Table: EIRR of sensitivity analysis

Base case scenario	Project Benefits					Project Costs		Delay in benefits		Adoption rate	
	-30%	-20%	-10%	+10%	+20%	+10%	+20%	1 year	2 year	60%	50%
20.8%	14.7%	16.9%	18.9%	22.6%	24.3%	19.1%	17.6%	17.6%	15.1%	18.1%	15.0%
						Total costs		Total benefits			
Switching values						+69%		-30%			

Table: EFA compliance with features of CSA

Features of CSA	Score	Explanation
Context-specificity (location)	++	Crop models aligned to agro-ecological zones
Increased production cost; family labor	nc	Not mentioned
Phasing of crop yields	nc	Not mentioned
Climate adaptation and resilience	nc	Not mentioned
GHG emission reduction and carbon sequestration	nc	GHG Accounting was performed but value not included in economic analysis
Heterogeneity of farmers	nc	Average farming household is assumed.
Partial adoption of CSA	nc	Not mentioned
Climate-smart landscapes	+	On-site public benefits are mentioned qualitatively, but not quantified.
Combination of practices	+	Combination of practice but not an assessment whether single or combination works better
Livestock (information on benefits and herd development)	Not applicable	
Equity	nc	Not mentioned
TOTAL CSA - SCORE	**0.36**	
CSA – Intensity	**1.3**	

P125728: Tanzania - Southern Agricultural Growth Corridor Of Tanzania (Sagcot) Investment Project

33. **The Project Development Objective (PDO)** is to increase the adoption of new technologies and marketing practices by smallholder farmers through expanding and creating partnerships between smallholder farmers and agribusinesses in the Southern Corridor of Tanzania.

Table: Project components

Component 1	Strengthening of Southern Agricultural Growth Corridor of Tanzania (SAGCOT) Support Institutions
Component 2	Strengthening Smallholder Business Linkages
Component 3	Project Management and Monitoring and Evaluation

34. **Approach of the EFA**: Project benefits include: improved productivity; value-addition, and market opportunities, resulting in increased incomes and employment opportunities, and improved food security. These benefits will primarily result from: (a) adoption of new technology packages which lead to increased production and productivity; (b) reduced post-harvest losses; (c) improved produce processing and/ or packaging; (d) improved access to services, markets, and information; (e) reduced transaction costs; (f) improved product quality and producer (farm-gate) prices; and (g) improved economies of scale. Increased output, income, and employment in the targeted zones will result in increased demand for goods and services, which is expected to generate additional income and employment effects, and increase government tax revenues. There are also institutional benefits and social benefits.

35. The mode of intervention will be a partnership, with nucleus farmers, warehouse operators, processors or other private entities, who will extend services to smallholder farmers and create market opportunities for their production. The Project will provide grants to the private investors to help them meet the initial costs required to establish out-grower schemes, or other contract farming arrangements. This estimate has been based on a methodology whereby the Project is assumed to trigger private sector initiatives that otherwise would not happen. The increase in outputs and profits associated with the Project is therefore expected not to be realized without the Project. Nonetheless, to simplify the analysis the indirect benefits have been excluded, thus, giving lower results that would have been the case otherwise.

36. As for **financial analysis**, the valuation of the benefits uses a two-stage calculation which first estimates the extra output created by assisted firms, and second estimates the profit associated with that output. The increase in output is solely attributed to the increased production of smallholder farmers. The analysis is based on two models: an avocado out-grower scheme with packing, storing and exporting facility and rice out-grower scheme. All prices are expressed in constant prices of August 2012 and the foreign exchange rate is fixed. Economic farm-gate prices of internationally traded agriculture inputs and outputs are calculated in the form of export or import parity prices. No shadow prices are assumed. Transfer payments such as tax, duty or subsidy interest are not applied and were excluded in estimating economic benefits and costs. Financial costs equal economic costs.

Table: Economic and financial indicators

Key project indicators	
Beneficiaries	100,000 smallholder farming households

	(some 500,000 people) and at least 40 agribusiness operators	
Total investment costs	US$ 108.5 million	
Timeframe	20 years starting from 2015	
Economic discount rate	12 percent	
Economic models	**NPV**	**IRR**
Benefits to Smallholder Farmers only	US$8,848,646	15.6 percent
Benefits to smallholder farmers and agribusinesses	US$9,482,121	14.4 percent
Financial models		
avocado out-grower scheme with packing, storing and exporting facility	US$1,083,875	19.5 percent
rice model out-grower	US$307,592	14 percent

37. **The sensitivity analysis** switched values on the matching grants component. The first evaluation was done by elongating the disbursement to 6 years by delaying disbursement of each respective grant by 1 year. The effect on the project was that the NPV was reduced to US$3.5 million and the EIRR to 12.9 percent. This suggested that a slower implementation period would have a significant material effect on the economic impact of the project. The second evaluation was done by modifying the success rate of chosen projects. In this case by increasing the failure rate from 10 percent (the base case) to 20 percent, the NPV remained positive at US$4.8 million with an EIRR of 13.3. Reducing the expected benefits by 10 percent produces an EIRR of 12.3 percent and a NPV of US$1.1 million.

Table: EFA compliance with features of CSA

Features of CSA	Score	Explanation
Context-specificity (location)	nc	Not mentioned
Increased production cost; family labor	nc	Not mentioned
Phasing of crop yields	++	Late onset of yields is explicitly mentioned
Climate adaptation and resilience	nc	Not mentioned
GHG emission reduction and carbon sequestration	nc	Not mentioned
Heterogeneity of farmers	nc	Not mentioned
Partial adoption of CSA	nc	Not mentioned
Climate-smart landscapes	nc	Not mentioned
Combination of practices	nc	Not mentioned
Livestock (information on benefits and herd development)	nc	Not mentioned
Equity	nc	Not mentioned
TOTAL CSA - SCORE	**0.18**	
CSA – Intensity	**2**	

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38. **The Project Development Objective (PDO)** of WAAPP-2A —"to scale-up the generation, dissemination and adoption of improved technologies in the Participating Countries' priority agricultural commodity areas", fully encompasses the new activities envisaged under the AF.

Table: Project components

Component 1	Enabling conditions for Sub- Regional Cooperation in the Generation, Dissemination and Adoption of Agricultural Technologies
Component 2	National Centers of Specialization (NCOS)
Component 3	Support to Demand-driven Technology Generation, Dissemination and Adoption
Component 4	Project Coordination, Management and Monitoring and Evaluation

39. **Approach of the EFA**. The EFA was based on technical and financial data collected from groundnut producers. The methodology used is an incremental cost-benefit analysis. It assessed and compared costs and benefits under two scenarios: with and without the project. The "without project" scenario used data to estimate trends in area, yield, production, costs and margin based on an eight-year series of dataset (2008-2015) collected by agricultural cooperatives. The financial analysis used following farms models promoted under WAAPP: (i) model of groundnut certified seed production farm evolving from 2 to 4 hectares over a ten-year period; (ii) model of farm of 5 ha producing for household and oil industry consumption; (iii) model of farm processing in an artisanal way groundnut oil using improved technologies to control for the toxin (aflatoxin); and (iv) model of groundnut seed cooperatives accounting 650 members on average.

Table: Key economic and financial indicators

Key project indicators				
Beneficiaries	150,000			
Total investment costs	US$ 20 million			
Discount rate	6%			
Economic indicators				
ENPV	US$9.0 million			
EIRR	18 %			
	Production of groundnut certified seeds	Groundnut of household and oil industry	Improved processing of groundnut oil	Seed cooperative
Financial indicators				
FNPV	US$4,200	US$2,800	US$5,500	US$389,500
FIRR	31 %	27 %	33 %	84 %

40. The **sensitivity analysis** showed that the project is slightly sensitive to the increase of investments costs but very sensitive to the decrease of yield and output prices. Overall, from the financial analysis can be concluded that the project is financially sound as it increases farm margin. Consequently, the project has particularly, an important impact on farmers' income. The results above from the economic analysis showed that the AF is an economically acceptable project. The sensitivity analysis table below shows the robustness of the analysis and confirmed the economic soundness of the project.

Table: Sensitivity analysis

	Base case	Changes in total project cost	Changes in gross margin

Changes %		+10	+20	+50	-10	-20	-50
EIRR %	18	17	15	12	16	14	7

Table: Scoring whether EFA addresses salient features of CSA – as identified in the report section X.

Features of CSA	Score	Explanation
Context-specificity (location)	nc	Not mentioned
Increased production cost; family labor	nc	Not mentioned
Phasing of crop yields	nc	Not mentioned
Climate adaptation and resilience	nc	Not mentioned
GHG emission reduction and carbon sequestration	nc	Not mentioned
Heterogeneity of farmers	nc	Not mentioned
Partial adoption of CSA	++	Evolving farm sizes were assumed
Climate-smart landscapes	nc	Not mentioned
Combination of practices	+	Combination of practices but the difference between single and combination wasn't tested
Livestock (information on benefits and herd development)	Not applicable	
Equity	nc	Not mentioned
TOTAL CSA - SCORE	**0.27**	
CSA – Intensity	**1.5**	

Note: (+) moderately complies; (++) strongly complies; nc: not clear from description, or doesn't comply; Total CSA-score: average across 11 categories; CSA- Intensity: average across all pluses.