



The Economic Advantage

Assessing the value of climate-change actions in agriculture

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Abbreviations and acronyms

ABA	adaptive behaviour analysis
ASAP	Adaptation for Smallholder Agriculture Programme
AWD	alternate wetting and drying
CBA	cost-benefit analysis
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FONERWA	Environment and Climate Change Fund for Rwanda
GCM	general circulation model
GHG	greenhouse gas
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPCC AR5	Intergovernmental Panel on Climate Change Fifth Assessment Report
IRRI	International Rice Research Institute
NAP	National Adaptation Plan
NDC	nationally determined contribution
NPV	net present value
OECD	Organization for Economic Cooperation and Development
SRI	system of rice intensification
UDP	urea deep placement
UNFCCC	United Nations Framework Convention on Climate Change

Key definitions

Adaptation	In human systems, the process of adjustment to the actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to the actual climate and its effects; human intervention may facilitate adjustment to the expected climate.
Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Economic assessment	The process of defining objectives, examining options, weighing up the costs and benefits of those options and understanding incentives of different actors and intended beneficiaries to inform a decision.
Net present value	Difference between the present value of a stream of costs and a stream of benefits.
Cost-benefit analysis	Quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a measure of economic value.
Benefit-to-cost ratio	Attempts to identify the relationship between the cost and benefits of a proposed project. The ratio is calculated by dividing the total discounted value of the benefits by the total discounted value of the costs.
Gross margin	The percentage of total sales revenue that a company retains after incurring the direct costs associated with producing the goods and services it sells. Gross margin is the difference between revenue and cost of goods sold, divided by revenue and expressed as a percentage.
Discount rate	The interest rate used to discount a stream of future cash flows to their present value. A discount rate is a theoretical or observed rate at which people discount future payoffs.
Internal rate of return	Makes the net present value of all cash flows, both positive and negative from a particular investment, equal to zero. Internal refers to the fact that its calculation does not incorporate environmental factors. It can also be defined as the rate at which an investment breaks even.
Smallholder farmer	A farmer with limited resources, including land, relative to other farmers in the sector.
Adoption	Uptake of new technologies, practices and institutions at scale. Adoption is a process that begins with awareness and progresses through a series of steps to appropriate and effective use.
Incentive	A positive intentional device, such as the promise of a reward, that aims to motivate a desired action or behaviour.

Executive summary

This report is aimed at readers who seek to build economic evidence in support of the inclusion of actions on agriculture in climate change plans and programmes, particularly at the national level under the umbrella of nationally determined contributions (NDCs) to the December 2015 Paris Agreement, which aims to restrict a rise in global temperatures and manage risks.

Agriculture is a sector especially sensitive to climate change. It also accounts for significant emissions and is, therefore, a priority for both adaptation and mitigation plans and actions at global, national and local levels. The majority of NDCs, which are voluntary national submissions for post-2020 action under the Paris Agreement, express national-level intentions for action on adaptation and mitigation in agriculture: 84 per cent of intended NDCs propose mitigation actions in agriculture and land-use sectors and 92 per cent of intended NDC adaptation plans prioritize agriculture. However, economic assessment and financial analysis of agriculture in NDCs, and in related plans like national adaptation plans (NAPs), are weakly developed to date. Credible economic and financial proposals with a high likelihood of delivering meaningful returns are needed to unleash large-scale public and private investment in agriculture under climate change.

Globally, there is a strong economic case to invest in agriculture for future food security and rural livelihoods under climate change. For example, the world's largest programme for smallholder farmers' adaptation, IFAD's Adaptation for Smallholder Agriculture Programme (ASAP), will deliver globally positive returns to investment across a range of climatic futures if adoption rates are high. Ex-ante economic analysis shows that the 32 country-level ASAP investments approved since 2010 generate and redistribute net worth US\$0.44-1.63 per dollar invested over a time frame of 20 years to smallholder farmers and other project beneficiaries, generating a mean net present value of US\$6.8 million over the period. Similarly, widespread adoption of improved practices in production of major staples will provide economic pay-offs to future food security under climate change.

Iterative climate-risk management can address the specific challenges of climate change in agriculture by proposing actions in three different time frames: immediate actions to address current climatic risks and variability, integration of adaptation into current investments with long lifetimes, and early monitoring, research and learning to prepare for the future impact of climate change.

At the farm level, positive economic returns can be demonstrated for multiple practices that build adaptive capacity and reduce emission intensity across several of the priority subsectors highlighted in the NDCs – soil and land, water crops, livestock, fisheries and trees. Portfolios of actions may deliver better outcomes than single interventions. In the livestock sector, for example, combining pasture management with improved breeds, watering systems and supplementary feeding can double gross margins while conferring adaptation and mitigation benefits. Importantly, however,

the economic results of agricultural practices are highly context-specific and may take several years to deliver positive returns.

Alongside farm-level actions are a further set of non-technical mitigation and adaptation interventions, which are just as important but more difficult to quantify and value. These include capacity-building, institutional strengthening, services to provide finance, information, extension and research, policy and legal frameworks, and, finally, programme management, particularly for monitoring and evaluation. Development of policy-based actions may not comprise a major cost component in NDCs or related instruments, but it can provide major leverage for behaviour change among farmers and other value-chain participants.

Climate change plans for the agricultural sector need to be based on solid economic assessment that includes policy mainstreaming, iterative planning, a balance of project-level and farm-level assessments of costs and benefits, and appraisal of economic incentives and the enabling environment for farmers and other private-sector actors. Supplementing cost-benefit analyses with better understanding of drivers of behavioural change, including at different scales and time frames within an overall theory of change, will provide better guidance for investment.

NDCs are generally well aligned with national development plans so that proposed actions for both adaptation and mitigation contribute to improved development outcomes at the national level, but they do not yet collectively meet the global ambitions of the Paris Agreement. The more ambitious NDCs provide the political capital to promote transformative actions that bring together multiple, longer-term agendas for social, economic and environmental benefit.



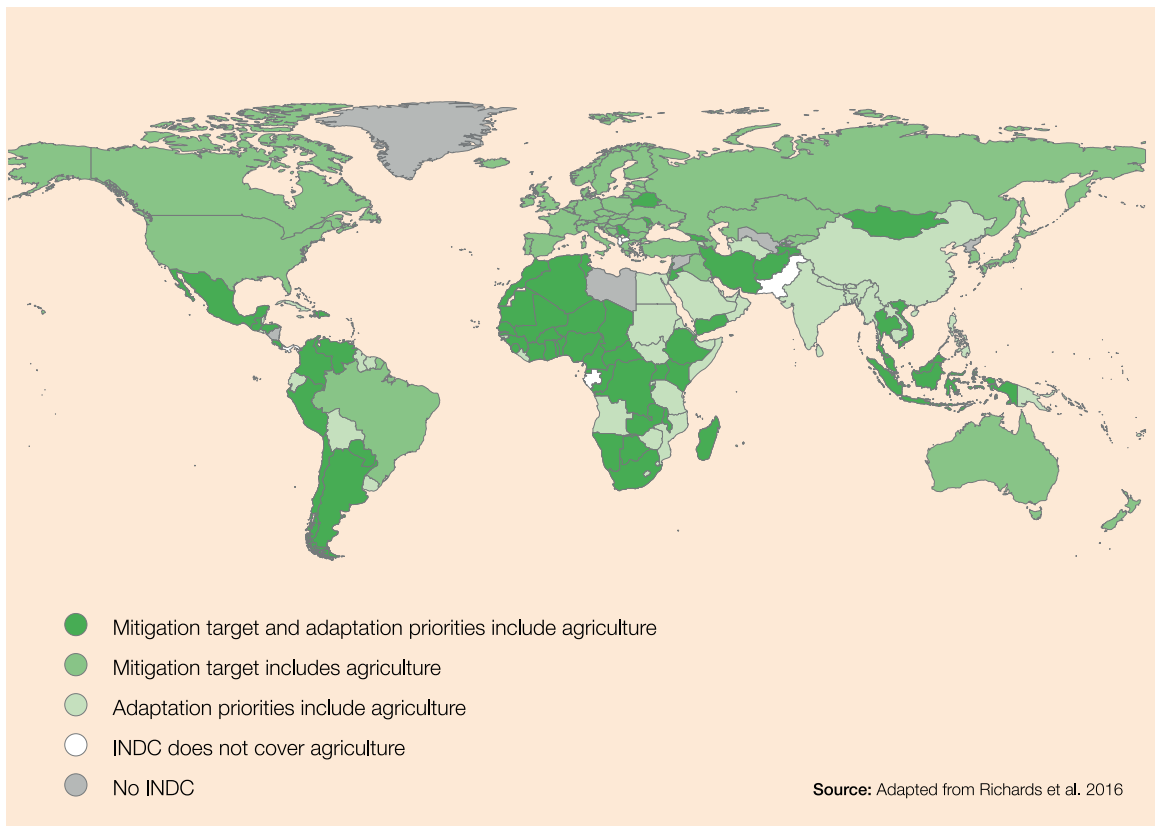
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Introduction: towards economically beneficial actions on climate change in agriculture

Key messages:

- Agriculture is a sector especially sensitive to climate change. It also accounts for significant emissions and is, therefore, a priority for both adaptation and mitigation plans and actions at global, national and local levels.
- The majority of nationally determined contributions (NDCs) to the Paris Agreement express national-level intentions for action on adaptation and mitigation in agriculture.
- However, economic assessment and financial analysis of agriculture in NDCs, and in related plans like national adaptation plans (NAPs), are weakly developed to date.
- Credible economic and financial proposals with a high likelihood of delivering meaningful returns are needed to unleash large-scale public and private investment in agriculture under climate change.
- This report contributes arguments and information on economic assessment for agriculture under climate change.

Diagram 1. Inclusion of agriculture in the INDCs



The Paris Agreement has given the world a powerful platform for action on food and agriculture under climate change. Food security is at the crux of the agreement. Among the 189 submitted intended nationally determined contributions (INDCs), 84 per cent propose mitigation actions on agriculture or land use and 63 per cent include agriculture specifically in their quantitative targets for mitigation (Richards et al. 2015 and 2016). Agriculture is even more prominent in INDC adaptation plans: an overwhelming 92 per cent prioritize actions in the sector (diagram 1). INDCs become nationally determined contributions (NDCs) once parties ratify the agreement (box. 1).

Together the NDCs provide a stable, transparent enabling environment for both public and private investment, linking to and building on associated climate-policy instruments, such as national adaptation plans (NAPs). Yet the substance of the NDCs' intentions for the key sector of agriculture remains vague. NDCs tend to indicate generic areas of intervention, such as water management or livestock, rather than actual proposals for bringing about change. Economic assessment is not yet well developed or consistent, particularly for returns on investment or even for immediate costs and financing needs. This matters a great deal, not just for national outcomes, but also for achieving the global goals, since NDCs distinguish conditional and unconditional actions, linked to targets that countries commit to with or without additional climate finance.

Box 1. What are NDCs, and how do they link to other climate-change instruments, such as NAPs?

NDCs are voluntary submissions by parties to the United Nations Framework Convention on Climate Change (UNFCCC); they provide a public statement of intended post-2020 climate actions in support of the Paris Agreement of December 2015. Ahead of the Paris Agreement, parties submitted their proposed actions in the form of intended nationally determined contributions (INDCs). For all parties that have subsequently ratified the agreement, their INDCs have become NDCs.

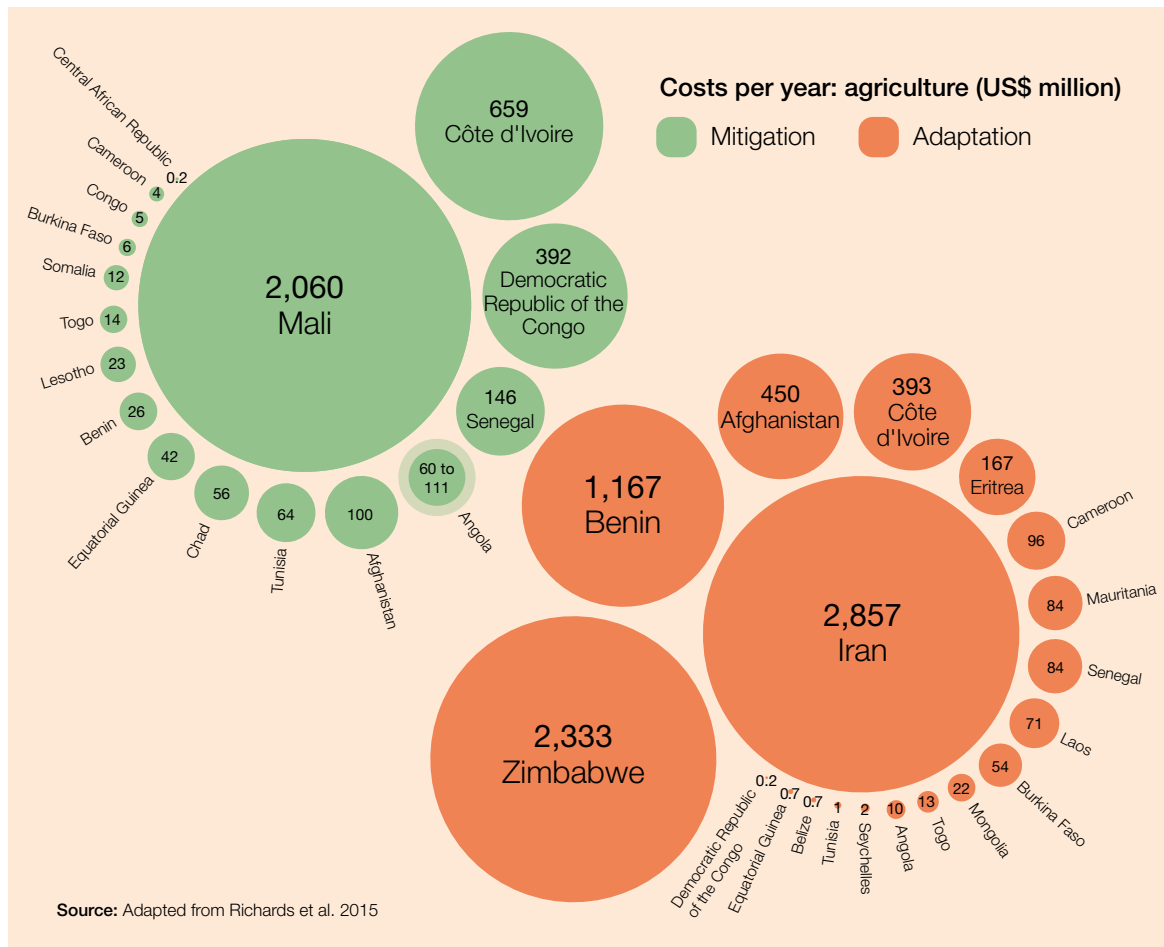
All NDCs include proposals for mitigation, which cover actions to reduce net loads of atmospheric greenhouse gases (GHG). Collectively, these actions comprise the basis of post-2020 global emissions-reduction commitments under the Paris Agreement to hold the increase in global average temperature to well below 2°C and to pursue efforts to limit it to 1.5°C. Many NDCs also include proposals for action on adaptation to climate change, under the assumption that it may not be possible to avoid all climate change.

NDCs are voluntary and self-determined, without a standardized format for communication. Therefore, it is not possible to add up the global benefits or costs of parties' NDCs accurately, for either mitigation or adaptation. On the other hand, the diversity of approaches means that the majority of parties have been able to achieve a strong alignment between NDCs and pre-existing climate plans. For example, parties that have included adaptation actions in their NDCs have largely aligned these with their national adaptation plans (NAPs).

There will be progressive steps to review and raise the ambition of NDCs. A facilitated dialogue is proposed for 2018, followed by a new round of NDCs in 2020 outlining ambitions up to 2030. In 2023, there will be a formal global stocktake of the NDCs against the global ambition of the Paris Agreement.

All NDCs are linked to, or build on, other climate-change planning instruments, such as the NAPs, which are the main instrument for adaptation planning at the national level, as well as nationally appropriate mitigation actions (NAMAs) and other national climate-action plans. Agencies such as the UNFCCC Secretariat and the Convention's Green Climate Fund (GCF), which assists developing-country parties, are actively working to support this coherence and coordination; for example, by making all NAPs available on the UNFCCC website and recognizing them as the basis for GCF support for adaptation. The analysis that we present in this report can be applied not only to NDCs, but also to NAPs, NAMAs and other national-level climate-change plans.

Diagram 2. Proposed annual costs of actions on agriculture in NDCs



The handful of countries that specify financing requirements for agricultural adaptation vary widely in their approaches and figures (diagram 2). Estimates of their individual costs range from a few hundred thousand dollars to US\$35 billion, over various time frames. Preliminary analysis shows that there is no relating of annual financial requirements to the size of agricultural gross domestic product (GDP) or the apparent risk to agriculture of climate change (Gregersen et al. 2016). African parties to the Paris Agreement that have costed their agricultural mitigation targets show wide variation. The proposals range from single projects, for example, US\$2.5 million for a programme to reduce slash-and-burn agriculture in the Central African Republic, to full sectoral mitigation plans, such as Senegal’s US\$1.8 billion proposal (Richards et al. 2015). By comparison, global studies have estimated the additional costs of adaptation to climate change within the agricultural sector at US\$7 billion per year up to 2050 (Nelson et al. 2009), with a further US\$7.7 billion per year to counter the impact on children’s nutrition (World Bank 2010), US\$11.3–12.6 billion per year in the year 2030 (Wheeler and Tiffin 2009) and a cumulative US\$225 billion up to 2050 (Lobell et al. 2013).

As the next chapters will show, there is little doubt of the economic advantages of investing in agriculture to meet climate challenges, and better economic information is available to weigh up the viability and prioritization of investments. Agriculture as a sector offers unique opportunities for integrating mitigation and adaptation. Economic returns of smart investments accrue both to agricultural development and to emissions reductions. But serious public and private investment in agriculture under climate change is going to need credible financial proposals with a high likelihood of positive outcomes. These proposals will need to address not just technical interventions but also capacity-building, institutions, services and administration. Future iterations of NDCs will also need to address how investment in national-level public goods will contribute to global public goods. As discussed further in chapter 5, the mitigation targets in the current set of NDCs do not yet add up to the global goal of the Paris Agreement to hold the increase in average surface temperature to well below 2°C above pre-industrial levels.

There are many ingredients for successful investment, such as new and expanded financial instruments, mechanisms to blend private and public finance, access to information on financing sources, support to farmers' business and financial capacities, and deployment of public-sector economic instruments (Chambwera et al. 2014, Falconer et al. 2015, Goldman et al. 2016). Here we focus on just one of these ingredients: evidence from economic assessments, with a focus on agriculture and the NDCs. We concentrate on case studies from countries where agriculture constitutes a high proportion of GDP and rural employment. Economic information is not the only input to any policy decision, but it is an important one. In this report, our purpose is to support the next step from generic plans for agriculture in NDCs to actionable and beneficial measures that collectively deliver agriculture's fair share of the global ambitions of the Paris Agreement.



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The global case for investing in agriculture under climate change

Key messages:

- Globally there is a strong economic case to invest in agriculture for future food security and rural livelihoods under climate change.
- For example, the world's largest programme for smallholder farmers' adaptation, IFAD's Adaptation for Smallholder Agriculture Programme (ASAP), will deliver globally positive returns to investment across a range of climatic futures, if adoption rates are high.
- Similarly, widespread adoption of improved practices in production of major staples will provide economic payoffs to future food security under climate change.

Agriculture is the major employer and accounts for more than 30 per cent of GDP in low-income countries (World Development Indicators 2014 data) and is among the most sensitive sectors to climate change. Meta-analysis presented in the Fifth Intergovernmental Panel on Climate Change (IPCC, 2013) report provides evidence that climate change without adaptation will have negative effects on the yields of major staple crops where local temperatures increase 2°C or more above 1990s levels – tropical regions are likely to experience stronger yield declines than temperate

regions (Porter et al. 2014). Combined with future challenges of population growth, demographic transitions and conservation of ecosystem services, climate change puts future food security and rural prosperity at stake.

The good news is that farmers, governments, researchers and businesses already have the capacity and knowledge to implement appropriate near-term measures and longer-term transformative changes to agriculture and food systems in response to climate change. This chapter provides two examples that contribute to a global case for investment in agriculture under climate change: first, the geographic perspective of investments in national programmes supported by IFAD, and, second, the value-chain perspective of global investments in specific commodities and technologies, using rice as an example. These examples show that economic returns to investment in agriculture under climate change are positive and substantial in best-case scenarios that assume high levels of uptake.

A case for national investments: the example of ASAP

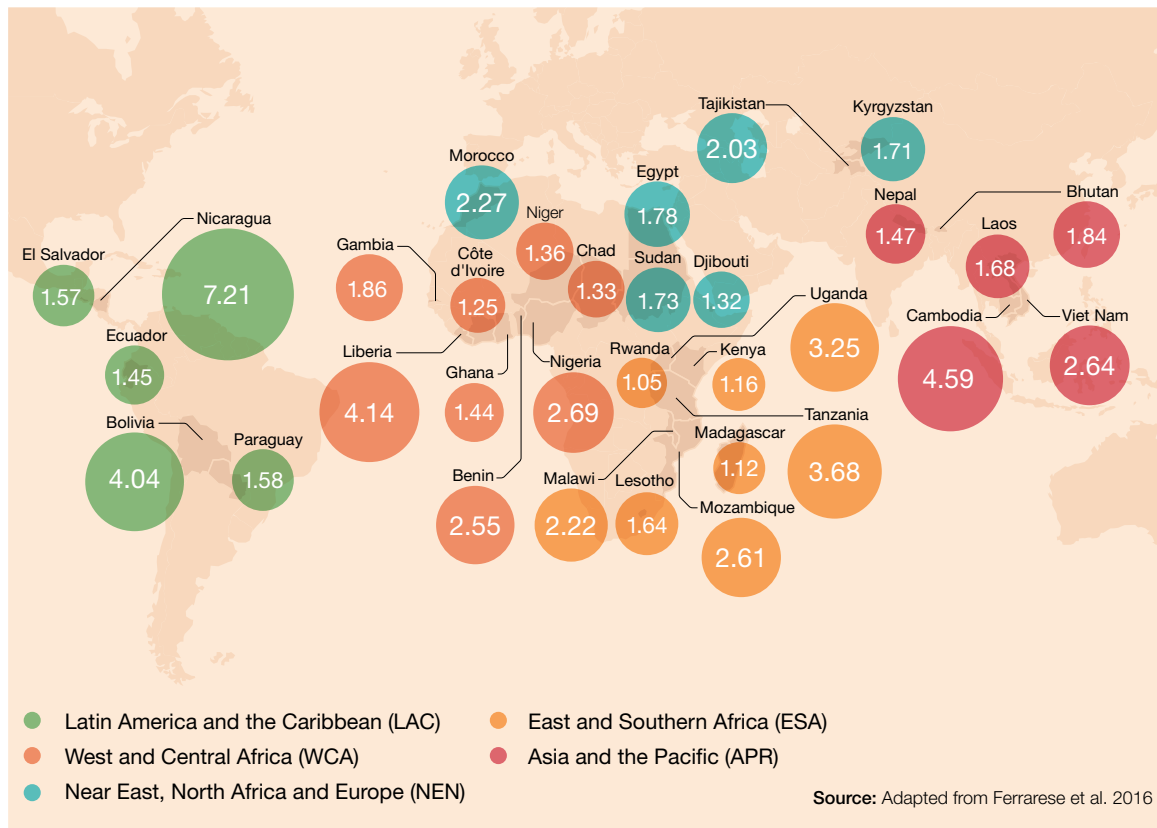
IFAD's ASAP is both the largest global financing source for smallholder adaptation and a trailblazer that can offer useful lessons to emerging climate-finance mechanisms at national, regional and global levels. ASAP works in over 30 low-income and middle-income countries, using climate finance to make rural development programmes more climate-resilient. Much of the finance goes to farmers themselves and to farmer-led adaptation, through financing of, and decision-making by, local farmer and community organizations.

Ex-ante economic analysis (Ferrarese et al. 2016) shows that a representative project among the 32 country-level ASAP investments approved since 2010 generates and redistributes net worth US\$0.44-US\$1.63, for every dollar invested through ASAP, to smallholder farmers and other project beneficiaries over a time frame of 20 years. Each project, whose implementation lasts between five and seven years, will completely offset its costs and contribute to value generation of US\$350,000 per year, generating a mean net present value of US\$6.8 million. Benefit-to-cost ratios are positive in all target countries, and reach values of over 4:1 in Cambodia, Liberia, Bolivia and Nicaragua (diagram 3).

The analyses are ex-ante and will be confirmed by ex-post analyses during monitoring and evaluation of project performance. The projected income generation assumes an average implementation rate for projects of 65 per cent or more, which may be a generous assumption. Results are intended as best-case scenarios for future outcomes from the set of ASAP investments to provide an accountability system to donors and internal learning for ASAP. IFAD's system for ex-post analysis and evaluation of project impact will be used to assess ASAP performance during the project (mid-term review) and at completion (project completion report).

Project activities and costs include: institution-building and capacity-building, particularly at the local level and including support to market development; technical interventions and infrastructure, such as building bunds for rainwater harvesting and improving resilience of post-harvest storage infrastructure to heat, wind and rain; services (financial, information, extension, research); management and delivery of finance; policy and legal frameworks; and programme management, particularly monitoring and evaluation. These are all additional climate-change investments over

Diagram 3. Benefit-to-cost ratios of ASAP investments in 32 countries

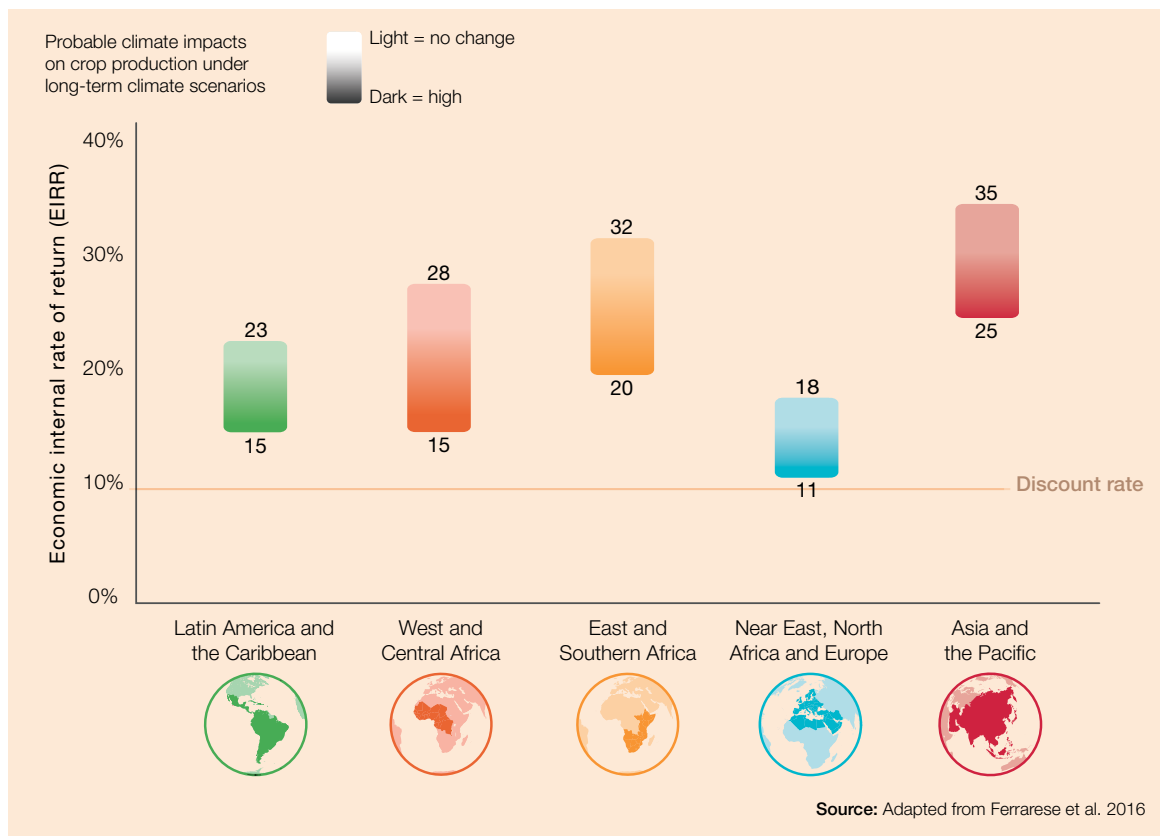


and above the main investments of the country loan for agricultural development. They may often deliver low-regrets options (i.e. meaningful for any degree of climate change) such as erosion control, as well as broad-based development benefits, for example, development of farmers' associations, rather than being tailored to very specific climate risks. An example of a country investment is provided in the Nicaragua country case study at the end of this report.

On average, the socio-economic benefits generated by the implementation of such interventions lead to a 6 per cent increase in the economic well-being of direct beneficiaries in the target areas (Ferrarese et al. 2016). The ASAP programme contributes 3-10 per cent of total GDP generated over the 20 years. This translates into a GDP growth contribution at the national level of up to 0.68 per cent a year. The cumulative net wealth creation globally is US\$274 million, compared to US\$200 million distributed as grants. Environmental benefits – such as biodiversity conservation, soil and water conservation and carbon sequestration – provide an additional benefit over and above the direct socio-economic benefits. The added economic benefits range from 10-25 per cent additional benefit in countries such as Ghana, Madagascar and Bolivia, through to a more than doubling of the total economic benefit in Djibouti.

The analysis also shows that returns from ASAP are robust across a set of climatic futures (diagram 4). At the higher end of climate-change impact, losses to crop yields are estimated at 27-40 per cent below expected mean values without climate change

Diagram 4. Rate of return of ASAP investments across lower and higher climate impact in five regions



(at the lower end). All countries presented an economic return on project investments greater than the opportunity costs of capital, using a discount rate of 10 per cent. In this analysis, the West Central Africa region shows highest variability under climate change, while the Near East and North Africa region is closest to losing net benefits from interventions under progressive climate change.

A case for investments in commodities and value chains: the example of rice

A strong rationale for investing in agriculture under climate change is also apparent taking a commodity perspective rather than a country perspective. Sustainable Development Goal 2.3 calls for “doubl[ing] agricultural productivity and incomes of small-scale food producers by 2030” – thus farmers need options to increase production and to improve rural incomes and food security, while ideally reducing emissions. Rice is a key food-security crop and cash commodity that provides farm incomes throughout the tropics and sub-tropics. This staple accounts for about 23 per cent of the global harvested area of cereals (FAOSTAT 2013) and generates substantial methane emissions – an estimated 9-11 per cent (Smith et al. 2014) of the total greenhouse gas emissions from agricultural production.

Among the most promising agricultural practices and technologies that might help farmers to achieve higher productivity and incomes, while also reducing



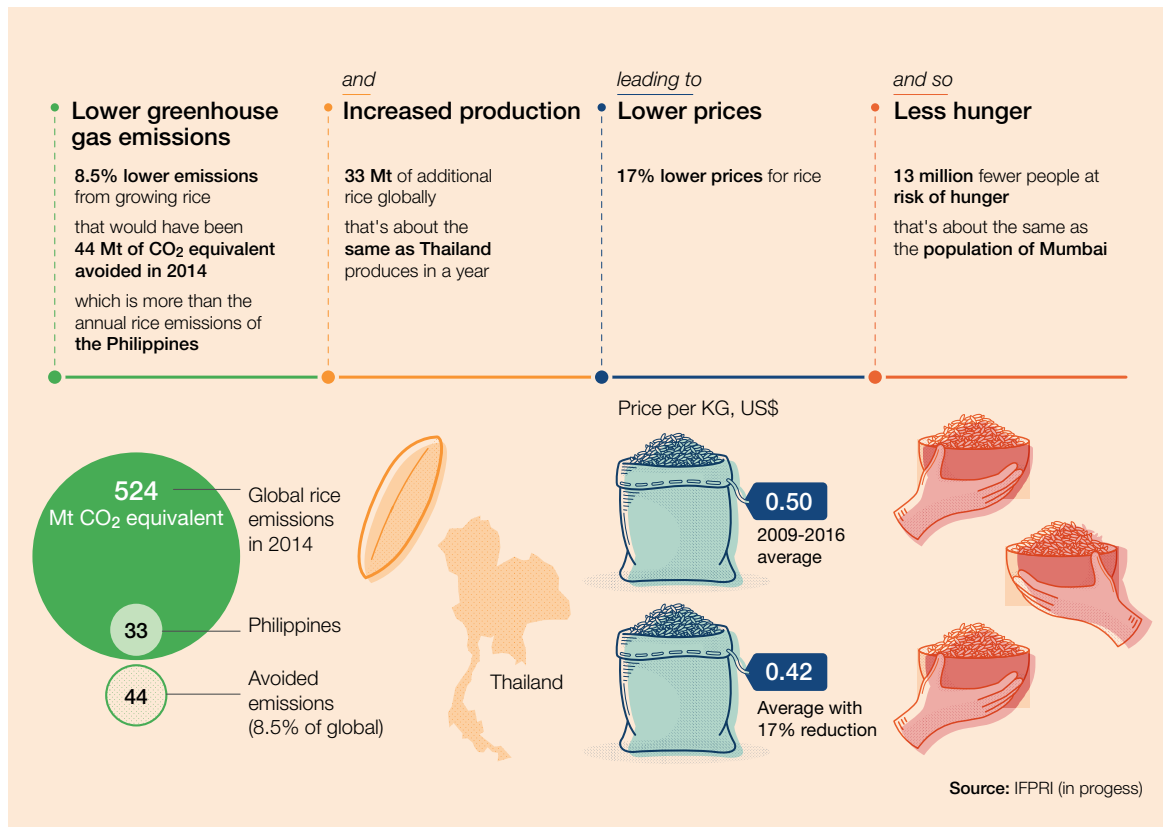
Vietnamese dean of agriculture

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methane emissions, two stand out: alternate wetting and drying (AWD) and urea deep placement (UDP). AWD consists of repeated interruptions of flooding during the season, causing the water level to decline as the upper soil layer dries out, before subsequent re-flooding. This practice increases the efficiency in water usage with little or no effect on yields, and brings a significant reduction in methane emissions. UDP is a technology that aims at increasing efficiency in the plant uptake of nitrogen. It consists of strategic burial of urea “supergranules” near the root zones of crop plants; it is expected to have positive effects on yields and lead to a significant reduction in nitrogen emissions.

In a 2016 analysis conducted by a team of researchers at the International Food Policy Research Institute (IFPRI), the effects of a wide adoption of these practices were simulated. Data on costs of adoption are still scarce and limited to very specific and localized conditions, and it was decided to assume that adoption would occur only when it generated higher yields. The underlying assumption is that rice farmers can choose among existing practices and the two alternatives and select whichever returns the highest yields. But there is a caveat – the effects on farmer incomes, which might be as important as the combined effects of higher yields and lower food prices, are not considered. The results still represent a best-case scenario because documented adoption rates are much lower than 100 per cent, even when the alternatives are generally deemed more profitable than the status quo. Simulations were carried out using the international model for policy analysis of agricultural commodities and trade (IMPACT) using two global circulation models, HadGEM2-ES and GFDL-ESM2M (a drier and cooler model), under Representative Concentration Pathway 8.5 and the Shared Socioeconomic Pathways 2 scenario, an IPCC middle-of-the-road projection.

Diagram 5. Projected global benefits 2010-2050 of adoption of alternate wetting and drying (AWD) and urea deep placement (UDP) among rice farmers



Results show substantial benefits to global rice production of around 5 per cent in 2050, compared to 2010, and commodity-market price reductions of 16-17 per cent. While falling market prices from higher supply can hurt farmers, and may change farm-management strategies, poor consumers can benefit from lower food prices. The inclusion of the global trade model shows that there are net benefits to both nutrition and emission reductions globally, leading to a global reduction in the risk of hunger for 12-13 million people and reducing cumulative global greenhouse gas emissions from rice by 7 to 9 per cent (diagram 5).



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Economic assessment of public investments under NDCs and related climate plans

Key messages:

- Economic assessment provides a key input to planning of mitigation and adaptation actions in agriculture at national and project levels, offering an important tool to support planning, prioritization and mainstreaming of climate actions in sectoral development plans.
- Key challenges for economic assessment of adaptation and mitigation actions in agriculture are: trade-offs among the multiple functions of agriculture, the importance of non-technical measures, which are more difficult to quantify, cost and value, and future uncertainty.
- Iterative climate-risk management can help to address these challenges by proposing actions at three different time frames: immediate actions to address current climatic risks and variability, integration of adaptation into current investments with long lifetimes, and early monitoring, research and learning to start planning for the future impact of climate change.

- At the farm level, positive economic returns can be demonstrated for practices that build adaptive capacity and reduce emissions intensity across several of the priority subsectors highlighted in the NDCs, though these are context- and site-specific and thus highly heterogeneous and time-dependent.
- Development of policy-based actions may not comprise a major cost component in NDCs or related instruments, but it can provide major leverage for behaviour change among farmers and other value-chain participants.
- Non-technical mitigation and adaptation interventions at the project and national level are just as important as farm-level actions, but more difficult to quantify and value. These include capacity-building, institutional strengthening, services to provide finance, information, extension and research, and programme management, particularly for monitoring and evaluation.

While the economic case for investing in agriculture at the global level under climate change is strong, the situation at the national and local levels is more nuanced. Best practices may not translate across all countries or regions, as outcomes are site- and context-specific. This chapter presents economic information relevant to the development of plans for agricultural mitigation and adaptation in NDCs. It starts with a discussion of the national-level planning modality and entry points for mainstreaming NDCs. It then looks at some of the challenges of economic appraisal of national mitigation and adaptation, before moving to the project level to consider economic assessment of project-wide activities, such as capacity-building and provision of financial and knowledge-based services. The second half of the chapter considers actions at the farm level, where economic benefits of investments can vary widely with different climatic and agro-ecological zones, farmer wealth and capacity, ecological and social contexts, and timescales for accrual of benefits.

National agricultural planning and the NDCs

National agricultural policy is critical for advancing coherent and structured agricultural growth and development by providing an enabling environment and incentives for farmers and other participants in agricultural value chains. Public policy addresses various market failures, policy failures, governance failures and behavioural barriers, which are all major issues for adaptation and mitigation. The starting point for the NDCs is, therefore, the existing policy, planning and socio-institutional landscape for agriculture at the national level.

There is an increasing emphasis on integrating, or mainstreaming, adaptation and mitigation into current policy and development, rather than implementing measures as a stand-alone activity. This means taking account of broader policy objectives and wider costs and benefits, not only for climate-change risks. Thus the challenge for the NDCs is to shift underlying growth and development pathways towards low-carbon pathways and climate-resilient growth. Effective mainstreaming requires the identification of suitable entry points in the policy and development planning process, noting these will differ across sectors and national contexts. For agriculture, the key entry point is usually the sector development plan, traditionally

a five-year planning document, which is then subsequently implemented through investment plans and programmatic policies and strategies.

Economic assessment in sector development planning

National-level public planning usually involves a series of steps built around a policy cycle. This typically involves understanding the problem, identification of options, appraisal of options, implementation, and monitoring and evaluation. Several tools are available to structure this cycle, such as the online climate-smart agriculture (CSA) guide, which includes a four-stage CSA plan of situation analysis, targeting and prioritization, programme support and monitoring, and evaluation and learning (see recommended further resources).

Economic assessment provides key inputs at several points in the policy cycle and economic analysis supports the development of policy and strategy. In many countries there is existing guidance on how to undertake this economic support, often with mandatory impact assessment or economic-policy appraisal. There is a key role for economics in the early steps of public-policy development, for example, in identifying the existing problems and understanding the justification for planned public interventions, such as to address existing market failures. Subsequently, there is a role for economic assessment in helping decision-making and prioritization, especially to identify and short-list options and later to prioritize and compare these options, which involve economic decision-support tools, such as cost-benefit analysis. Three country case studies at the end of this report (Nicaragua, Rwanda and Viet Nam) show the use of economic assessment at national and farm levels.

As well as economic assessment, there is increasing demand for financial appraisal as a decision tool for climate-change planning, particularly for mitigation and for projects that involve private-sector financial services. Financial appraisal involves a different set of information inputs, analytic tools and approaches to externalities, compared to economic appraisal (box 2).

Economic appraisal of mitigation and adaptation

As highlighted above, economic appraisal is an important input to national policy appraisal that can help prioritize options for an NDC. While these standard approaches – as used for developing national-level policy – are the starting point for the NDCs, mitigation and adaptation present some particular challenges necessitating some additional considerations for economic assessment. Mitigation, which addresses a global burden, has a simple common metric for assessing different options, in terms of greenhouse gas emissions: the cost-effectiveness metric of United States dollars per ton of CO₂-equivalent reduced. While this is not always measurable with a high degree of accuracy, it does allow comparison and ranking of options within and across sectors, including in agriculture. This approach has been commonly used in preparing national mitigation plans and many NDCs.

A key issue for mitigation at the national level is the potential trade-off between profitability and growth within a sector, for example, for farmers and agricultural industries. In developing the NDC in Colombia, the government assessed how different options of pasture reduction, limiting deforestation and stalling the expansion of palm oil deliver on both emissions reductions and private profits (diagram 6). The results

Box 2. Economic versus financial appraisal

Social cost-benefit analysis (CBA) is frequently used in assessments of public investment options by governments. It aims to value all relevant costs and benefits of a proposed project or programme to society, allowing comparison of costs and benefits using a common metric – money. It aims to achieve the maximum social welfare. CBA compares options using net present values (NPV), calculated as total discounted benefits minus total discounted costs, or benefit-to-cost ratios. As it identifies whether benefits exceed costs, it can justify intervention and allow resources to be allocated efficiently against other priorities, facilitating ranking of options.

This can be contrasted with a financial appraisal, which aims to assess the return on investment (the internal rate of return [IRR]) of different options. This can be used as a complementary tool in decision support, though it approaches the analysis from a different perspective, maximizing towards the individual, and excludes societal costs and benefits, such as external costs related to the environment. Financial appraisals are widely used in the private sector and are also an increasingly important component of financial applications to multilateral sources, such as the Green Climate Fund.

Additional financial information that might be included in NDCs includes: flows of finance to fulfil mitigation pledges, agendas for increased financial flows from developed to developing countries, strengthened practice on green finance, major finance gaps (matched to funding sources) in developing-country agendas for mitigation and adaptation, and details on implementation of policies, incentives for private-sector action, and fiscal and regulatory systems (Hedger and Nakhooda 2015).

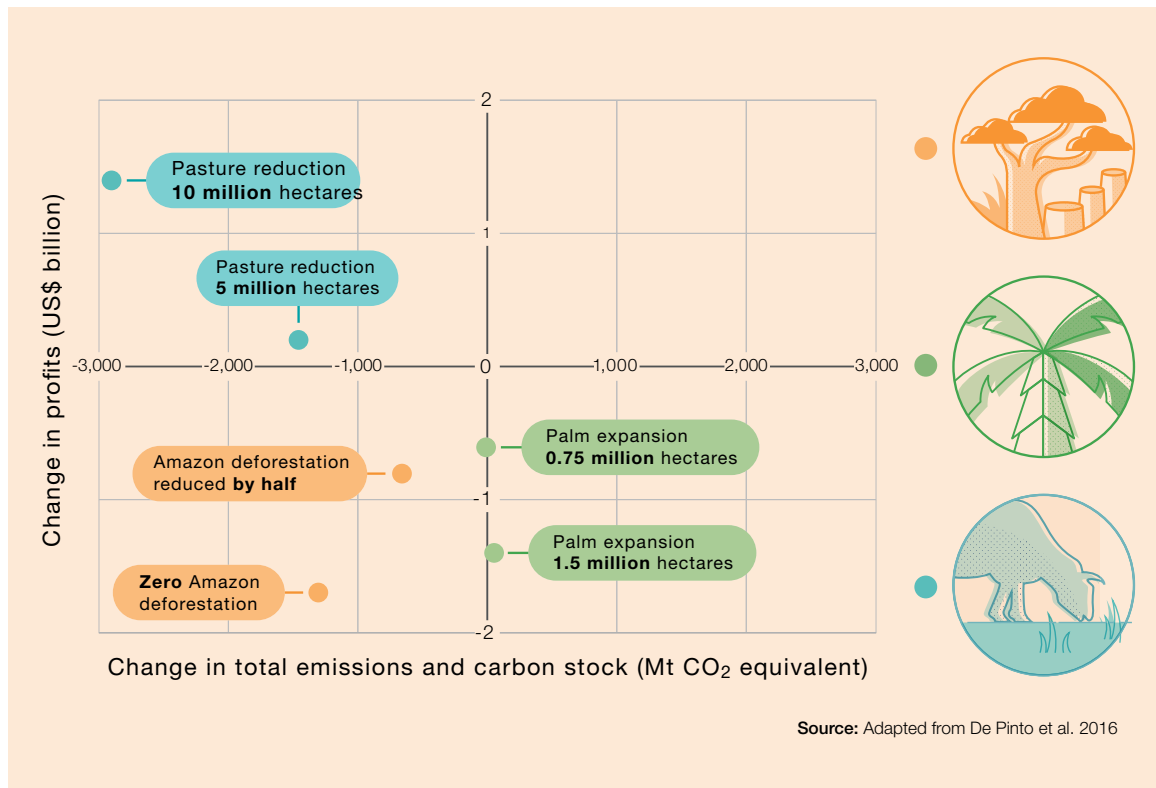
strengthened the case for government programmes to support pasture reduction, which delivers both higher profits and emissions reductions (De Pinto et al. 2016).

The lack of a common metric for adaptation makes it very challenging to compare options across sectors, and even within a sector, as adaptation is a response to individual risks. The only common metric is money, and thus economic analysis can have an important role in helping to prioritize options, such as in an NDC. However, the economic analysis of adaptation is challenging for a number of reasons. First, adaptation is strongly related to a much wider set of objectives, criteria, costs and benefits, due to the multifunctional nature of agriculture, and all need to be considered in the decision. These often involve ancillary non-market aspects. Second, building of resilience to climate change stems largely from alternative livelihood options, capacity-building and other non-technical measures, which are more difficult to quantify, cost and value. Third, adaptation faces particular challenges of uncertainty, as discussed below.

Iterative climate-risk management

The impact of climate change and the benefits of adaptation primarily arise in the future. This creates a particular challenge in terms of economics. Early action to address longer-term risks will incur costs in the short term, but these are difficult

Diagram 6. Synergies and trade-offs between profits and emissions reductions in Colombia



to justify when the benefits will only accrue later; people (and society) generally prefer to receive goods and services immediately. Climate change also involves high uncertainty. While NDCs set out potential emission-reduction pathways at the national level, collective achievement at the global level remains uncertain. Moreover, even if a future emission scenario is defined, different climate models project very different futures and time frames relevant to agriculture at the local scale. All this uncertainty makes it difficult to plan exactly what to do and when. Early action may underestimate the risks and yield incremental low-regret responses insufficient to meet the scale of the climate risks, or it may overestimate them and trigger investment in costly adaptation that will not be needed.

These challenges can be overcome with the use of iterative climate-risk management as recommended in the IPCC Fifth Assessment Report (IPCC 2014). Iterative frameworks can help in identifying early adaptation actions and with the timing and sequencing of options, bringing together the key areas of advice and guidance on economic analysis of adaptation options put forward by the IPCC (box 3).

An iterative approach starts with analysis of the impacts of current climate variability and extremes, and then considers the risks of future climate change, including uncertainty. It then looks at a complementary set of three types of interventions (diagram 7):

1. Immediate actions that address the current risks of weather and climate extremes (the adaptation deficit) and also build resilience to future climate change.



Coast farmer: Vietnamese watermelon farmer

©IFAD/Christopher Neglia

These include early capacity-building and the introduction of low and no-regret actions, which provide immediate economic benefits as well as future benefits under a changing climate, such as soil and water conservation.

2. Integration of adaptation into immediate decisions or activities with long lifetimes, such as infrastructure or planning. This involves different options (to above) because of future climate change uncertainty. It involves a greater focus on climate-risk screening and the identification of flexible or robust options that perform well under uncertainty.
3. Finally, early monitoring, research and learning to prepare for the future impacts of climate change. This includes a focus on future options, adaptive management, and the value of information, knowledge and learning.

The three categories can be considered together in an integrated adaptation strategy, often termed a portfolio or adaptation pathway (diagram 7). This can be particularly

Box 3. Desirable features in economic analysis of adaptation options

- Clear application to, and sequencing within, actual processes of priority setting and decision-making
- A broad representation of climate stressors, including both gradual change and extreme events, and spanning multiple possible future outcomes.
- A wide variety of alternative adaptation responses.
- (For preferred responses only) Rigorous economic analysis of costs and benefits over time.

Source: IPCC Fifth Assessment Report, Working Group II (Chambwera et al. 2014)

Diagram 7. Three areas for action at three stages of the adaptation pathway

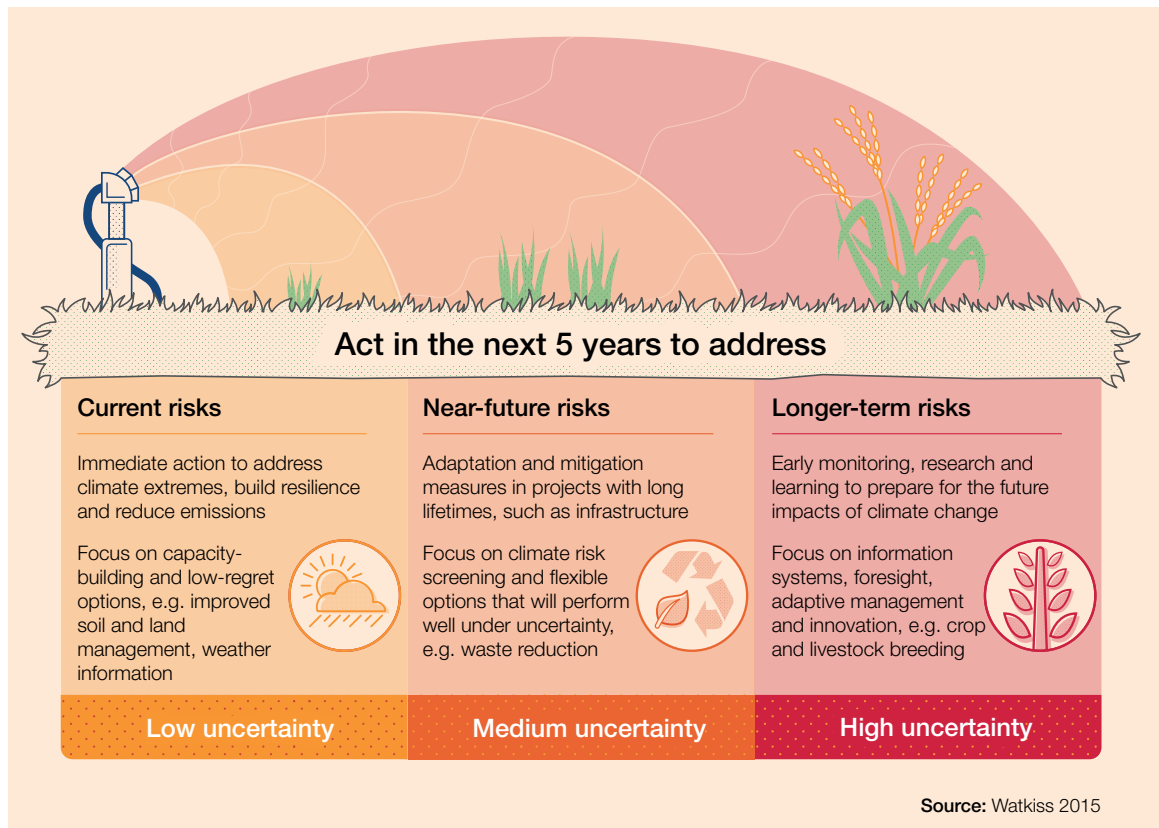
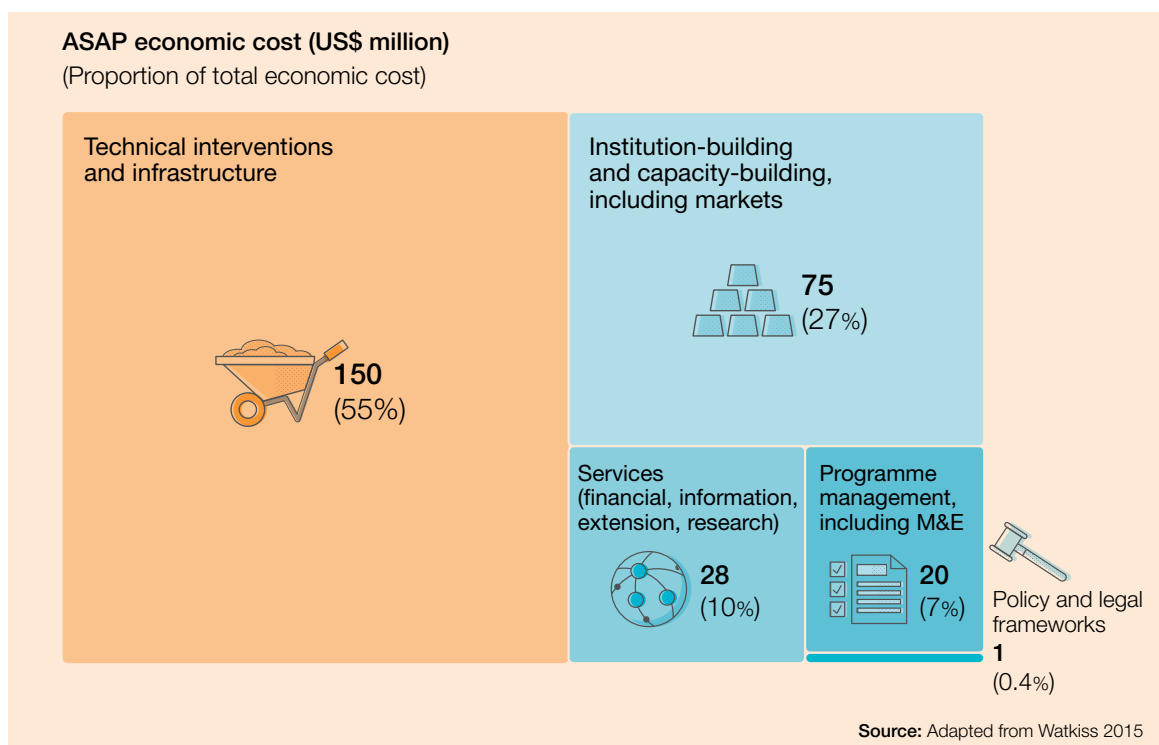


Diagram 8. Globally aggregated distribution of spending across ASAP-supported activities



useful in NAPs and NDCs to identify adaptation that could be undertaken in the next decade to address the impacts of short-, medium- and long-term climate change. This identifies early options that can be justified (in economic terms) under conditions of uncertainty. The Rwanda and Nicaragua country case studies at the end of this report illustrate use of an iterative approach to climate-change planning in agriculture.

Economic and financial appraisal at the project level

Adaptation and mitigation in agriculture involves far more than new technologies and infrastructure. Equally critical will be investments in institution-building and capacity-building, in services to provide finance, information, extension and research, in policy and legal frameworks, and in programme management, particularly for monitoring and evaluation. These categories overlap considerably in real programmes, so it is impossible to derive completely accurate analyses or guidance for how best to allocate funds or to understand resulting benefits. Nonetheless, a superficial assessment of spending categories of IFAD's ASAP shows a very substantial level of investment in non-technical, non-infrastructure activities (diagram 8).

All of these types of options – institution-building and capacity-building, services, policy and legal frameworks, and programme management – will be important within NDCs, but are challenging to assess through quantitative economic appraisal. In the sub-sections below, we discuss the key issues and available information for use in economic assessment of these options in the context of agriculture and climate change.

Institution-building and capacity-building

In the agricultural sector, the importance of building capacity at all levels – from governmental institutions to farmers – is widely recognized, particularly as climate change introduces a new set of dynamics and challenges. However, the quantitative and economic estimation of these benefits is challenging and they are generally omitted from economic ex-ante appraisal.

At the institutional level, there are potentially large benefits from institutional-strengthening and technical-assistance programmes, provided these are designed well. In such cases, ex-post evaluation has demonstrated that these programmes improve governance, increase the capacity for sector oversight and strengthen government institutions, which in turn leads to high benefits. Likewise, implementation of technical-assistance projects can substantially increase investment, improve government oversight of a sector and lead to greater accountability of revenue streams generated. These institutional-strengthening and capacity-building aspects are particularly important for adaptation, due to the additional challenges involved, such as long lifetimes, high uncertainty and cross-sectoral risks (Watkiss and Cimato 2016).

In terms of valuation of such programmes, it is possible to assess the benefits of institutional strengthening and technical assistance using evidence from previous studies (and their ex-post findings). Another approach is to compare the costs of a project to the benefits that would be needed to justify the investment. For example, in Mozambique, a World Bank project – Agricultural Sector Public Expenditure Program (World Bank 1999) – did this by estimating the agricultural GDP growth rate that would be necessary to justify the costs of the programme (the switching value).

Nonetheless, many appraisals consider the cost-effectiveness or value for money of these investments, rather than undertaking a cost-benefit analysis.

Assessment of the effectiveness and economic value of institutional strengthening has also tended to have a bias towards governmental organizations, with much less attention paid to private-sector or civil-society institutions and capacities, including in assessments of IFAD investments (Anyonge et al. 2013). In particular, there is seldom analysis of the role of informal organizations or institutions in achieving benefits from national programmes. Part of the problem is that capacity-building is often interpreted in a narrow sense as provision of skills training to individuals, rather than development of sustained organizational functions.

Services

A growing area of investment is in public and private-sector services to farmers and other value-chain actors that improve resilience and enable adoption of adaptation and mitigation practices at the farm level. These include: weather and climate-information services; early warning systems; finance, micro-credit and weather insurance; and knowledge services, research and development. Economic assessments of these services are now accumulating, providing useful guidance on design and targeting. For these studies, it is possible to appraise costs quantitatively. The analysis of benefits is more challenging, but in economic terms, these can also be quantified.

Weather and climate-information services have generated a reasonable literature to inform economic assessment. Analysis by the World Meteorological Organization (WMO) shows that benefit-to-cost ratios for national hydro-meteorological services are positive in all reviewed cases globally (WMO 2015). Improvements in climate-information services to reduce disaster losses at the national level have benefit-to-cost ratios of 4:1 to 36:1. Household-level benefit-to-cost ratios are also positive. For example, early warning systems on drought in Ethiopia deliver up to sixfold returns for households in terms of reductions to livelihood losses and dependence on assistance. The economic value of climate information services in agriculture is well established, providing benefits to crop management, irrigation decisions and herd management (Clements and Ray 2013). Detailed guidance is available for development of economic assessment at the national level (WMO 2015).

Index-based weather insurance is increasingly promoted as it overcomes challenges of moral hazard and high transaction costs, which made traditional loss-based crop insurance unfeasible for smallholder farmers. Empirical studies show that insurance can improve farm livelihoods by reducing loss of productive assets and enhancing adoption of agricultural innovations. Low demand for, and trust in, insurance products among farmers may limit benefits at scale, but evidence suggests that better design can rapidly improve uptake of insurance (Greatrex et al. 2015).

Knowledge services, research and development are widely understood as critical to climate-change actions in agriculture. For example, empirical evidence shows that access to knowledge increases women farmers' propensity to adopt climate-change innovations (Twyman et al. 2014). Over a third of submitted INDCs outlining intentions on adaptation specifically refer to knowledge systems, knowledge transfer and indigenous knowledge (Richards et al. 2016). While there are several economic assessments of knowledge and extension systems from pre-2000, there are fewer

more recent appraisals that address the added risks of climate change. There are, however, several economic appraisals of returns from research to climate-sensitive agricultural livelihoods. For example, adoption of improved maize varieties that include climate-resilient traits increased in West and Central Africa from less than 5 per cent of the maize area in the 1970s to about 60 per cent in 2005, yielding an aggregate rate of return on research and development investment of 43 per cent, plus annual poverty reduction of 0.75 per cent per year (Alene et al. 2009). These are generally participatory research programmes that involve farmers in design, field trials and interpretation of results.

Policy and legal frameworks

In many cases, the role of public policy – especially at the national level – will be in creating the enabling environment for private actions at the farm level and in the value chain. There are important barriers to mitigation and adaptation, including market failures, policy failures, governance failures and behavioural barriers (Cimato and Mullan 2010) that make it more difficult to plan and implement actions, and/or lead to missed opportunities and higher costs, which need to be addressed to enable effective and efficient implementation. They are particularly important for national-level policy and, therefore, for NDCs. Development of policy-based actions may not comprise a major cost component in NDCs or related instruments (e.g. diagram 8), but can provide major leverage for behaviour change among farmers and other value-chain participants.

A recent study undertakes an economic analysis of the costs and benefits of climate-adaptation policy in four countries (Malawi, Tanzania, Bangladesh and India), examining returns to public policies and programmes in climate-related research and extension, input quality and availability, water availability, market access and infrastructure, and improving value chains (Cacho et al. 2016). The study shows positive economic returns to investments and policy changes in these programmatic areas, including significant improvements in a composite resilience indicator, particularly in South Asia. Notably, a key finding is that meeting the size of the climate-change challenge will require a package of integrated policies, rather than a selection of single best-bet policy interventions.

To justify increasing investment in policy interventions – for example, increasing the US\$1 million in global ASAP policy and legal framework interventions (diagram 8) – there are ways to track the benefits of policy outcomes that go beyond economic and financial modelling (Tsui et al. 2014). IFAD is currently developing methods to measure the impact of policy engagement across its project and grant portfolio.

Project management and monitoring

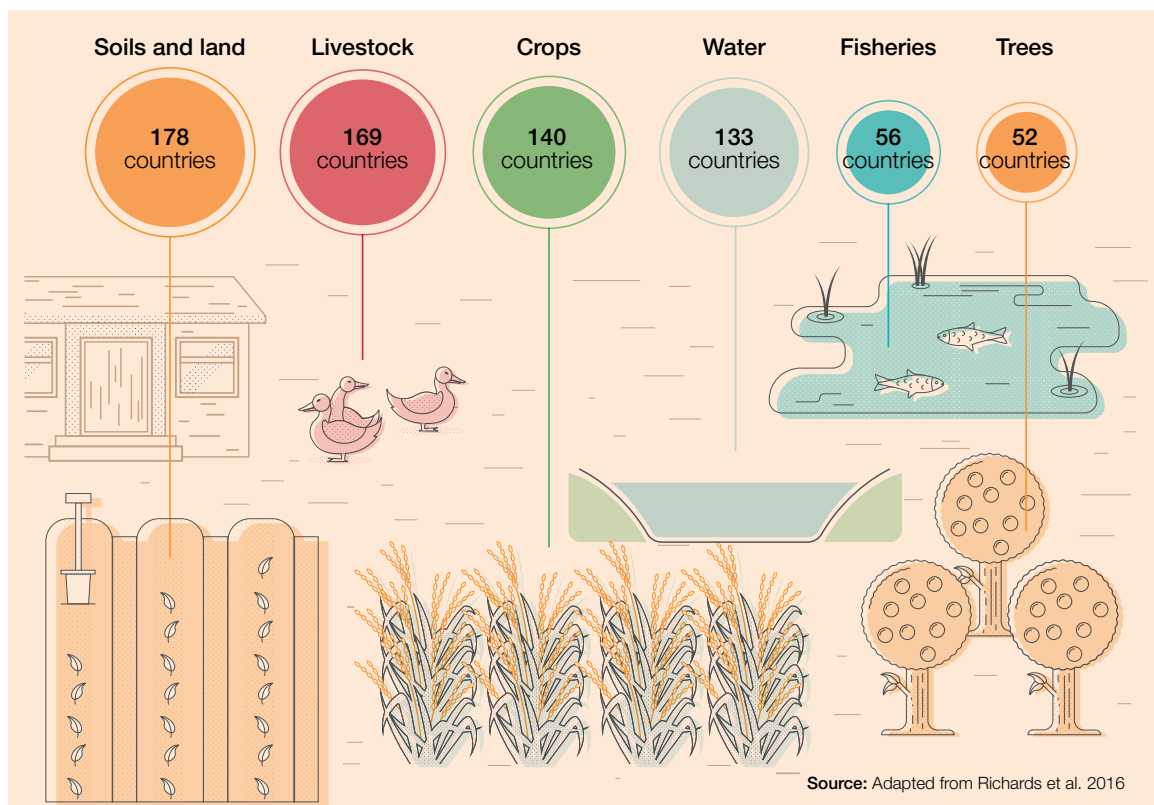
Effectiveness of finance requires consideration of project management and monitoring costs to deliver and demonstrate impact and outcomes. For example, under the UNFCCC mechanism REDD+ (Reduced Emissions from Deforestation and Forest Degradation), there are formal requirements for monitoring, reporting and verification. Start-up and operational costs for these depend strongly on design features of the project, such as technical capacities, existing data sources and the level of cooperation across sectors and agencies (GFOI 2014).

Economic value of adaptation and mitigation actions at the farm level

Many of the NDCs that include agriculture in their plans for mitigation and adaptation specify key subsectors for support to action at the farm level (diagram 9). Appraisal of costs and returns of adaptation and mitigation actions provides an important indicator for mitigation and adaptation decision-making. Understanding the effect on net income of adopting a practice, and the net present value or rate of return on the initial investment associated with adoption, allows decision makers to prioritize actions. It also assists them in promoting actions, assessing their likely adoption by particular groups and seeing where additional support or incentives may be needed for those with delayed benefits or large public, but small private, benefits. The Viet Nam country case study at the end of this report shows the importance of understanding heterogeneity among farmers.

As a result of heterogeneity among farmers, the costs and benefits of practices and the potential for a practice to increase net income are also highly heterogeneous. As these depend on agro-ecological variables, market conditions and political contexts, costs and benefits may accrue to different social groups or actors in the value chain, depending on their social, political and economic power. The temporal distribution of returns from a practice is also important to consider. Many actions intended to preserve or enhance the natural resource base – soil conservation measures, for example – do not have positive effects on crop yields until several years after adoption. In this section, we have attempted to summarize the current knowledge on economic

Diagram 9. Inclusion of subsectors in the mitigation and adaptation plans of NDCs





Water tower

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costs and benefits of adaptation and mitigation practices at the farm level, with an eye towards their potential to increase net farm income. We have limited our discussion to incremental (rather than systemic or transformational) adaptation options and mitigation options, excluding land-use change, as these have the most relevance for farm-level economic analysis. This summary is intended to provide a general sense of the economics of adaptation and mitigation options and the variables that most influence economic returns. However, it cannot replace a thorough ex-ante analysis in a particular project location.

One emerging finding is that options may be most effective when implemented as portfolios rather than individual actions, and that extension services are key in supporting these. For example, one economic assessment found a portfolio of improved seeds, together with soil and water-conservation measures, was most effective in enhancing agricultural production in climate-vulnerable areas of Ethiopia (Di Falco and Veronesi 2013). Similarly, new econometric modelling suggests that programmes to support adaptation and mitigation practices among farmers will be more effective when packaged as sets of complementary actions – for example, improved seeds coupled with extension services, support to input and output markets and reductions in post-harvest losses, rather than as stand-alone interventions (Cacho et al. 2016).

Soils and land

Climate change poses a number of challenges to maintaining the stability and productivity of soils. Less and more erratic rainfall reduces the capacity of soils to supply water and nutrients to plants; more intense storms increase soil erosion, and higher temperatures speed mineralization of soil organic matter (FAO 2013). A suite of practices can contribute to the stability and productivity of soils and the resilience of agricultural systems to climate change by protecting soils from erosion and compaction, maintaining high organic matter and supporting nutrient cycling. On croplands, minimum or no-till combined with mulch or other soil cover

Table 1. Summary of farm-level economic value of adaptation and mitigation practices related to soils and land

Practices	Adaptation	Mitigation	Economics
Tillage and residue management.	Improves soil structure and fertility. Reduces the negative yield effects of rainfall variability.	Combining no-till with residue retention increases the potential for carbon accumulation in soils.	Evidence on the profitability of tillage and residue management is mixed.
Improved pasture (irrigation, planting leguminous or improved species, fertilization).	Improved ecological functioning allows pastures and rangelands to continue supporting livestock, even with variable or extreme weather.	Enhances carbon storage.	Generally profitable for market-oriented farmers.
Earth or stone bunds, terraces.	Reduces erosion, increases water infiltration.	May have carbon sequestration potential; little empirical evidence available on the magnitude of this potential.	Increases yields where water is a key constraint. Lack of empirical evidence on net economic impact.

References: Blanco and Lal 2008; Conant 2001; Corbeels et al. 2013; Erenstein and Laxmi 2008; Mafongoya et al. 2016; McCarthy et al. 2011; Nyanga et al. 2012; Powelson et al. 2016; Smith et al. 2008; Zougmore et al. 2014

Examples

In a review of tillage practices in the Indo-Gangetic Plain, net returns from zero-tillage were US\$97 higher than conventional tillage (Erenstein and Laxmi 2008).

A six-year study in Zimbabwe found negative net present value (NPV) for switching from conventional tillage to conservation agriculture (Mafongoya et al. 2016).

A programme in the Brazilian Amazon combining pasture restoration with breeding, watering systems and supplementary feeding increased gross margins by US\$1,853-US\$2,797 per year (Marcuzzo 2015).

Stone bunds increased sorghum yields between 33% and 55% in Burkina Faso's central plateau area and millet yields by more than 40% in Niger (Zougmore et al. 2014).

(sometimes called conservation agriculture) reduces erosion by up to 80 per cent, increases soil organic matter, increases soil-water infiltration and reduces runoff (Richards et al. 2014). On grasslands, improvement of pasture with irrigation, nutrient inputs or leguminous species can provide more feed for livestock and avoid land degradation. On steeply sloped areas, structures such as earth bunds and terraces or live barriers help limit runoff and erosion (Howden et al. 2007). Incorporation of perennials into crop and livestock systems (discussed under “trees,” below) can further support resilience to wind and water erosion and provide organic inputs in the form of leaves and root biomass.

Time frame	Factors influencing distribution of benefits
Long-term.	May have higher chance of profitability in mechanized cereal agriculture (e.g. in Indo-Gangetic Plain) due to decreased tillage costs. Profitability in non-mechanized systems depends on cost of labour and competition for crop residue. May shift labour burdens between women and men.
Long-term. More likely to provide early economic benefits to farmers when combined with other productivity-enhancing practices.	Livestock are often owned or controlled by men, so care must be taken to ensure benefits accrue equitably. Farmers with small herds may bear higher opportunity costs than those with medium and large herds.
High costs for construction and annual maintenance.	Best in steeply sloped, arid areas. May reduce yields where there is risk of high rainfall and waterlogging. Heavy labour requirements.

Livestock

Climate change threatens to affect livestock systems in several ways, such as in the quality and quantity of pasture and forages, reducing water supply for animals and feed production, thermal stress to animals, and increased exposure and susceptibility of animals to pests and diseases (Thornton et al. 2009). Potential adaptation options to moderate climate impact include: changing livestock breeds or species, adjusting stocking densities to feed availability, altered and adapted forage crops (Thornton and Herrero 2014), use of irrigation, and adaptations to animal housing for better

Table 2. Summary of farm-level economic value of adaptation and mitigation practices for livestock

Practices	Adaptation	Mitigation	Economics
Changing breeds or species.	Native tropical breeds and species (e.g. <i>Bos indicus</i> cattle) are generally more heat and drought-tolerant but lower performing. Breeding of high-performing, heat-adapted animals is a promising strategy, but a slow process.	Increasing animal performance or switching from cattle to smaller livestock reduces GHG emissions per unit of food produced; breeding animals for lower methane emissions is possible but likely still several decades off.	System-level adaptations that improve productivity and link farmers to markets generally increase net income; potential trade-offs between productivity, heat tolerance and emissions at the individual animal level.
Grazing management (adjust stocking densities to feed availability, rotational grazing).	Improved ecological functioning of pastures and rangelands may lead to reduced variability in livestock production and increase resilience to drought.	Optimal grazing levels can enhance C storage; effects not well established.	Generally profitable for market-oriented livestock keepers. Restoration practices that require excluding livestock are expensive.
Improved feeding, adjusting forage crops.	Reduces fluctuation of feed during dry season.	Improves system productivity, reducing emissions' intensity (emissions per unit of meat or milk).	Generally increases net revenues, depending on cost of improved feed.

References: Boettcher et al. 2014; Bryan et al. 2013; de Haas et al. 2016; Garg et al. 2013; McCarthy et al. 2011; Thornton and Herrero 2010

Examples

In dairy systems, increases in milk yield have been shown to correlate with decreases in emissions intensity (Gerber et al. 2013) and increases in gross margins.

A dairy intensification programme in Brazil nearly doubled gross margins from US\$5,440 per hectare to US\$10,473 per hectare using a combination of practices, such as rotational grazing, feed supplementation during the dry season and improved breeds (Novo et al. 2013).

Studies from Uganda and Kenya showed net returns of US\$62-US\$122 per year for supplementary feeding with nitrogen-fixing *Calliandra* species (Dawson et al. 2014).

pest and disease management. Adaptation options that improve the resilience of cropping systems (considered in “crops” below) are also relevant to livestock, given the importance of crop residues as a feed source. For countries with low livestock productivity, investments in improving animal and herd productivity can also reduce greenhouse gas emissions per unit of milk and meat production. Livestock production contributes about 14 per cent of greenhouse gas emissions globally, most of it released from enteric fermentation in the gut of ruminants (Gerber et al. 2013).

Time frame	Factors influencing distribution of benefits
Economic benefits of more productive animals are immediately visible. Heat tolerance has latent benefits.	Potential to positively impact the incomes and livelihoods of rural women, who comprise two thirds of low-income livestock keepers (Distefano 2013). However, men are often responsible for commercialization of livestock products, and women have difficulty in accessing financial services and markets, creating a risk that benefits will accrue to men and bypass women. Gallina (2016) and Distefano (2013) provide examples of how to design livestock interventions with gender-differentiated roles and responsibilities in mind.
Long-term. More likely to provide early economic benefits to farmers when combined with other productivity-enhancing practices (e.g. improved breeds).	
Benefits visible within one year.	

Crops

Many farm-level adaptation options for cropping systems are similar to existing options to manage risk or enhance productivity (Howden et al. 2007). Farmers may change crop varieties or species to those more resistant to climate stresses, such as heat, drought and disease, or those with requirements more adapted to the new climate (such as replacing coffee with cocoa). They may also change the timing or location of particular cropping activities; for example, to accommodate later or more

Table 3. Summary of farm-level economic value of adaptation and mitigation practices for cropping systems

Practices	Adaptation	Mitigation	Economics
Changing crop varieties or species.	Increases tolerance to heat, drought, pest or disease pressure.	Negligible mitigation potential unless changing from annual to perennial species.	Improved crop breeds generally have substantial positive effects on net income; switching crops can also increase income, depending on markets for alternative crops.
Changing timing or location of cropping activities.	Reduces risk of crop loss due to drought or other weather extremes.	Negligible mitigation potential. Has potential to increase emissions, if croplands encroach on forest.	Little empirical evidence.
Improved pest, disease and weed management.	Reduces risk of crop losses due to biological pressures; improves water and nutrient use efficiency.	Negligible mitigation potential.	Little empirical evidence on profitability as an adaptation strategy.
Nutrient management.	Supports resilience of crops, increases yields.	Moderate mitigation potential due to reduced nitrogen (N) loss as N ₂ O.	Substantial economic benefits where fertilizers have been under-applied. Modest increases in net income due to savings in fertilizer use where fertilizers have been over-applied.
Diversifying crop species, changing balance of crop and livestock activities.	Reduces livelihood vulnerability by providing other sources of food or income.	Adding tree crops can have substantial mitigation benefits.	Generally modest increases in net income. Highly dependent on portfolio of crops and animals chosen.

References: Branca et al. 2011; Khatri-Chhetri et al. 2016; McCarthy et al. 2011; Seo 2010; Shongwe et al. 2014; Smith et al. 2008; Thornton and Herrero 2014

Examples

Use of improved seeds increased net returns of rice-wheat cultivation in India by approximately US\$230 per hectare (Khatri-Chhetri et al. 2016).

Optimization of N fertilization rate (e.g. using optical sensors that allow field-specific application of fertilizer) has been shown to increase net returns on a per hectare basis in India and Mexico (Basak 2016a).

Other practices that reduce greenhouse gas emissions from fertilizer, such as shifting from urea to ammonium sulphate or nitrate, use of controlled-release fertilizers, nitrification inhibitors and fertilizer deep placement are not currently financially viable at the farm level (Basak 2016a).

variable rainy seasons. As climate alters pest and disease dynamics, more effective pest, disease and weed management may be critical to the resilience of cropping systems, along with improved nutrient management. Finally, diversifying crop species can be an adaptive practice, along with diversifying farm and livelihood activities as a whole, by altering the balance of crop and livestock activities or taking off-farm employment. Water management in cropping systems (discussed under “water”) is also critical to climate resilience and relevant to mitigation in irrigated rice systems.

Time frame	Factors influencing distribution of benefits
Improved varieties have low up-front costs, with yield benefits visible in first season. Cultivating different species may require up-front investment and a learning curve until the system becomes profitable.	Not available to farmers without access to input markets.
Little empirical evidence.	Little empirical evidence.
Long-term.	Highly knowledge-intensive; farmers with little access to information may be at a disadvantage.
Economic benefits usually visible within first season.	Dependent on access to input markets.
Diversification with tree crops requires several years for trees to mature. Adding livestock or annual crops has more immediate benefits.	Can provide new income opportunities for women. Requires local understanding of gendered roles in agriculture and livestock production.

Water

Water-management technologies for climate adaptation include water harvesting (capturing and storing water for later use), practices to conserve soil moisture (such as plastic mulching) and more efficient use of irrigation water (such as drip irrigation). In irrigated rice systems, periodic drainage has been used in water conservation for decades in some Asian countries, and can also reduce methane (CH₄) emissions.

Table 4. Summary of farm-level economic value of water-management practices

Practices	Adaptation	Mitigation	Economics
Water harvesting, supplemental irrigation.	Increases crop yield. Buffers against drought.	Can enhance carbon storage through increased yields and residue returns.	Substantially increases net profits.
Efficient use of irrigation water, conservation of soil moisture.	Reduces water use; buffers against drought.	Potential energy savings; reduction in CH ₄ in the case of irrigated rice.	Highly dependent on irrigation system; drip irrigation has not been shown to increase net income for smallholders.
Periodic drainage of irrigated rice.	Reduces water use by up to 30%.	Can reduce CH ₄ emissions by up to 50% or more, if practised correctly.	Increases profits due primarily to savings on irrigation and pumping costs. May improve yields.

References: Basak 2016; Biazin et al. 2012; Fox et al. 2005; Gallina and Farnworth 2016; Mostafa and Thörmann H-H. 2013; Mupaso et al. 2014; Richards and Sander 2014; Shongwe et al. 2014; Wanvoeke et al. 2015

Examples

A study of water harvesting, with supplemental irrigation, of sorghum and maize estimated a net profit (per hectare per year) of US\$151-US\$626 in Burkina Faso and US\$109-US\$477 in Kenya, compared with US\$15 to US\$83 for the Burkina Faso case and US\$40-US\$130 for the Kenyan case for existing farming practices (Fox et al. 2005). Positive net returns are dependent on nutrient inputs to obtain high crop productivity, otherwise, the initial costs outweigh the economic benefits (Biazin et al. 2012).

In a review of alternate wetting and drying in Bangladesh and Viet Nam, Basak (2016) found positive benefit/cost ratios of between 1.7 and 3.8, and increases in net profits of 8%-41%. The profitability of the practice is highly dependent on irrigation costs.

Time frame	Factors influencing distribution of benefits
Increases yield within first season, but has high upfront cost.	Substantial initial investment, which may be a barrier for resource-poor farmers.
Little immediate economic benefit unless irrigation has not been used previously.	Knowledge-intensive; drip irrigation and similar systems require substantial initial investment that may be a barrier for resource-poor farmers.
Immediate cost savings.	Economic benefits may be limited to farmers that pay per unit of irrigation water; gender impacts require further study.

Fisheries

Climate change has the potential to significantly affect aquaculture and fisheries through temperature variations and saline intrusion into freshwater habitat, reducing rate of growth, size, total production, reproduction and even reproductive capability of fish species. Adaptation strategies for aquaculture and fisheries are based on ecosystem approaches, which aim to increase the resilience of aquatic ecosystems, fisheries and aquaculture production systems (Cochrane et al. 2009).

Table 5. Summary of economic value of adaptation and mitigation practices for fisheries

Practices	Adaptation	Mitigation	Economics
Adaptation options for capture fisheries (ecosystem approaches, coastal protection, early warning systems, governance of fisheries, shift to cultivated systems).	Goal of adaptation is adjustment of fishing pressure to sustainable levels.	Mangrove protection and rehabilitation has moderate mitigation potential.	Limited empirical evidence; depends on management instruments used.
Adaptation options for aquaculture (breeding for resilience, infrastructure improvements, water use efficiency, change feed, diversify livelihoods).	Goal of adaptation is reduced vulnerability to temperature changes, saltwater intrusion, floods and droughts, and changes in water quality (e.g. eutrophication).	Minimal mitigation potential, mostly related to energy use.	Limited empirical evidence on economic impact of adaptation options in aquaculture systems.

References: De Silva and Soto 2008; Grafton 2010; Kam et al. 2012; Ponzoni et al. 2007; Ponzoni et al. 2008; Shelton 2014

Examples

As adaptation strategies for capture fisheries require action at community, national and even international levels, economic returns are more appropriately expressed at these levels than at the farm level (Shelton 2014). In an economic study of adaptation costs and benefits in catfish and shrimp farms of the Vietnamese Mekong Delta, the cost of planned adaptation funded by the government would constitute 0.7% of the total export value from 2010 to 2020, and would be much less costly than if farmers were left to adapt by themselves (Kam et al. 2012).

Genetic improvement of aquaculture species has shown positive returns at the farm and programme level for Nile tilapia (Ponzoni et al, 2007) and common carp (Ponzoni et al 2008).

Genetic improvement, species redistribution and diversification of livelihoods are also potential adaptation measures, along with improved forecasting, early warning systems, disaster preparedness and integrated coastal-area management. The protection and restoration of coastal and marine ecosystems also have mitigation potential via carbon storage in plants (e.g. mangroves) and sediments, often called “blue carbon” (McLeod et al. 2011).

Time frame	Factors influencing distribution of benefits
Long-term.	Limited empirical evidence.
Long-term.	Limited empirical evidence.

Trees

Tree-cropping systems, such as coffee, cocoa and palm oil, face similar climate challenges as annual cropping systems in terms of rainfall variability, heat stress, and pest and disease pressure. Adaptation options are, therefore, similar as well: diversification with shade trees or other productive tree species (which also has

Table 6. Summary of economic value of tree-based adaptation and mitigation practices

Practices	Adaptation	Mitigation	Economics
Incorporation of perennials into livestock or annual cropping systems, or diversifying perennial cropping systems with shade trees or other useful species.	Supports ecological functioning (nutrient cycling, water storage, erosion control) and creates favourable microclimate for other crops (e.g. coffee) that can provide animal fodder or additional income sources.	Adding tree crops and other woody perennials can have substantial mitigation benefits.	Adding trees to agricultural systems generally improves profitability, as long as competition with other crops is managed.
Improving soil, nutrient and pest-management practices in perennial cropping systems.	Reduces risk of crop losses due to biological pressures. Improves water and nutrient use efficiency.	Nutrient management has moderate mitigation potential due to reduced nitrogen (N) loss as N ₂ O.	Has been shown to be profitable for high-value tree crops.

References: Ajayi et al. 2009; Branca et al. 2011; Kiptot et al. 2014; Lasco 2014; Magne et al. 2014; McCarthy 2011; Zomer et al. 2016

Examples

When well-managed, agroforestry systems are generally profitable. In a large-scale study, the majority of the 56 agroforestry systems had positive NPV using a 20% discount rate (Mercer 2004; Current et al. 1995).

The marginal rate of return for adding banana to mono-cropped coffee in Uganda was 911% in arabica and 200% in robusta-growing regions (van Asten et al. 2011).

Incorporating nitrogen-fixing shade species such as *Inga spp.* and *Machaerium arboreum* into tree-cropping systems improves soil fertility and can partly or fully replace fertilizers (Lasco et al. 2014).

Timber-producing shade trees have low management costs and are considered a “savings account” that can be realized at times of low prices or failure of the underlying crop, reducing vulnerability to environmental or economic shocks (Tscharntke et al. 2011).

mitigation potential), improved soil, nutrient and pest management practices, adapted varieties, and irrigation or more efficient water use. Integrating trees into existing cropland and grazing land has significant potential for increasing agroecosystem resilience and mitigating climate change via carbon sequestration.

Time frame	Factors influencing distribution of benefits
Tree crops and timber species require several years for trees to mature before benefits accrue.	Women can benefit substantially from agroforestry systems, if constraints to their participation are addressed (e.g. lack of capital, poor market infrastructure, high cost of transportation). Initial investment and access to seedlings may be a barrier for resource-poor farmers. Secure land tenure (Mbow et al. 2014) and market access for perennial crops are key to profitability.
Little empirical evidence.	



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Beyond cost-benefit analyses: promoting incentives and enabling conditions for change

Key messages:

- Limited funds for action on climate change mean that wise investments will be those that provide strong incentives and leverage, and spread benefits widely.
- Supplementing cost-benefit analyses with better understanding of drivers of behavioural change, including at different scales and time frames within an overall theory of change, will provide better guidance for investment.
- Private-sector actors other than farmers can play significant roles in promoting climate-change mitigation and adaptation throughout the agricultural value chain, by providing finance, knowledge, technologies and market incentives.
- Public agencies and policies can enable positive action across the private sector through regulation and standards, knowledge management and extension, risk-management institutions, finance mechanisms and stable resource rights for smallholder farmers, among others.

Analyses of costs, benefits, internal rates of return and net present value (NPV) can provide crucial inputs to inform policies, priorities for investment, business cases and finance plans. Climate-change policy frameworks, such as NAPs and NDCs, are a key mechanism for stimulating action towards meeting adaptation and mitigation targets, and cost-benefit analyses (CBAs) may provide valuable information to support this process. But these types of information alone may not be enough to trigger the kind of wide-scale change we need to meet the challenges of climate change. By themselves, CBAs may not consider a number of features that could enhance their ability to lead to positive outcomes.

The Fifth Annual Assessment Report of the IPCC signalled a move beyond cost-benefit analyses towards greater consideration of drivers of behaviours, non-monetary factors, heterogeneity and inequality in the economics of climate change (Chambwera et al. 2014). These further considerations have the potential to induce transformative change by taking on a much wider range of social, political and cultural factors as internal to economic decisions taken by governments, as well as by farmers, companies, non-governmental organizations (NGOs) and consumers. Financial institutions may also be able to play a role in accelerating transformative change.

Funds for action on climate change in the agriculture sector are extremely limited. Thus, it's all the more important to invest resources wisely, to make smart investments that will leverage the most behaviour change and, where possible, to leverage additional financial resources from the public and private sectors. If CBAs are enhanced with better information on incentives and drivers of behaviours, climate-change policy frameworks, such as NAPs and NDCs, should be more effective. They will also have the chance to reach real scale and provide a platform for transformative change that brings broad-based benefits to the poorest members of society.

Adaptive behaviour of smallholder farmers

Combining cost-benefit analysis with adaptive behaviour analysis

Using CBA to assess whether and where to allocate money tends to assume that people will respond in known ways to specific investments and that there will be uptake. The assumption is: "If we build it, they will come." But if smallholder farmers do not respond as positively as we assume, then NPVs are likely to overstate the actual returns to investments. This difference between project-level analysis and actual smallholder behaviour is observed over and over again. For example, a recent study in Kenya found that local people valued a proposed agroforestry intervention at 70 per cent below the calculated NPV, which reduced uptake and adoption. There were a number of reasons for this response, including low levels of information and knowledge of these types of interventions, coupled with aversion to risky innovations (Chaudhury et al. 2016).

More generally, the large literature on adoption and adaptation suggests that our blanket assumptions about people's behaviour are too simple and often wrong. Instead, it is important to pay attention to the heterogeneity in adaptive behaviour and to understand why different types of people do what they do. Smallholders' decisions are affected by many factors besides current material assets, cash flow and market signals, such as family, culture, tenure, local politics and perceptions of risk.

It is often tempting to conclude that CBAs at a local level can also help understand local behaviours and preferences. We assume that households undertake activities that yield positive NPVs. A range of additional approaches that we can call “adaptive behaviour analysis” can improve the efficacy of CBA in targeting effective investments. Adaptive behaviour analysis (ABA) has a number of differences to CBA (table 7). Some of these differences represent fundamental differences in approaches driven by different objectives (i.e. CBA to inform government investments versus ABA to understand why smallholders do what they do). Others involve differences in practices that could potentially be done similarly for both approaches, but are frequently limited by data availability.

The two approaches provide complementary information: CBA on the net benefits that accrue to households or society and ABA on the factors affecting behaviour change. Some balance between CBA and ABA is needed. For example, a first stage might be to screen proposed climate-change actions using a simple form of ABA. An action that meets criteria for participation among specific target groups (the “they will come” criteria) can go to the second stage, where CBA analyses are undertaken for those sets of households that may truly benefit from investments. The CBA might reveal that the NPV is not attractive enough, either at the local or national level, even if there is willingness among farmers. Thus, ABA and CBA together can provide guidance on how best to incentivize uptake of beneficial practices and to make sure that benefits are shared across society, particularly among poorer and more marginalized people.

The practice of alternate wetting and drying in rice (AWD) provides one example. A meta-analysis of CBAs shows that the practice is profitable for farmers across several countries, giving a positive NPV at the farm level, as well as delivering higher-level social benefits, including substantial reductions in methane emissions (Basak 2016). But a quick look at adaptive behaviour tells a different story: despite the clear benefits, uptake is slow among farmers. According to experts, there are two main factors influencing farmers’ willingness to try out AWD. The first is that farmers tend to pay for water by land area not by water volume, so they do not prioritize reductions in water usage and they think that only the pump operators, who do pay by volume, benefit from the water savings of AWD. The second is that management of land is seldom consolidated; farmers who manage their land collectively, through some form of management agreement, are much better placed to save costs and undertake innovations (Basak 2016). Furthermore, women are often excluded from water-management institutions and from extension services, even though they provide half of the labour on Asian rice farms, and may be eager to switch to labour-saving, low-emissions practices like dry-field direct planting (IRRI 2016). The lesson here is that CBA alone, even at the farm level, cannot tell policymakers where to put the smart investment, or smart economic incentive, to improve management of rice paddies under climate change and to improve outcomes for women as well as for men.

Understanding drivers of behaviour within a wider theory of change

Are independent behavioural analyses necessary for all groups of farmers, or are there some generic behaviours and preferences? Empirical research at the global scale is rare, but recent analysis shows that some drivers of adaptation are common across

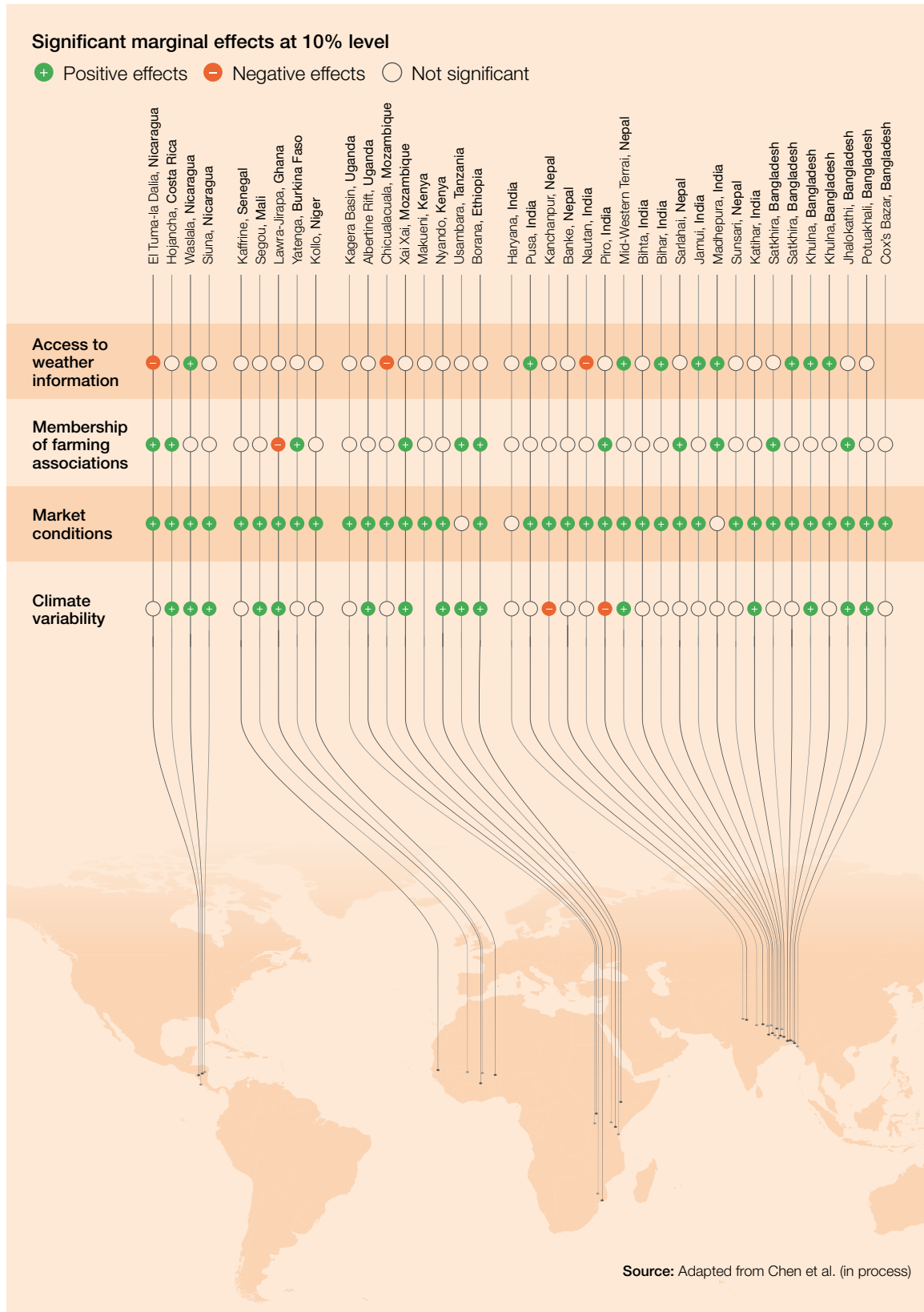
Table 7. Differences between cost-benefit analyses and adaptive behaviour analyses

Cost-benefit analyses (CBA)	Adaptive behaviour analyses (ABA)
<i>Fundamental differences In approaches</i>	
Social-accounting stance	Private-accounting stance
Social discount rate	Private rate of time preference
Probabilistic approaches or sensitivity analysis	Risk preferences and option values
Analysis of a single activity	Portfolio analysis
Institutional and transaction costs largely ignored	Institutional and transaction costs considered
<i>Differences in practices that could change</i>	
Typically at a high level of scale	Typically at a low level of scale
Aggregated measure of NPV	Heterogeneity in behaviour and drivers
Often at national scale, though a small number of studies give household NPVs	Greater attention to gender and within-household differences
<i>Types of indicators and survey methods</i>	
NPV, internal rate of return	Observed adaptive behaviour, willingness to accept/pay, elicited risk preferences or observed behaviour

many regions of the world. For example, analysis of adaptation behaviours in CCAFS-CGIAR research sites finds that two drivers – membership of farmers’ organizations and access to climate information – are somewhat universal across countries and continents (diagram 10). Other drivers, such as physical assets, are important at only a minority of sites (Chen et al. in progress). We can also understand better the reasons that people give for changes in behaviour. At the CCAFS-CGIAR research sites, farmers across all sites say that they make changes in response to both markets and climate variability, although markets are a more widely shared reason than climate (diagram 10).

This data analysis across multiple sites (diagram 10) also points to the importance of understanding farmers’ behaviours and preferences within the context of different scales of time and space. Farmers across Asia, Africa and Latin America widely report that markets are a key driver of their on-farm practices and choices; markets provide a strong link between actions at the farm level and actions at the national and international levels. Due to causal links across scales, local-level CBA is at best only part of the story. Improved practices that increase yields at scale will shift the supply-demand equilibrium and in most cases reduce producer prices, which in turn

Diagram 10. Map showing importance of four key factors – weather information, farmer organizations, markets and climate variability – correlated with adaptation at CCAFS-CGIAR research sites



will have a dampening effect on uptake of the new practices. This may explain low adoption rates of innovations, such as drought-resistant seed in sub-Saharan Africa, for example. Thus, iterative analyses at different scales are needed, covering both private and social outcomes.

Similarly, farmers' behavioural patterns of adoption and preferences for different practices will be driven by their attitudes to risk. One shortcoming of a classic CBA can be the assumption of standard conditions across years. Yet farmers respond to climate variability (diagram 10), which is likely to be increasingly important as both the frequency and magnitude of extreme or unusual climatic events – such as dry spells during the growing season, heatwaves or floods – are expected to have greater impacts in many farming locations under progressive climate change. Farmers' appetite for innovations will depend on how the new practice or technology performs in good, average and bad years. Smallholder farmers are often characterized as risk-averse, meaning that they have a greater interest in avoiding losses in bad years than in maximizing gains in good years. Therefore, some form of risk analysis, for example, testing of farmers' behaviours or stated preferences across the spectrum of current (and/ or future) climate variations, will improve the quality of any economic assessment.

A final point is that the level of adoption and uptake of interventions to build climate resilience will depend on the mode of design and delivery. Local institutions and local ownership often constitute the key to success. For example, in the water and sanitation sector, the "community-led total sanitation" approach has significantly improved adoption rates of modern sanitation and outcomes for health. The approach focuses more on local leadership of community-wide behavioural change than on building toilets and washing facilities. Similarly, the IFAD ASAP investments are as strongly targeted towards building of local institutions for climate-change adaptation as on building the needed infrastructural or technological hardware.

In summary, for an economic assessment to be a strong decision tool, it needs to go beyond CBA to a more nuanced understanding of the drivers of, and incentives for, behavioural change, particularly at the farm level, but also more widely in the value-chain or food system (next section). Understanding the drivers of behaviour provides us with important information to improve the efficacy of CBA in targeting effective investments. If we understand behaviour, we can target a subset of investments where we have empirical evidence to support the proposition that "If we build it, they will come." Moreover, understanding these drivers (such as access to information about weather variability) may in itself suggest investments (i.e. the public provision of that information) that can yield positive returns to investments.

The arising practical advice is to include both CBA and ABA within an economic analysis of options for action on mitigation and adaptation, whether in the agricultural sector or more widely in rural or national development policy. The most useful approach may be to embed CBA and ABA within a "theory of change" – a hypothesis or proposed storyline on how a sequence of actions leads to a desired outcome, such as raised climate resilience or reduced emissions in agriculture. A theory of change need not be complex (box 4). Its purpose is to question the assumptions that we might make during policy formulation or programme design – assumptions such as high levels of adoption among farmers, robustness over a wide range of possible climate futures, or equal benefits to both women and men.

Economic incentives for private-sector action

Role of private sector in agricultural adaptation and mitigation

Private-sector actors other than farmers can play a significant role in promoting climate-change mitigation and adaptation throughout the agricultural value chain. This is underlined by the fact that annual global food retail sales total approximately US\$4 trillion (USDA 2016), indicative of the scale of the financial influence of the food and agribusiness sector, compared to public climate finance in the region of US\$35 billion a year across all sectors (ODI and Heinrich Boll Stiftung 2016). A major incentive for private actors across the value chain is the “value at risk” concept (i.e. the proportion of either their production or procurement at risk of being damaged or of failing altogether due to climate-change effects.) A PricewaterhouseCoopers analysis from 2015 indicates that across the three major crop categories included in the IPCC’s Fifth Assessment Report (rice, maize and wheat), 32 per cent of the annual crop was estimated at risk of failure in 2012; and by 2050, this number is projected to rise to 41 per cent (WBCSD 2015). Table 8 provides some examples of the roles that different private-sector actors play in promoting climate-change mitigation and adaptation in the value chain.

How the public sector can enable private-sector actions

Public agencies and policies can provide incentives and enabling conditions for the private sector to further integrate climate mitigation and adaptation in their activities.

National governments can focus on creating a supportive regulatory environment for multi-sector partnerships. Given the high risks associated with investing in or lending to smallholders or agribusinesses, various financiers, investors and project development companies need to apply innovative financing arrangements and business models among multiple actors in the value chain. Through these multi-party financing arrangements, such as those with banks, farmers or agribusinesses, different capital providers have been able to spread their risk and develop substitutes for collateral. However, creating these partnerships remains challenging in many parts of the world as financial regulation, guidance and support lag behind. Key sectors where government could provide the enabling conditions for partnerships and investment include: mobile phone services for farmers (which are increasingly being used for e-payments and weather information systems), climate-resilient infrastructure, agricultural extension, local capacity in science and research, technical

Box 4. Basic components of a theory of change

- Problem description and desired outcomes (who, when, what).
- Context for the initiative, including social, political and environmental conditions.
- The actors that can create change.
- Process and sequence of changes anticipated to lead to the desired outcomes.
- Assumptions about how these changes might happen.
- Usually a diagram that shows the problem, actors, process and desired outcomes.

Source: Adapted from Vogel 2012

Table 8. Roles of private-sector actors in promoting climate-change mitigation and adaptation

Type	Role in promoting climate-change adaptation and mitigation
Suppliers and processors	<p>Share knowledge on climate-resilient, low-emissions practices.</p> <p>Facilitate the aggregation and organization of farmers to help them access finance and loans for investing in equipment and technology. This aggregation can also help farmers become certified against sustainability standards.</p> <p>Provide agri-finance to smallholders (e.g. Olam, an agri-business, provided US\$183.7 million in short- and medium-term financing in 2014 under its Olam Livelihood Charter).</p> <p>Integrate renewable energy into processing facilities e.g. use of by-product to fuel machinery, such as seed husks.</p>
Input providers	<p>Supply appropriate technology to strengthen smallholder resilience (e.g. low-cost water management) and train and support farmers in using inputs efficiently.</p> <p>Support the efficient operation of local input markets and address the counterfeit input market.</p> <p>Collaborate in partnerships with local governments, donors, scientists and communities to streamline logistics and input services (e.g. fertilizer concern Yara's work to establish the Ghana Grains Partnership provides farmers with credits for inputs, a guaranteed purchase price for outputs, and training).</p>
Traders	<p>Optimize systems to reduce waste in the value chain, e.g. improving efficiency of storage facilities.</p> <p>Transfer knowledge of products down to producers and provide training to suppliers. Provide guidance to farmers on potential certification options with a sustainability standard that is aligned with climate-change mitigation and adaptation behaviours.</p>
Retailers and consumers	<p>Adopt sustainability standards or certification schemes to encourage farmers to take up these standards in exchange for a price premium.</p> <p>Encourage co-investment in the training of traders, processors and suppliers in climate-resilient, low-emissions technologies and practices.</p>
Financial service and agri-credit providers	<p>Provide innovative financial services to farmers, e.g. loans to farmers that lack access to traditional collateral, or support in accessing insurance schemes.</p> <p>Deliver finance to those farmers not necessarily embedded in value chains, such as subsistence farmers, who with the necessary investment capital could make value-added investments to grow their businesses.</p>

assistance on sector-specific risk assessment and structures to assess and manage risk (such as credit bureaux).

National governments could also revise existing agricultural subsidies to promote climate resilience and low emissions' development. For example, Zambia's e-voucher programme, which reduces corruption by using mobile-phone technology to track the distribution of subsidized seeds and fertilizers, has been piloted in 13 districts with

241,000 farmers (Kasonde 2015). However, its current design does not factor in the ability of the programme to improve climate resilience or reduce emissions. Another key incentive that national governments can provide is better legal recognition and protection of local and customary land rights, including improving land registries and records. This would incentivize farmers to invest in climate-change adaptation and mitigation technologies that provide returns over the longer term. It would also mean that agribusinesses can sign contracts of sufficiently long duration with farmers and cooperatives to justify significant investment in these suppliers.

Similarly, multilateral and bilateral development partners have important roles to play in providing incentives for private-sector action. They can promote knowledge-sharing to ensure that corporate approaches to mitigation and adaptation in agriculture align with global standards and methods, like the Sustainable Development Goals indicators. For example, international climate and land-use financing and donor programmes could align application criteria, agree on common metrics and share monitoring tools to facilitate access to finance and to engage large and small businesses more actively. Building national capacity in monitoring and reporting systems is another key role for development partners to enable private-sector performance on climate mitigation and adaptation to be monitored independently.

Multilateral and bilateral development partners can also work to ensure that existing or new donor and climate finance programmes build in strong scope to engage and partner with the private sector in financing and implementing their activities. To be attractive to the private sector, finance systems will need to be simple, willing to take on feedback, transparent in governance, geographically flexible to match the value-chain coverage of the programme with that of the private-sector company, and have clear co-investment criteria and guarantees of the leverage this would result in. Suppliers, processors and traders, in particular, tend to operate low-margin businesses where investments have to show an attractive return.

Private-sector actors are not motivated by near-term margins alone; they will be attracted by a well-developed proposition of the non-financial benefits of participating in a financial mechanism or multilateral partnership. For programmes that seek to harness the power of business to raise resilience among smallholders, some examples of benefits to companies may be: greater connectivity to smallholder farmers and opportunities to increase producer loyalty; access to research and data on climate risk and smallholder farmer production patterns; development and training opportunities for their staff; and networking opportunities with other private- and public-sector partners.



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Conclusion: towards greater ambition

Key messages:

- Evidence of actions in agriculture that have a high likelihood of delivering meaningful economic and financial returns under climate change has been shown for global, national, project and farm levels.
- The ingredients of a strong economic assessment for NDCs and other climate-change plans for agriculture include policy mainstreaming, iterative planning, a balance of project-level and farm-level assessment of costs and benefits, and appraisal of economic incentives and the enabling environment for farmers and other private-sector actors. NDCs are generally well aligned with national development plans so that proposed actions for both adaptation and mitigation contribute to improved development outcomes, but they do not yet collectively meet global ambitions of the Paris Agreement.
- The more ambitious NDCs provide the political capital to promote transformative actions that bring together multiple longer-term agendas for social, economic and environmental benefit.

This report has presented evidence of actions in agriculture that have a high likelihood of delivering meaningful returns under climate change, from an economic and financial perspective. At the global level, the economic case can be made through several examples of positive returns for future food security and rural livelihoods under climate change (chapter 2). At the farm level, positive economic returns can be demonstrated for multiple practices that build adaptive capacity and reduce emissions intensity across several of the priority subsectors highlighted in the NDCs – soil and land, water crops, livestock, fisheries and trees. Evidence is emerging that combining these actions into portfolios linked to institutional support, such as extension, research and value-chain development, will deliver the best economic returns over time (chapter 3). Understanding and influencing the behaviours of farmers and other private-sector actors will be critical to success (chapter 4).

Building on the economic evidence available has the potential to generate new credible proposals that could then drive large-scale public and private investment in agriculture under climate change. The credibility of these proposals will depend on better-quality economic assessments. To recap from chapters 3 and 4, the key ingredients of a strong economic assessment in support of action on climate change in the agricultural sector are summarized below.

The ingredients of a strong economic assessment

This report's review of recent economic information pertinent to the agricultural components of NDCs and related climate-change plans at the national level, such as NAPs, suggests some key ingredients for a robust economic assessment:

Mainstreaming with development policy (chapter 3): Any economic appraisal that aims to contribute to decisions on climate-change actions in agriculture needs to be mainstreamed into current policy processes. In the ideal scenario, these policies are in alignment with each other. These include:

- Climate-change policies and plans, including NDCs, NAPs, nationally appropriate mitigation actions (NAMAs) and others
- Agricultural sectoral development plans
- National multi-sectoral strategies, such as rural development plans and green growth strategies
- Multi-sectoral plans wherever possible, for example, on nutrition and health, gender equality or environmental protection

Iterative climate-risk management (chapter 3): An iterative approach considers both the impacts of current climate variability and extremes and the risks of future climate change, including uncertainty, to propose a complementary set of three types of interventions:

- Immediate actions that address the current risks of weather and climate extremes
- Integration of adaptation into immediate decisions or activities with long lifetimes, such as infrastructure or planning
- Early monitoring, research and learning to prepare for the future impacts of climate change

Project-level economic assessment (chapter 3): Project-level and national-level investments are likely to be critical to positive outcomes from the climate-change interventions specified in NDCs – but there is less economic information readily available than for technologies. Relevant investments to include and appraise economically include: institution-building and capacity-building; services to provide finance, information, extension and research; policy and legal frameworks; and programme management, particularly for monitoring and evaluation.

Farm-level economic assessment (chapter 3): Many of the NDCs that include agriculture in their plans for mitigation and adaptation specify key subsectors for support to action at the farm level. Economic information is available for subsectors, such as soil and land, livestock, crops, water, fisheries and trees, though relevant information may be highly context-specific and time-specific.

Understanding farmers' behaviours within a theory of change (chapter 4): Economic assessment to inform the agricultural components of NDCs and related climate-change plans will be improved by:

- Combining cost-benefit analysis and financial appraisal with adaptive behaviour analysis
- Assessing economic performance in relation to climate variability
- Including economic processes above the farm scale
- Structuring economic analysis within a “theory of change” on how a sequence of actions leads to desired outcomes

Incentives and enabling environment for private sector throughout the value chain (chapter 4): Private-sector actors other than farmers can play significant roles in promoting climate-change mitigation and adaptation throughout the agricultural value chain by providing finance, knowledge, technologies and market incentives. Public agencies and policies can enable positive action among farmers and other private-sector entities through regulation and standards, knowledge management and extension, risk-management institutions, finance mechanisms and stable resource rights for smallholder farmers, among others.

NDCs as a platform for better development

The future of agriculture and food at the global level will depend on large-scale trends in supply, demand and trade – and climate-change impacts across the whole value chain. But to be successful, NDCs and related climate policies such as NAPs will also need to deal with farmers' realities and create tangible economic returns within five years, not 20. At the same time, they will need a vision for a future in which food security and rural development are likely to be vastly different from today, with much uncertainty around climate, demography and geopolitics. Thus, plans for near-term economic returns, farm profitability, jobs, emissions reductions and other benefits need to be complemented with mechanisms for more transformational change which address the root causes of climate vulnerability, long-term sustainability and social equity.

NDCs are generally well aligned with national development plans so that proposed actions for both adaptation and mitigation contribute to improved development outcomes at the national level. But the NDCs are not yet consistent with the international goal of limiting global temperature rise to 2°C (diagram 11) and fall far short of the aspirational 1.5°C increase. The unconditional components of the NDCs have a 50 per cent chance of holding temperature rises to 2.6-3.1°C by 2100; adding in the actions that are conditional on finance or other factors improves this only to 2.5-2.9°C (Rogerlj et al. 2016). The new round of NDCs in 2020 will provide an important opportunity to close the gap between national and global goals. More ambitious targets are likely to involve mitigation actions that limit short-term development aspirations – while keeping climate change sufficiently in check that longer-term development remains possible. Agriculture would need emissions reductions of one gigaton (Gt) per year to contribute to the global target without compromising food security. Current technologies can achieve 21-40 per cent of this and the remainder will need to come from much stronger cross-sectoral policies, for example, shifts in diets and food waste, and technological breakthroughs (Wollenberg et al. 2016).

More optimistically, climate change encourages longer planning horizons for agriculture than are usual in policymaking. In their NDCs, countries need to contend with potential shifts in production areas for crops, livestock and fisheries, and in turn significant changes in global food prices and countries' comparative advantages. The longer time horizon and new climate funding mechanisms put a greater value on public goods, like the reduction of emissions. In a sense, the NDCs have given policymakers the political capital to promote transformative actions on a broad scale, bringing together multiple agendas for social and environmental benefit. Strong NDCs have the potential to drive effective national policy instruments, provide incentives for positive behaviour change at scale, and achieve the global goals of the Paris Agreement and the Sustainable Development Goals (diagram 12). The question is whether the changing political economy and stricter environmental regulations are inducing more efficient use of resources and encouraging innovations towards green growth. The more ambitious NDCs signal transformative actions that could trigger a new era of reciprocity between economics and environment.

Diagram 11. Gap between the current collective ambition of the NDCs and the global 2°C goal

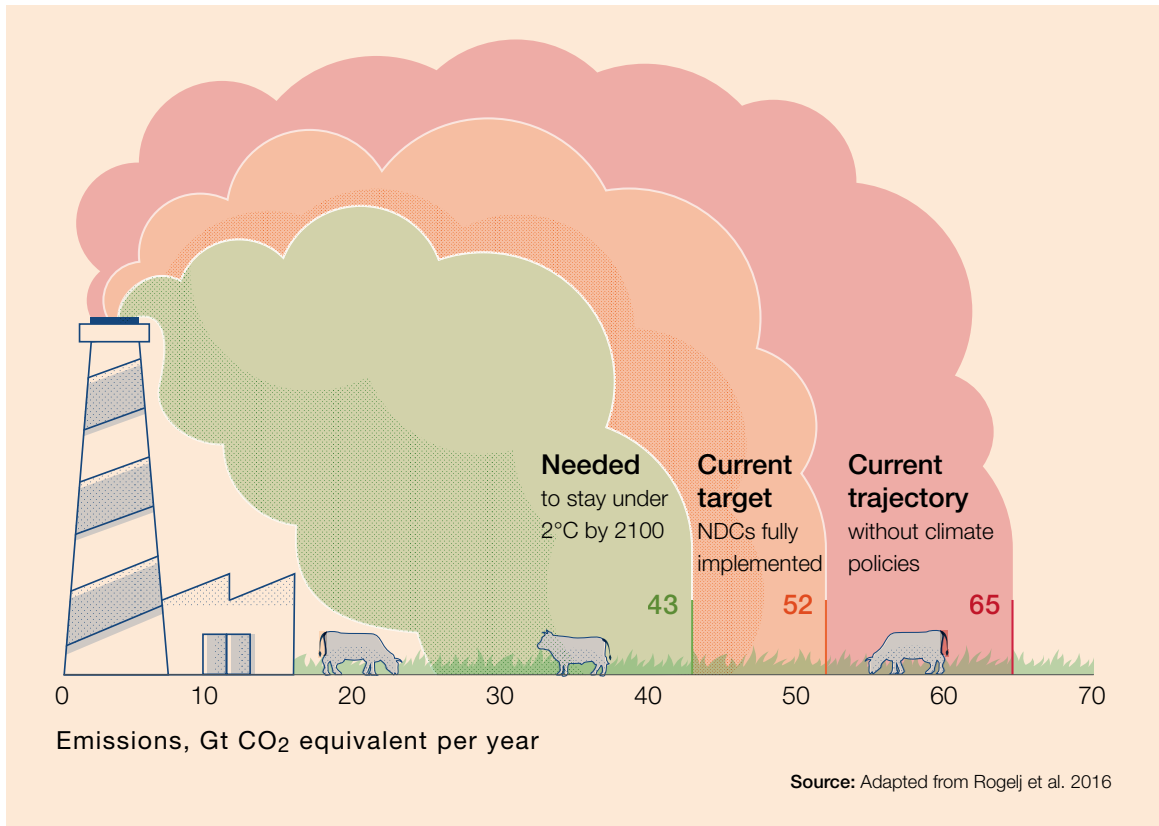
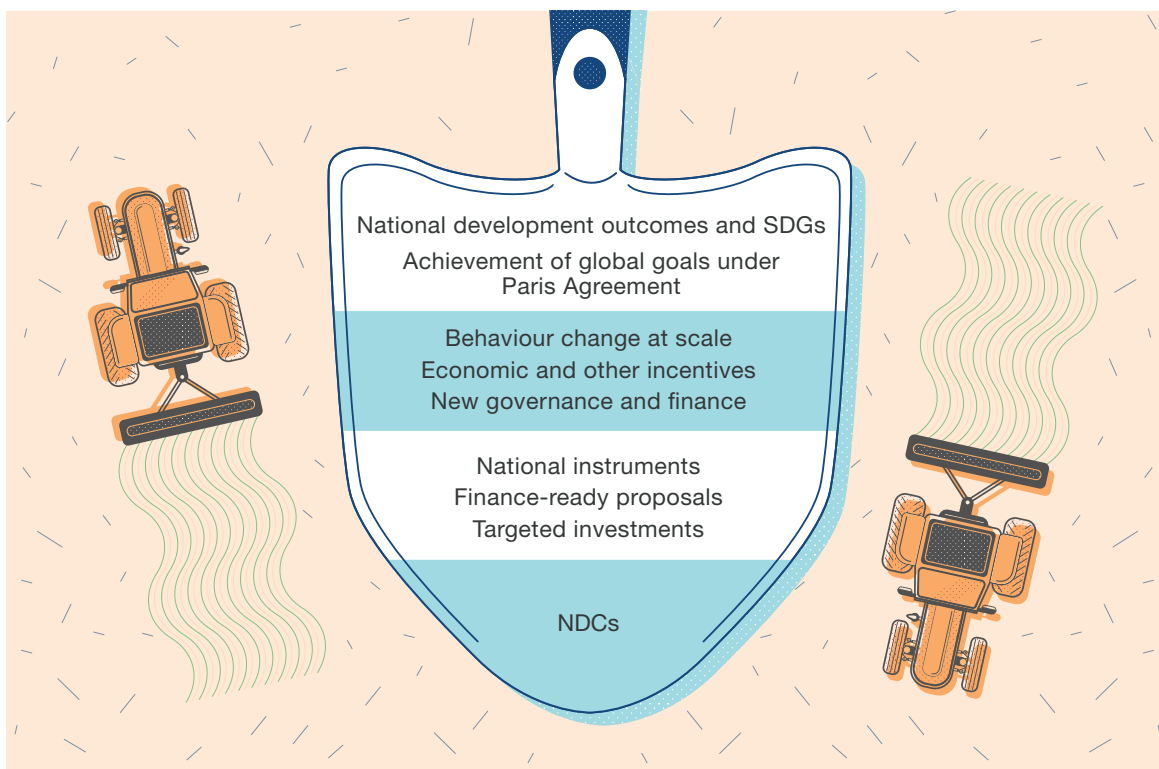


Diagram 12. Pathways of impact between NDCs and global public goods



Country case studies

Viet Nam country case study

How the value of investing in agriculture under climate change at the national level translates into value for farmers

Viet Nam's NDC is embedded in the national green growth strategy, "a comprehensive, integrated and effective part of national planning, which also prioritizes greenhouse gas (GHG) emission-reduction efforts and facilitates mainstreaming into a long-term policy framework" (MARD et al. 2015). The NDC has both short- and medium-term objectives, while the green growth strategy is a national long-term strategy for socio-economic growth resilient to climate change.

The NDC proposes actions in the rice sub-sector which have the potential to deliver for both environmental and developmental goods. Inefficiencies in the use of inputs are an important issue in rice production in Viet Nam. Interventions that raise efficiency can increase productivity, improve product quality and reduce GHG emissions per unit of production. Calculations indicate that there are several practices readily available that can reduce emissions in certain contexts. For example, the use of alternative nitrogen fertilizers, like ammonium sulphate, can reduce emissions and increase revenues by US\$1.2 billion.

The IFAD-supported adaptation project in Ben Tre and Tra Vinh provinces is investing US\$34 million to build the adaptive capacity of communities and institutions in the Mekong Delta. The ASAP project is investing in climate-change knowledge enhancement, climate-informed planning, rural financial services and specific investments in resilience and adaptation at community and household levels. The project is expected to provide additional worth across smallholders and other project beneficiaries of about US\$1.63 per dollar spent on an annual basis over a time frame of 20 years. The net present value equals US\$19.4 million, putting Viet Nam in the top two most-valuable country investments in the Asia and Pacific Region, representing 37 per cent of the overall regional value generated under ASAP (Ferrarese et al 2016).

While ASAP-supported investments generate strong economic and livelihood benefits at the project level, that's no guarantee that all farmers and intended beneficiaries will take a fair share of this value. Information on the heterogeneity within farming communities, such as demographic information, income, education, farm size, household labour and current climate risks, all help to target investments and assure higher adoption of practices and scaling up for greater impact.

An economic study in the two provinces (Lan et al. 2016) shows how the attractiveness of practices differs among income groups. For example, ASAP promotes planting of coconut and sugarcane in areas no longer suitable for rice cultivation (due to rising salinity or reduced water availability) and farmers concur that this is a high-priority action. However, economic analysis shows that it is mainly suitable for higher-income, better-educated farmers (groups 1 and 2 in the typology (see below)),

as the initial cost is a relatively small proportion of their annual income (14 per cent and 26 per cent, respectively). However, given that their income dependency on rice is small (10 per cent and 13 per cent, respectively), they might not be interested in shifting rice to coconut and sugarcane, unless they face serious losses due to drought. On the other hand, for farmers in group 3, shifting rice to coconut and sugarcane requires significant initial investment, equivalent to 67 per cent of income, and brings fairly low benefits (only around 22 per cent). Under extreme climate conditions for rice, households in group 3 might consider these practices, if financial support were available.

	Group 1	Group 2	Group 3
Characteristics	16% of households High income level (US\$3,214/year/capita) Low labour density (2 persons/ha) Better education level (avg=3)*	18% of households Medium income level (US\$1,644/year/capita) Medium labour density (2.7 persons/ha) Better education level (avg=3)	66% of households Low income level (US\$445/year/capita) High labour density (3.6 persons/ha) Lower education level (avg=2)
Adoption probability	More likely to adopt practices that: - require no initial investment - require low complexity - can be labour-intensive	More likely to adopt practices that: - require no initial investment - require low complexity - can be labour-intensive	More likely to adopt practices that: - require low to medium initial investment - require low to medium level of complexity - are low to medium labour-intensive

*Education levels: 1 = no school, 2 = elementary school, 3 = secondary school, 4 = high school, 5 = above high school

Broadly, if a more realistic and heterogeneous farmer population is considered, the NPV of a climate intervention tends to be smaller, since in a real-world scenario not all expected beneficiary farmers would adopt the practices. Taking into account heterogeneity of adoption across the farmer population, the economic return of IFAD's investment is likely to be much smaller – approximately US\$70 million – than when assuming a homogeneous population and a blanket adoption rate of 70 per cent, which yields approximately US\$109 million based on four farmer profiles or practices.*

The good news is that project costs may be lower than anticipated. In the NDC for Viet Nam, all mitigation costs are positive while in reality this is usually only the case for entirely new practices, as improvements on existing practices tend to have negative costs. In other words, only the difference between the existing and the new

* The estimated economic return of options based on adoption probability derived from farmer profiles, including: (i) SRI: 98 per cent of total IFAD's expected area of adoption (2,000 ha); (ii) shifting rice to coconut sugarcane, 39 per cent of 2,175 ha; (iii) coconut to cocoa, 39 per cent of 1,325 ha; (iv) improved variety, 81 per cent of 6,200 ha.

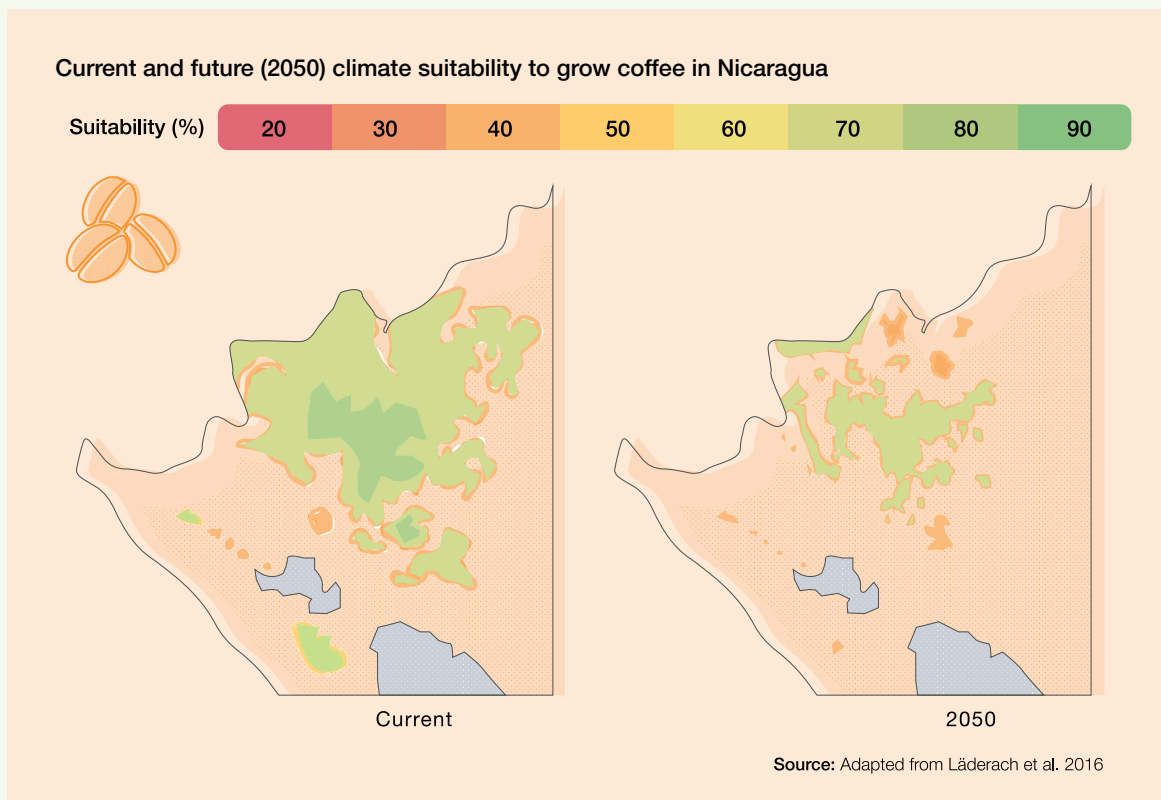
cost has to be accounted for, not the investment of starting from scratch. For example, the cost of adopting the system of rice intensification (SRI), a climate-smart method of improving rice productivity, in our analysis amounts to -US\$17 per ha, while in the NDC the mitigation cost is US\$413 per ha. Or for integrated crop management, the mitigation cost in the NDC is US\$10/ha while we calculate -US\$503 per ha.

Nicaragua country case study

Building economic development of agriculture under uncertain climatic future

Projections of future crop suitability under climate change face the challenge of large uncertainties in both climate and the models. But across different climate projections, there is absolute agreement regarding changes in suitability for coffee in Nicaragua. By 2050, coffee-growing areas will have moved approximately 300 metres higher and pushed farmers at lower altitudes out of coffee production, increasing pressure on forests and natural resources in higher altitudes and putting the coffee value chain in jeopardy (Läderach et al. 2016).

Recognizing this, the Nicaraguan Government, in its NAP for agriculture, prioritized the adaptation of smallholder coffee-farmers' livelihoods, together with market-based diversification. The national policy led the government to request IFAD support in developing climate-change adaptation actions within coffee and cocoa value chains. IFAD committed US\$24.12 million to raising the adaptive capacities of poor smallholder producers, strengthening public institutions, improving climate information systems and formulating incentive-based public policies.



Crop substitution from coffee to cocoa is a no-regret option at low elevations. In higher areas where climate is expected to remain suitable for coffee, investments are oriented to improve productivity, replant old plantations and produce ecological coffee. The table below shows the expected economic return per farmer for the proposed interventions.

Region	Altitude and climate	Prioritized solutions/practices	Beneficiaries	Expected economic return	Internal rate of return (IRR)
Southern cacao region	Warm and humid	<ol style="list-style-type: none"> 1. Improve productivity of existing cocoa production 2. Plant new cocoa trees 3. Maintain maize and bean 	5,000 producers	C\$ 51658	51%
Indigenous cacao region	Hilly terrain Warm and humid		4,000 producers	C\$ 434827	72%
Coffee-cacao diversification zone	800 metres above sea level Warm and humid	<ol style="list-style-type: none"> 1. Improve productivity of part of existing coffee 2. Replace old coffee trees 3. Improve productivity of existing cocoa 4. Plant new cocoa trees 5. Maintain maize and bean 	11,000 producers	C\$ 42990	56%
Coffee Zona Norte	800 metres above sea level Temperate climate	<ol style="list-style-type: none"> 1. Improve productivity and replant old coffee 2. Plant new coffee 	20,000 producers	C\$ 22598	25%

Rwanda country case study

Progress from a national plan for adaptation to an application to the Green Climate Fund

Following the publication of a green growth and climate resilience strategy – the National Strategy for Climate Change and Low Carbon Development, Government of Rwanda, 2011 – there has been a concerted effort in Rwanda to mainstream climate change in national and sector development planning. This has included the introduction of climate-change (and environment) mainstreaming as one of seven cross-cutting issues in sector development plans, including in the Strategic Plan for the Transformation of Agriculture.

Rwanda has also set up and received capital for a national environment and climate fund – Environmental and Climate Change Fund for Rwanda (FONERWA). This is funding many relevant projects, for example, on soil and water conservation, and it also has a dedicated thematic funding window for proposals for environment and climate-change mainstreaming. The fund can provide incremental finance for the additional costs of mainstreaming within government.

These two initiatives have recently been drawn together within an advanced mainstreaming pilot for the tea and coffee sector in Rwanda, which has been funded by FONERWA.

In Rwanda, tea and coffee are grown where the soil, temperature and rainfall are suitable. The main production areas (especially for tea) are at higher elevations, where the climate is cooler. Production and quality of both crops are affected by the variability of annual rainfall, and the climate also affects the incidence and severity of pests and diseases. Climate change could have a large impact on these sectors, which are critical for exports: it will affect the productivity and quality of existing plantations and the suitability of areas for growing these crops, as well as the range and prevalence of pests and disease. These effects are particularly important because tea and coffee are long-lived crops and new plantations are managed over decades. Importantly, there are plans to expand the areas of tea and coffee under production and there is a need to plan these areas with the future as well as the current climate in mind.

The mainstreaming pilot project has applied the iterative climate risk-management approach set out above and made an economic and financial analysis of the options. It first identified the current and future climate risks and the types of early policy decisions needed and from this identified three areas of adaptation to consider in the overall plan. These include:

- The introduction of low and no-regret actions (climate-smart agriculture) and capacity-building to address the current impact of climate variability on tea and coffee. These actions bring immediate economic benefits, as well as offering future benefits under a changing climate.
- Integrating adaptation into immediate decisions or activities with long lifetimes, in this case using climate-risk screening to look at the climate-smart development of new tea plantations, making sure that they are located with the future as well as the current climate in mind.
- Finally, the project has a programme of monitoring, research and learning to start planning for the future impact of climate change. This includes a more explicit application of adaptive management – looking at possible key impacts and thresholds and putting in place monitoring, especially of pests and diseases.

The pilot is being used to provide a framework for the further mainstreaming of climate change into the next revision of the overall sector development plan, with a resource mobilization plan to look for further opportunities for support from international climate finance, including the Green Climate Fund.

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Recommended further resources

- Analysis of agriculture in INDCs:** database and maps on inclusion of agricultural mitigation and adaptation in INDCs, including analysis of inclusion of specific measures and finance requirements. <https://cgspace.cgiar.org/handle/10568/73255>
- Climate-Smart Agriculture (CSA) Country Profiles:** give an overview of the climate change challenges and solutions in selected countries in Latin America and the Caribbean, Africa, Asia and Europe. <https://ccaafs.cgiar.org/publications/csa-country-profiles>
- CSA Guide:** guidance for practitioners, decision makers and researchers for implementing Climate-Smart Agriculture projects and programmes. Includes guidance on entry points for interventions, planning, financing, and monitoring and evaluation. <https://csa.guide/>
- EconAdapt:** supports climate-change adaptation planning by providing user-oriented methodologies and evidence relating to economic appraisal criteria. Decision areas covered include extreme weather events, long-term adaptation and financial instruments, including overseas development assistance for adaptation. <http://econadapt.eu/>
- EPIC:** the Economics and Policy Innovations for Climate-Smart Agriculture (EPIC) programme supports formulation of investment proposals, provides advice on the formulation and implementation of policies and conducts research on impacts, effects, costs and benefits as well as incentives and barriers to the adoption of practices. <http://www.fao.org/climatechange/epic>
- FAO Investment Centre:** supports increased and more effective public and private investment in agriculture and rural development, working directly with governments and other investors, and providing practical online resources, including guidelines, reviews of good practices and country case studies. <http://www.fao.org/investment/ourwork/en/>
- NAMA Facility:** support to preparation of nationally appropriate mitigation actions (NAMAs) <http://www.nama-facility.org/start.html>
- NAP Support Portal:** guidance on preparation of NAPs, including data and analysis https://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/7279.php
- United Nations Development Programme (UNDP) Designing and Preparing NDCs:** guidance on preparation of NDCs, including data and analysis <http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/designing-and-preparing-intended-nationally-determined-contribut.html>

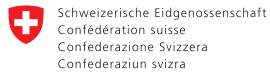
ASAP Donors and Partners

IFAD's Adaptation for Smallholder Agriculture Programme (ASAP) is a multi-donor programme that helps smallholder farmers cope with the impacts of climate change so they can increase their resilience.

As of 1 October 2015, the total commitments from nine donor countries (Belgium, Canada, Finland, Netherlands, Norway, Republic of Korea, Sweden, Switzerland and United Kingdom) amounts to US\$366,498,858.



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