Ceres2030:

Sustainable Solutions to End Hunger

SUMMARY REPORT

Ceres2030
Sustainable Solutions to End Hunger

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FOREWORD: A WORLD WITHOUT HUNGER IS POSSIBLE

BY DR. AGNES KALIBATA AND DR. GERD MÜLLER

Planet Earth has the potential to feed 10 billion people. No one should have to suffer hunger or malnutrition. Worldwide, there is a vast variety of factors causing hunger and malnutrition: war, disasters, and diseases have fatal consequences, as does climate change. Today, more than 10 million hectares of land are already lost to erosion every year. Droughts and heat are reducing yields. In the future, water will become a scarce, life-saving resource.

Too much food also rots in the field, is destroyed by pest damage or thrown away because of inadequate storage or cooling facilities, processing or logistics. But hunger is also a problem of poverty. Two-thirds of hungry people live in rural areas: they are smallholder families. Every day, the global population grows by 250,000 people – 80 million a year, two-thirds of them in developing countries. Africa's population is set to double by 2050.

The answer to the global hunger problem has many facets and requires different approaches – but we know which way to go, we have the knowledge and the technology. What is needed, above all, is a change in government decision-makers' way of thinking so they make agricultural development a priority in each country and combine investment in the food and agriculture sector with training campaigns, the development of decentralized energy systems, appropriate mechanization, the further development of animal and plant breeding, and equal access to land ownership for women and men.

There are many avenues that we jointly have to pursue in order to create a world without hunger. *Ceres2030: Sustainable Solutions to End Hunger,* is a unique research project that provides practical recommendations. Scientists from Cornell University, the International Institute for Sustainable Development (IISD) and the International Food Policy Research Institute (IFPRI), using the latest AI technology, have painstakingly investigated the most effective instruments and actions to end hunger by 2030 worldwide and on a lasting basis. They have also calculated the costs of this endeavor. In association with Ceres2030, Nature is dedicating a special edition to this issue, telling us how we can make a world without hunger – if we act now.

The study comes at a critical time. The dramatic consequences of the COVID-19 crisis are exacerbating the suffering of the most vulnerable, especially in the poorest regions of the world. For them, the COVID-19 pandemic is also a hunger pandemic. With this in mind, next year the UN Food Systems Summit will launch bold new actions, solutions and strategies to deliver progress on all 17 Sustainable Development Goals, each of which relies on healthier, more sustainable and more equitable food systems. The Summit is already sending a message: do more, do it better – and start now!

Here are some figures that highlight the urgency of taking action: 690 million people worldwide suffer from hunger daily – as many as the combined populations of our two countries, Rwanda and Germany, plus the populations of the United States and Indonesia. The UN's Food and Agriculture Organization

expects this will grow to 840 million by 2030 – instead of reaching zero as resolved by the nations of the world in 2015 in their pact on the world's future.

In order to eradicate hunger within the ten years that remain, eight Ceres2030 teams of 77 researchers from 23 countries and 53 organizations collected the most promising solutions. The researchers came up with ten key recommendations on the sort of interventions that work, and conclude that approximately 330 billion US dollars will be needed in additional funding in the period up to 2030 – in other words, 33 billion dollars a year (or 28 billion euros).

These experts believe that it would be realistic for donor countries to provide an average of 14 billion US dollars a year, and low- and middle-income countries, 19 billion. After all, the world is also able to spend 1,917 billion dollars year after year on military and arms projects! The much lower spending needed to eradicate hunger, by contrast, will generate a revitalizing dividend. It will save hundreds of millions of people from starving, enabling most of them to lead productive lives and provide for their families.

The 330 billion dollars spent over the next decade would go, for example, toward farmers' alliances, enabling smallholders to work together and providing training for young people; the cultivation of climate-resilient crops; and appropriate irrigation, storage and processing of crops to prevent them from spoiling.

More thoroughly than ever before, the Ceres2030 researchers have explored which actions are effective, where they are effective, how effective they are – and what makes them fail. After all, there is no panacea. Governments, the private sector and scientists have to link several agendas.

Farmers not only have to be able to grow climate-resilient crops. They also have to be able to transport and sell their crops. Governments have to combine investments in agriculture with social protection programs, so as to ensure that people have an income and access to food even in difficult times. And the relevant government departments have to work together more closely: agriculture and environment, health and education, economic affairs and development cooperation.

If all this is in place, sustainable development can succeed – food security, resource-conserving productivity, fair trade, education, and protection from the consequences of climate change. This is why the Ceres2030 study is so important and its conclusion is truly transformative: a world without hunger is possible – it is within reach. So let us take action.

Dr. Agnes Kalibata
UN Special Envoy for the 2021 Food Systems Summit

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SUMMARY AND RECOMMENDATIONS

Hunger is rising, reversing decades of progress. An estimated 690 million people are hungry, an increase of 60 million people over the past five years (Food and Agriculture Organization of the United Nations [FAO] et al., 2020). We predict that a further 95 million people will be living in extreme poverty and hunger as a result of COVID-19 (Laborde and Smaller, 2020). Perversely, the very people whose livelihoods depend on food and agriculture are among the most likely to experience hunger. Small-scale food producers and food workers and their families are often left out of economic growth, technological change, and political decision making. Globally, today's food systems are not producing affordable healthy diets for all in a sustainable way (FAO et al., 2020). The climate crisis poses a mounting threat to food systems (FAO et al., 2018; Intergovernmental Panel on Climate Change [IPCC], 2018), while at the same time, the current food system is a major driver of climate change (FAO et al., 2020).

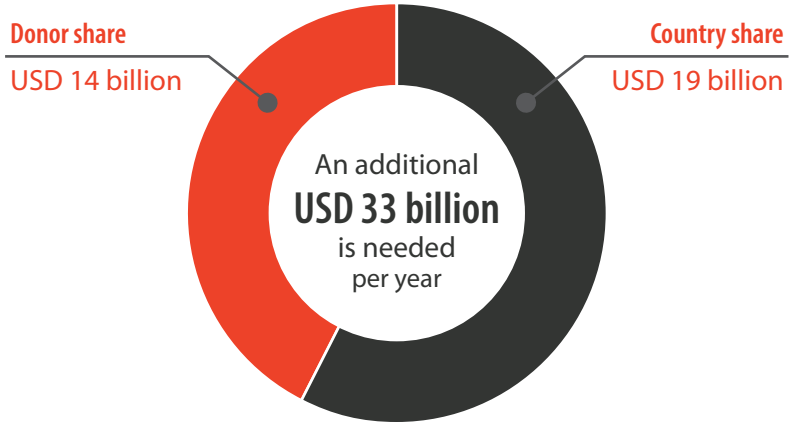
This is not how the UN 2030 Agenda for Sustainable Development was meant to unfold. The ambition was transformative. Governments acknowledged the central importance of ending hunger, but they set themselves a bolder target: they wanted everyone to enjoy an affordable, healthy and nutritious diet, and committed to supporting the most vulnerable food producers to earn the means to live in dignity. They also made a commitment to sustainable change, vowing to preserve biological diversity and to better protect the resources and the ecosystems that our children will need to feed themselves into the future.

Governments have 10 years to take back control of their bold agenda. Ceres2030 was an experiment designed to help with the challenge. The project team, employing a complex and rigorous economic model and cutting-edge machine-learning tools, made a partnership with Nature Research that focused on answers to two linked questions: First, what does the published evidence tell us about agricultural interventions that work, in particular to double the incomes of small-scale producers and to improve environmental outcomes for agriculture? And second, what will it cost governments to end hunger, double the incomes of small-scale producers, and protect the climate by 2030? The project focuses on three of the five targets in the second sustainable development goal (SDG 2) and looks at the public spending needed in low- and middle-income countries, including the contribution from donors through official development assistance (ODA).[1]

[1] The three targets of SDG 2 are ending hunger (Target 2.1), doubling the incomes and productivity of small-scale producers (Target 2.3), and producing food sustainably and resiliently (Target 2.4). The nutrition target (Target 2.2) was not included. This is because there are other global efforts to assess the cost of ending some forms of malnutrition (definitions vary) and they use a different model. The scope of malnutrition overlaps but also reaches beyond food and agriculture, making a comprehensive costing particularly complex. Biodiversity and preservation of associated traditional knowledge (Target 2.5) is also beyond the scope of the project. There is a dearth of data about biodiversity, and it remains an important area in which to develop quantification techniques.

Donors must spend an additional USD 14 billion a year on average to end hunger sustainably

FIGURE 1. ADDITIONAL PUBLIC SPENDING AND DONOR CONTRIBUTION



The Ceres2030 and Nature Research collection pushes the frontiers of science to support evidence-based decision making. It is the first attempt to analyze the past 20 years of agricultural development literature using artificial intelligence to support a rigorous methodology for evidence synthesis. The Ceres2030 team worked with researchers to support the integration of the findings from that research into the parameters of a general equilibrium model. The modelling is one of the most complex modelling exercises ever attempted, applying hundreds of thousands of equations to account for complex relationships across different levels of the economy over time. The model used data from all levels, from the global to the national, right down to the household.

The research shows that agricultural interventions are more effective with a population that enjoys at least a minimum level of income, education, with access to networks and resources such as extension services and robust infrastructure. Whether the intervention is climate-resilient crops, membership in a farmers' organization, or reducing crop losses, this minimum threshold matters.

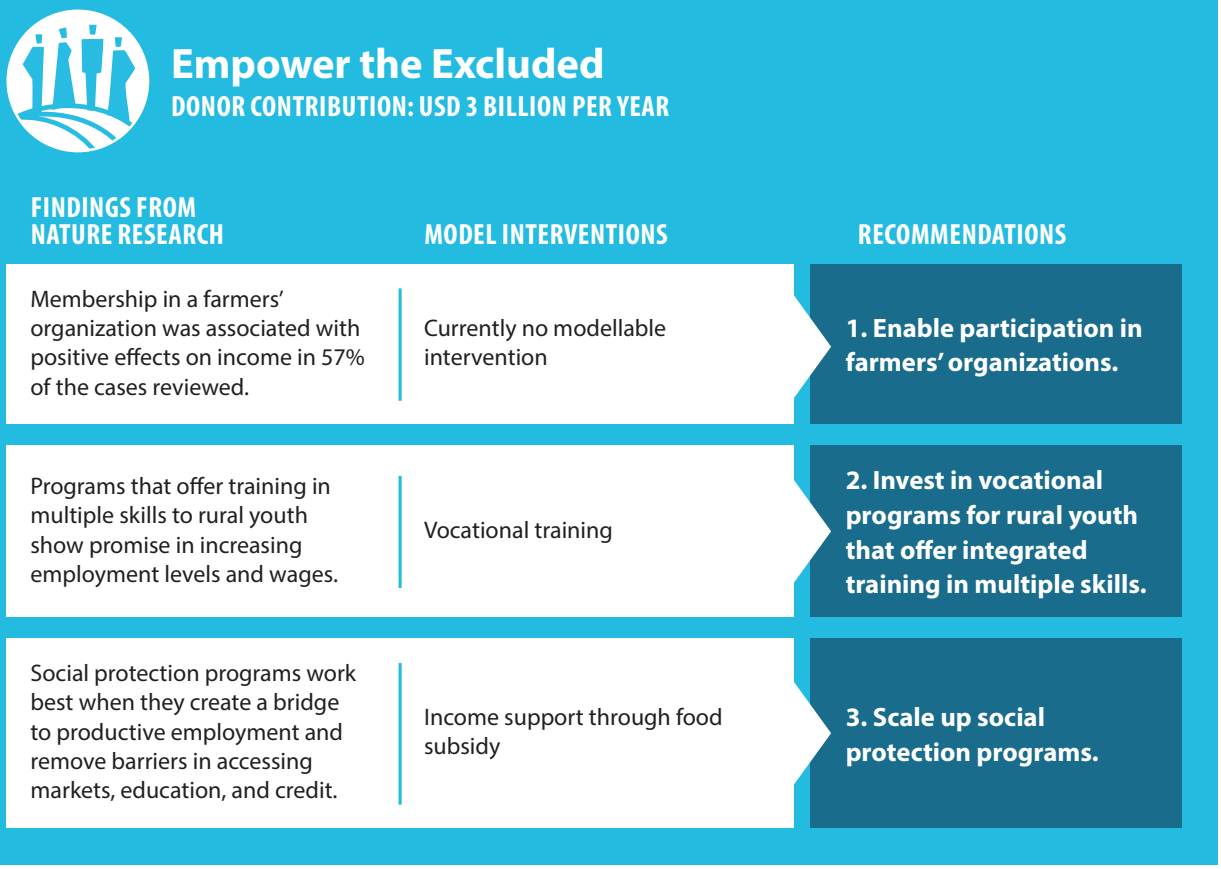
Both the evidence syntheses and the model show it is much more effective to create integrated portfolios of interventions rather than seek improvements in isolation. Interventions are also more successful if they are designed to meet complex objectives, such as paying attention to the marketability of a crop and not just its climate resilience or resistance to pests. The evidence from studies of small and medium enterprises (SMEs) working with small-scale producers in the informal sector shows significant success with linking producers to markets, particularly in Africa. Importantly, a large share of these SMEs provide other, linked services, such as capacity building and access to credit. The SMEs are correlated with higher levels of technology adoption and productivity among small-scale producers.

Crucially, the project team and researchers found there is surprisingly little research to support the types of questions that donors and governments are interested in answering—less than 2% of the available evidence base in our review. There is an urgent need to invest in the development of standardized frameworks to improve the quality and relevance of research for policy-makers. Evidence-based policy is only as good as the available evidence.

Ten recommendations emerged from the research on how to increase the effectiveness of public spending on agricultural interventions and how much it will cost donors (see Table 1). The topics were selected in an iterative process that relied on policy experts, a machine-learning-assisted review of the published data on agricultural interventions, and on decision-makers' experience. The costs are based on the results of the model, which optimally allocates financial resources among a portfolio of interventions. The modelled interventions are based on existing data sources and a number of new parameters from the collection of evidence syntheses published in *Nature Research*.

TABLE 1. TEN RECOMMENDATIONS AND THE DONOR CONTRIBUTION

The central findings with additional donor costs, from the results of the evidence syntheses in *Nature Research* and the interventions costed in one of the most complex modelling exercises ever attempted.



On the Farm

DONOR CONTRIBUTION: USD 9 BILLION PER YEAR

FINDINGS FROM NATURE RESEARCH	MODEL INTERVENTIONS	RECOMMENDATIONS
The most important determinants of adoption of climate-resilient crops were the availability and effectiveness of extension services.	Extension services	**4. Investment in extension services, particularly for women, must accompany research and development (R&D) programs.**
Market and non-market regulations and cross-compliance incentives that include short-term economic benefits are more successful than measures that only provide an ecological service.	Agroforestry subsidy Capital endowment Extension services Investment subsidy Production subsidy R&D National Agricultural Systems (NARS) & Consultative Group on International Agricultural Research (CGIAR)	**5. Agricultural interventions to support sustainable practices must be economically viable for farmers.**
Successful adoption is positively correlated with inclusive extension services, access to inputs, and crop varieties that are commercially viable.	Extension services combined with input, production, and investment subsidies R&D National Agricultural Systems (NARS) & CGIAR	**6. Support adoption of climate-resilient crops.**
Nearly 80% of small-scale farms in developing countries are in water-scarce regions. Underexplored solutions include digital applications and adding livestock to mixed farming systems.	Capital endowment Extension services Rural infrastructure (irrigation)	**7. Increase research on water-scarce regions to scale up effective farm-level interventions to assist small-scale producers.**
Obvious and useful options to improve the quantity and quality feed are being overlooked, such as better support for the use of crop residues.	Capital endowment Extension services Improved forage subsidy Production subsidy R&D National Agricultural Systems (NARS) & CGIAR	**8. Improve the quantity and quality of livestock feed, especially for small and medium-scale commercial farms.**

Food on the Move

DONOR CONTRIBUTION: USD 2 BILLION PER YEAR

FINDINGS FROM NATURE RESEARCH	MODEL INTERVENTIONS	RECOMMENDATIONS
Storage interventions are effective, but other interventions are also needed, such as better handling, improved packaging, and careful timing of the harvest.	Extension services Storage (post-harvest losses)	**9. Reduce post-harvest losses by expanding the focus of interventions beyond the storage of cereals, to include more links in the value chain, and more food crops.**
SMEs are successfully serving farmers in low and middle-income countries, particularly in Africa, and are correlated with technology adoption and higher productivity.	Rural infrastructure (roads) Storage (post-harvest losses)	**10. Invest in the infrastructure, regulations, services and technical assistance needed to support SMEs in the value chain.**

Sources: Acevedo et al., 2020; Baltenweck et al., 2020; Bizikova et al., 2020b; Laborde et al., 2020; Liverpool-Tasie et al., 2020; Piñeiro et al., 2020; Maiga et al., 2020; Ricciardi et al., 2020; Stathers et al., 2020; Wouterse et al., 2020.

WHAT WILL IT COST?

The results from the model show that donors need to contribute an additional USD 14 billion per year on average until 2030 to end hunger and double incomes of small-scale producers in low- and middle-income countries. The investment achieves these goals while maintaining greenhouse gas emissions for agriculture below the commitments made in the Paris Agreement (see Figure 1).

Donors currently spend USD 12 billion per year on food security and nutrition and therefore need to double their contributions to meet the goals. However, ODA alone will not be enough. Additional public spending of USD 19 billion per year on average until 2030 will have to be provided by low- and middle-income countries through increased taxation (see Figure 1).

Together, the additional public investment from donors and low- and middle-income countries will prevent 490 million people from experiencing hunger, double the incomes of 545 million producers and their families on average, and limit greenhouse gas emissions for agriculture to the commitments made in the Paris Agreement.[2] Importantly, the additional public spending will, on average, spur an extra USD 52 billion in private investment per year.

1. HUNGER, EXCLUDED SMALL-SCALE PRODUCERS, AND THE CLIMATE CRISIS: A TRIPLE BURDEN

Despite remarkable inroads made to reduce hunger worldwide, food insecurity is on the rise, while small-scale food producers are excluded from economic opportunities, and the climate crisis poses a mounting threat to food production and distribution. The number of people affected by hunger has increased by 60 million people over the past five years, and up to 130 million more people are at risk as a result of COVID-19 (FAO et al., 2020; Intergovernmental Panel on Climate Change [IPCC], 2019). Perversely, the very people whose livelihoods depend on food and agriculture are among the most likely to experience hunger. Small-scale food producers and workers and their families are among those most often left out of economic growth, technological change, and political decision making. Globally, food systems are not producing affordable healthy diets accessible to all. Instead, some forms of agriculture are important drivers of deteriorating environmental conditions. At the same time, agriculture is one of the sectors most at risk because of the climate crisis (IPCC, 2019).

The pressures of demographic change and economic growth driving increased future food demand are strongest in Africa and South Asia (FAO et al., 2018). Africa in particular is predicted to become the continent with the largest share and number of people living in poverty, a problem expected to be severely exacerbated by the COVID-19 pandemic. Africa still lags the world in terms of farm incomes and productivity, and its agriculture and food systems are characterized by the dominant role of small-scale producers. The continent is not on track to afford to achieve the transformative changes demanded by the UN 2030 Agenda for Sustainable Development. That ambition will require strong support from the global donor community. Indeed, ODA remains the first source of external financial resources for Africa south of the Sahara (36% in 2017), above remittances and foreign direct investment (OECD, n.d.b) (see Box 1).

[2] The results from the modelling should be interpreted as an estimate of the scale of resources needed at the big-picture level. This is useful to inform resource allocation decisions from the global level down to the national level but is insufficient to inform strategy, planning, and programming at the subnational level.

BOX 1. THE IMPORTANCE OF AID FOR AFRICA

ODA is a critical source of finance for developing countries, especially in Africa. It has been the largest single source of foreign finance since 2002, consistently providing over 30% of the total. In 2017, ODA represented 36% of the foreign finance received by African countries south of the Sahara compared to 31% from overseas personal remittances and 23% from foreign direct investment (FDI) (OECD, n.d.b). In other regions, ODA is less dominant. The main source of foreign finance in South Asia, for example, is personal remittances, comprising 55% of foreign finance; in South America, it is FDI, at 68% of the total (OECD, n.d.b).[3]

ECONOMIC PRECARITY AND VULNERABILITY OF SMALL-SCALE PRODUCERS

Small-scale producers in low- and middle-income countries face economic precarity and vulnerability. Too many live in poverty, at chronic risk of hunger. At the same time, they are among the populations most vulnerable to climate change (Bizikova et al., 2020; Acevedo et al., 2020). Yet this population is large and important, both for food security and the environment, which is why governments have singled them out for support in SDG 2. Small-scale producers represent over 80% of the world's farms (Lowder et al., 2016). Although the evidence base, especially from Africa, is far from complete, it is clear that small-scale producers make an essential contribution to the food supply. Recent studies using different methods and data have converged broadly around estimates that farms under 2 hectares produce 30%–34% of the global food supply and grow a greater diversity of crops than larger farms. Farms of less than 5 hectares are estimated to produce just over half the world's food calories (Samberg et al., 2016; Ricciardi et al., 2018).

Chronic underinvestment in the production systems of small-scale producers in low- and middle-income countries, particularly in Africa, has resulted in low productivity and incomes (FAO, 2012). This undermines efforts to move out of subsistence livelihoods and to eradicate hunger and poverty. Crops spoil due to a lack of good storage systems, insufficient processing capacity, or gaps in communications and transportation infrastructure. Livestock productivity is low, in part due to the poor quality and low availability of feed. Small-scale producers lack bargaining power in their markets, and there is a dearth of sustained vocational training for rural youth. Similarly, there is a marked lack of investment in water management and irrigation infrastructure, especially on the land farmed by small-scale producers, especially in some of the most drought-affected areas.

[3] Statistics of foreign financial resources in this section refer to values according to 2016 constant USD.

ADAPTING TO CHANGING WEATHER AND ECOLOGICAL CONDITIONS, WHILE REDUCING HARM TO THE ENVIRONMENT

There is strong evidence that some food and agriculture systems are an important source of GHG emissions (IPCC, 2019; Willett et al., 2019). The largest sources of GHG emissions linked to agriculture are land expansion, methane emissions from livestock and rice production, and nitrous oxide from the heavy use of synthetic fertilizers (IPCC, 2019). In addition to emitting GHGs, agriculture has contributed to 70% of biodiversity loss on land (Secretariat of the Convention on Biological Diversity, 2014). At the same time, climate change poses significant risks to food and agriculture systems. These risks include rising sea levels and coastal inundation, changing and less-predictable weather patterns, and an increase in the incidence of extreme weather events as well as the spread of new pests and crop diseases as average temperatures change. The expected impact of these events depends on their magnitude, as well as the capacities of producers, governments, and the private sector to adapt and build resilience. Typically, smaller-scale producers in countries facing the highest risks have limited access to risk management tools and climate-adapted technologies (Bizikova et al., 2020a; Porter et al., 2014).

The benefits that people derive from ecosystems (known as "ecosystem services"), such as the provision of food and clean water, or the control of floods and disease, are in general undervalued in markets and overlooked in investment strategies. Instead, many farmers struggle to balance their need for an income with the long-term health of their natural resources, including the soil and water (Piñeiro et al., 2020). The issue is particularly acute in low- and middle-income countries where producers' lack of access to information, financial services, and land rights create barriers to realizing opportunities and using incentives to address the trade-offs between ecosystem health and income (Lipper et al., 2020).

THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT

The adoption of the UN 2030 Agenda for Sustainable Development opened the possibility of new pathways for solving complex problems. It signalled a willingness from governments to embrace a significantly higher level of complexity than they had shown before. The Agenda lists 17 SDGs, including SDG 2, which is a commitment to eradicate hunger, improve nutrition, double the productivity and incomes of small-scale producers, promote sustainable and resilient food systems, and protect biodiversity. The goal deliberately sets out the complexity of the challenge societies face.

Ideally, increased investment in SDG 2 will also contribute to climate change mitigation (SDG 13), reduced inequalities (SDG 10), women's rights to full and equal participation in economic and public life (SDG 5), and to more sustainable patterns of production and consumption (SDG 12). Done wrong, however, agriculture can do significant harm to these other SDGs. For example, too many interventions designed primarily to increase crop yields have failed to pay sufficient attention to soil

health and local freshwater supplies. Increasing agricultural productivity is associated in some places with significant environmental damage and with undermining important ecosystem services that the wider rural community relied upon (Lipper et al., 2020). Relying on cereals such as rice and maize has successfully met minimum calorie needs in many countries but has discouraged the production of a diversity of cultivated and non-cultivated foods, including animal-sourced foods, that provided better nutritional outcomes, as well as opportunities for income diversification. Multifaceted commitments pose a puzzle for decision-makers. Some issues lack data and indicators with which to measure progress, while others are awash in data, but analysis of that data offers contradictory evidence (Lipper et al., 2020). It is in addressing this puzzle that Ceres2030 makes such an important contribution.

2. THE EVIDENCE BASE: END HUNGER, INCREASE INCOMES, AND REDUCE ENVIRONMENTAL HARM

The Ceres2030 and Nature Research collection is guided by the premise of SDG 2: increasing the incomes and productivity of small-scale producers, in a way that supports the transition to environmentally sustainable food systems, is the most effective way to end hunger. In the 2030 Agenda, governments identified increased productivity and incomes for small-scale producers and their families as essential to the goal of ending hunger sustainably. Our premise does not exclude the importance of supporting larger-scale producers to also make the transition to more sustainable practices, but it recognizes that small-scale producers are both caught up in the problem we are trying to solve and critical to the answers we seek.

The project was not mandated to work on nutrition specifically, though it is central to both food security and to the realization of SDG 2. There were, however, existing costing initiatives focused specifically on nutrition underway when the Ceres2030 project was launched in 2018, including work by the World Bank, Results for Development, and 1000 Days. Nutrition, moreover, is its own complex goal. Costing nutrition goes beyond agriculture and food systems, to include sanitation and access to clean water, for example. It also relies on intra-household-level data, which is a level of granularity that is not easily integrated with the global projections modelled by the Ceres2030 cost model. It would have required significantly more time and resources to include nutrition in the project.

The project relies on state-of-the-art economic modelling techniques, artificial intelligence, evidence synthesis, and a strong partnership with one of the world's leading publishers, Nature Research, which were the main tools used to build that evidence base (see Box 2). The results offer decision-makers a way to cost and assess interventions as a portfolio of complementary investments rather than in isolation. The combination of these research tools provides the kind of information that decision-makers can use to direct spending, and the confidence that it is backed by the highest standards of research.

BOX 2. THE CERES2030 AND NATURE RESEARCH COLLECTION

Ceres2030 includes the Nature Research collection of eight evidence syntheses and two front matter pieces published in Nature Research Journals; a report on what it would cost to end hunger, increase incomes, and mitigate climate change; and a policy brief comparing the CGE modelling approach in Ceres2030 to the marginal abatement cost curves (MACC) approach used by the Center for Development Research (ZEF) and FAO. A total of 84 researchers—economists, crop breeders, information specialists, and scientists—from 25 countries worked on the project. They reviewed over 100,000 articles, primarily published between 2000–2019. The project was guided by an advisory board of 20 food and agriculture experts from over 10 countries.

The economic modelling team worked with the evidence synthesis teams to see how to strengthen the evidence used to inform the economic cost model. Together, they set up a system to extract data from the articles the researchers were reviewing that could be used in the model. This eventually led to the inclusion of new interventions in the costing and the refinement of some of the existing interventions, improving the accuracy of the cost estimate.

The project is a working model of how a donor might use evidence to guide investment decisions. Ceres2030 demonstrates how to build an evidence base, assess it, quantify it, and how to use the results to answer complex questions for specific populations, grounded in country-specific contexts. The 2030 Agenda requires that governments meet multiple targets with their choice of interventions. If there are no considerable changes in agricultural management practices, a push to increase food production will increase GHG emissions (Mbow et al., 2019). The approach taken by Ceres2030 is to look at how interventions can be balanced to take account of trade-offs, manage competing goals, and enhance synergies, thereby achieving the multiple targets of SDG 2. For example, extension services can improve farmers' skills, while roads and storage capacity make an important contribution to farm income. Together, the benefits of each expand, strengthening the resilience beyond what either intervention can offer on its own and creating the possibility of greater returns. The economic model accounts for such interactions, using the relationships to generate a portfolio of interventions that complement each other and keep costs to a minimum while meeting objectives.

EVIDENCE SYNTHESIS AND NATURE RESEARCH

The evidence synthesis teams searched the databases for agricultural interventions that would increase the productivity of small-scale producers while supporting the transition to more environmentally sustainable production systems (see Figure 2 for more detail on the selection of the eight intervention topics). Specific areas of agricultural intervention were chosen that had demonstrated their importance to ending hunger inclusively and sustainably. For each research area, the task was to produce a synthesis of the available evidence, such as a systematic or scoping review. Evidence synthesis is an umbrella term for the process of drawing scientific findings and policy implications from a large database of evidence.[4] It uses a predetermined methodology to create replicability and to allow others to validate or falsify the results. Evidence synthesis is a still-evolving adaptation of evidence review methodologies, designed to cope with the heterogeneity of disciplines that produce agriculture and food systems research. The project published an open-source evidence synthesis protocol for agriculture and a machine-learning model, both of which make a lasting contribution to the use of evidence synthesis in agriculture and development (Young et al., 2019).

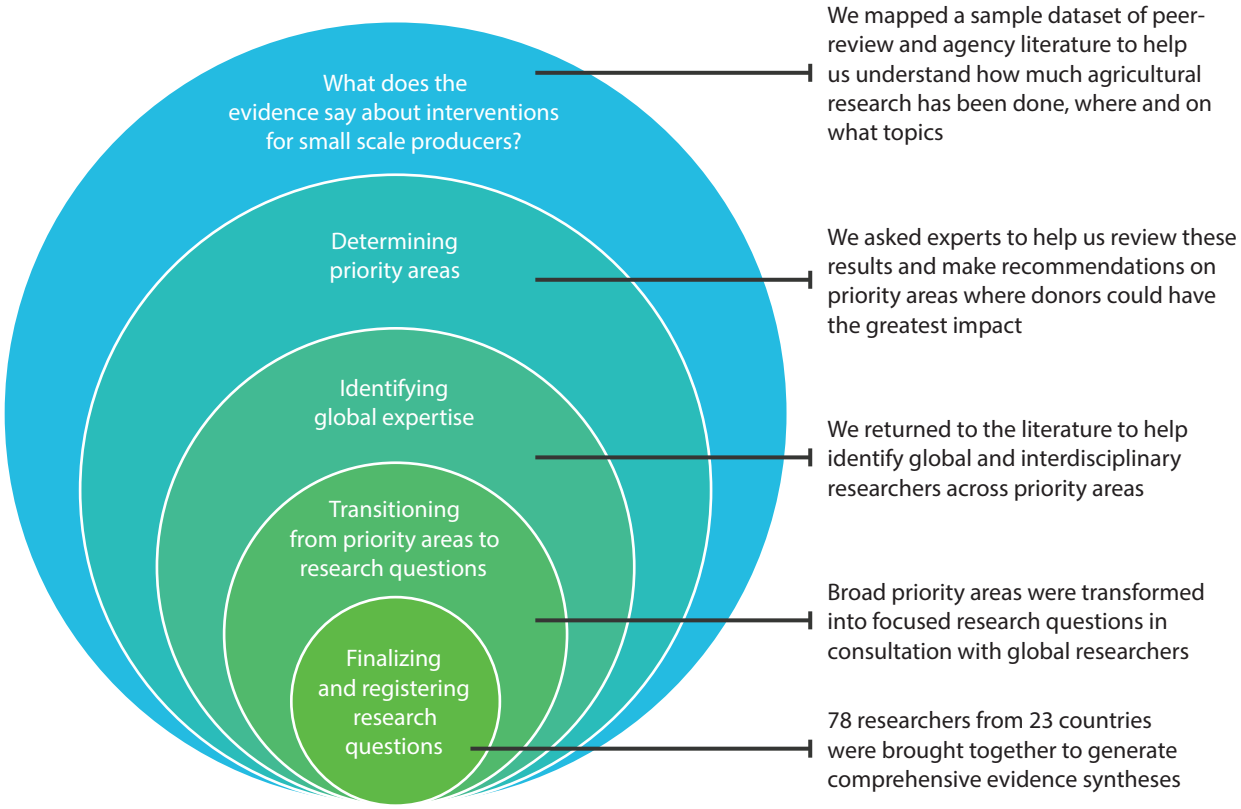
Tools to synthesize evidence are invaluable in the face of the volume of research being produced each year: global knowledge production is estimated to double every nine years (Bornmann & Mutz, 2015). The sheer volume makes new research tools necessary, including those made possible by the advent of artificial intelligence techniques. The team created a machine-learning model to provide each author team with a series of shortcuts to streamline the evidence synthesis process. The researchers worked with the machine-learning datasets to narrow their dataset in the initial title and abstract screening stages.

[4] Evidence synthesis is a guidelines-based approach to bring primary studies together and draw high-level conclusions. It provides a model under which policy and intervention examinations can be made with greater focus, reliability, and transparency. These approaches are more commonly known as systematic and scoping reviews, evidence gap maps, and meta-analyses.

A combination of expert consultation and artificial intelligence model led to the selection of the eight topics for Nature Research

FIGURE 2. HOW DID WE SELECT THE EIGHT TOPICS FOR NATURE RESEARCH?

The process of selecting the topics involved a hybrid expert consultation and an artificial intelligence model that eventually analyzed more than 500,000 articles and identified 77 researchers from 23 countries.



THE ECONOMIC MODEL

To answer how much it will cost governments to end hunger, double the incomes of small-scale producers, and protect the climate by 2030, Ceres2030 undertook one of the most complex equilibrium modelling exercises ever attempted. The modelling process applied hundreds of thousands of equations to account for complex relationships across different levels of the economy over time. It includes data from the international level all the way down to the household level, allowing for the simulation of targeted public investment. The model estimates the additional public investment needed to end hunger sustainably, as well as the private investment generated by that additional public investment. The model also calculates the share of the total cost that ODA donors need to commit.[5]

When the International Food Policy Research Institute (IFPRI) and International Institute for Sustainable Development (IISD) ran a similar model in 2016, they found that governments were not on track to end hunger by 2030 (Laborde et al., 2016). However, the model results showed the goal could be achieved if governments invested additional resources, prioritized countries with the highest need, and used a better mix of the most effective interventions. With Ceres2030, the project team has generated new estimates of the additional public spending needed, factoring in estimates of the impacts of the COVID-19 pandemic and the requirements that small-scale producer income should double and demands on the environment be minimized.[6] The strength of the model is that it captures the effects of the interactions among several interventions and uses household-level data to target spending to small-scale producers and households affected by hunger. It also captures the interactions between countries, considering positive spillovers through increased income and demand, as well as competitive effects through international trade. This allows decision-makers to optimize resource allocation and minimize their costs in their context. The additional public spending needed each year in each country is paid with a mix of external and domestic resources. The total costs are the sum of additional donor support required, together with the sums needed from domestic public spending in each country.[7]

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[5] The allocation decisions between domestic and external resources are driven by an econometrically estimated co-funding rule linking the level of ODA contribution to the domestic public spending in relation to the income per capita of the recipient country. We found that the richer the country, the less it depends on external resources for its public spending. Full dependency on ODA occurs for countries with income per capita below USD 500. At the other end of the range, ODA is phased out from the model for countries that have USD 15,000 per capita or more. The model assumes domestic taxation is used to make up the difference between the ODA contribution and total public funding needed (Laborde et al., 2016).

[6] Greenhouse gas emissions from agriculture, including through use of land, energy, and fertilizers, was used as one key proxy for environmental sustainability. Economic growth was constrained by the greenhouse gas emissions targets for agriculture that countries agreed to in the UNFCCC Paris Agreement of 2016 to avoid dangerous climate change by limiting global warming to well below 2°C, aiming for 1.5°C. The projected quantity of water used was also analyzed to ensure a sustainable extraction of freshwater resources.

[7] The results should be interpreted as an estimate of the scale of resources needed at a big-picture level. This is useful to inform resource allocation decisions from the global level down to the national level, but are insufficient to inform strategy, planning, and programming at the sub-national level.

In order to simulate the portfolio of interventions, the model uses policy instruments (for example, research and development spending in the CGIAR system) to represent the given intervention. Overall, 14 policy instruments were modelled based on existing data sources and a number of new parameters from the collection of evidence syntheses published in *Nature Research*. The 14 policy instruments are as follows: food subsidies, vocational training, investment subsidies, fertilizer subsidies, capital endowments, production subsidies, national R&D, international R&D, extension services, irrigation infrastructure, agroforestry, improved forage, storage, and roads. Three of the 14—vocational training, agroforestry, and improved forage—are interventions based heavily on the collaboration with the evidence synthesis teams. Of the 11 based on existing data sources, two—extension services and storage—were augmented based on knowledge and parameters emerging from collaboration with the evidence synthesis teams.

3. FINDINGS & RECOMMENDATIONS

EMPOWER THE EXCLUDED

MAIN FINDINGS

- **Enable participation in farmers' organizations.** Comparing data in 24 countries, mostly from Africa, membership in a farmers' organization was associated with positive effects on income in 57% of the cases reviewed. Other positive effects correlated with farmers' organizations included positive impacts on crop yield (19% of cases), crop quality (20%) and the environment (24%) (Bizikova et al., 2020).
- **Invest in vocational programs for rural youth that offer integrated training in multiple skills.** Programs that offer training in multiple skills to rural youth show promise in increasing employment levels and wages among the program graduates, creating new possibilities for income (Maiga et al., 2020).
- **Scale up social protection programs.** Social protection works best when the programs create a bridge for households living in poverty to find productive employment, removing the barriers they face in accessing markets, education, credit and other economic opportunities (Wouterse et al., 2020).

EVIDENCE ON EFFECTIVELY EMPOWERING THE EXCLUDED

Analyzing the available evidence with a focus on outcomes for small-scale producer income and productivity, it is clear that successful agricultural interventions work with a population that enjoys a minimum level of income and education, with access to networks and resources such as extension services and robust infrastructure. Whether the intervention is climate-resilient crops, membership in a farmers' organization, or reducing crop losses, this minimum threshold matters (Acevedo et al., 2020; Bizikova et al., 2020; Stathers et al., 2020).

For agricultural interventions to work, complementary approaches to overcome barriers to inclusion are important, especially for commonly marginalized populations such as small-scale producers. Important services that support the inclusion of small-scale producers include agricultural extension, market analysis (e.g., price information), and weather forecasts, all of which help to manage production risks (Acevedo et al., 2020; Piñeiro et al., 2020). One of the important enablers of improved income and productivity for producers is membership in a farmers' organization. However, household poverty is inversely related to the probability of membership in a farmers' organization (Bizikova et al., 2020). This is not only because poor households lack the means to pay membership fees and other participation costs, but also because small-scale producers are typically less well placed to take advantage of the services that membership in the organization confers, such as access to discounted prices on inputs or the opportunity to certify production. People living in poverty also have less capacity to participate in the governance of membership organizations (Bizikova et al., 2020).

Social safety nets can help to overcome these barriers. These interventions take the form of cash transfers, food stamps, or vouchers paid to people affected by hunger. They are expensive for public budgets but important. If well designed and given time, they can support the participation of poor households in productive economic activities and in supporting institutions such as farmers' organizations. More recently, social protection has become the focus of more ambitious program design, in policies that aim to build a bridge to productive employment. These social protection interventions are targeted to overcome the barriers people living in poverty face in accessing markets, including skills training, access to credit, and guaranteed employment (Wouterse et al., 2020). Social protection also plays a critically important role during a crisis. The COVID-19 pandemic has been a stark reminder of how quickly the impressive gains in reducing the incidence of poverty and hunger in the world could be lost. We predict that a further 95 million people will be living in extreme poverty and hunger as a result of COVID-19 (Laborde & Smaller, 2020). The primary cause will be the loss of income caused by economic measures imposed to contain the pandemic (Laborde & Smaller, 2020).

Reviewing evidence on the effectiveness of incentives to improve sustainable agricultural practices on-farm showed that equity and efficiency objectives can sometimes conflict. If programs are targeted to regions with higher wealth and environmental degradation, wealthier farmers are more likely to take up and use incentive programs. If financial incentives are used to encourage uptake, higher uptake by wealthier farmers could deepen inequalities. The review showed interventions should be

designed to take account of the population and to determine if incentives are needed to obtain the improved environmental practice desired (Piñeiro et al., 2020).

One of the time-tested ways that farmers have overcome their relative lack of bargaining power in their markets is by self-organizing. Returns to small-holder investment are determined by both efficiency gains (more output for units of land, labour, and purchased inputs) and the extent and nature of market distortions and market failures, both of which will change the profitability of an activity. Comparing data in 24 countries (primarily in East, Southern and West Africa, as well as India), the researchers found that membership in a farmers' organization is associated with positive effects on income in 57% of the cases reviewed. Other positive effects correlated with farmers' organizations included positive impacts on crop yield (19% of cases), production (20%), and on the environment (24%) (Bizikova et al., 2020). The literature shows the single greatest benefit farmers' organizations offer is to strengthen producers' market power, which increases the share of the benefits from agricultural production that producers receive (Bizikova et al., 2020). The review of services to small-scale producers provided by SMEs also showed the importance of farmers' organizations as an interface with the market (Liverpool-Tasie et al., 2020). Almost a quarter of the farmer's organizations (22%) in the cases reviewed provided product marketing services to their members (Bizikova et al., 2020).

The international development community has recognized the challenge of including youth in agricultural development for some time (FAO et al., 2014; IFAD, 2019). Despite this recognition, the researchers found almost no studies assessing interventions to provide vocational training to rural youth. Promising projects and programs, as well as lessons learned in other sectors, suggest the important benefits of investing in programs for rural youth that provide integrated training in multiple skills (both vocational and technical, and including information and communication technology skills) (Maiga et al., 2020). The findings underlined the importance of education more broadly, which was also supported in other evidence syntheses in the series (Acevedo et al., 2020; Piñeiro et al., 2020). The finding is another reminder of the indivisible nature of the 2030 Agenda, with SDG 4 committing to provide good quality education for all.

ON THE FARM

MAIN FINDINGS

- **Investment in extension services, particularly for women, must accompany R&D programs.** The most important determinants of adoption of climate-resilient crops were the availability and effectiveness of extension services (Acevedo et al., 2020). Small and medium-sized enterprises such as cooperatives, processors, traders, and marketing platforms frequently couple their provision of inputs and purchase of producer output with training or extension services; this was the case for 40% of cooperatives and 19% of processors studied (Liverpool-Tasie et al., 2020).
- **Agricultural interventions to support sustainable practices must be economically viable for farmers.** Market and non-market regulations, regulatory measures and cross-compliance incentives linked to short-term economic benefits have a higher adoption rate and have been more successful when it comes to improving the environment than those aimed only at providing an ecological service. In the long term, and regardless of the incentive type, one of the strongest motivations to adopt and maintain sustainable practices is when farmers perceive positive outcomes of these practices for their farm or the environment (Piñeiro et al., 2020).
- **Support adoption of climate-resilient crops.** Where they are accessible, small-scale producers will use climate-resilient crops to cope with stresses such as drought, heat, flooding, salinity, and changes to the growing season. Adoption is markedly improved if the crops are supported by inclusive extension services and access to inputs. Higher levels of education and socioeconomic status are also positively correlated with the adoption of climate-resilient crops, as are crops that are commercially viable (Acevedo et al., 2020).
- **Increase research on water-scarce regions to scale up effective farm-level interventions to assist small-scale producers.** Nearly 80% of small-scale farms across low- and middle-income countries are located in water-scarce regions, a number similar to larger-scale farms, yet around 35% are irrigated compared to over 40% of larger farms. Promising areas that remain underexplored for small-scale producers in water-scarce regions include digital solutions and livestock in mixed farming systems (Ricciardi et al., 2020).
- **Target improvements in the quantity and quality of livestock feed to small and medium-sized commercial farms.** Obvious and useful options to improve the quality of feed are being overlooked, including better support for the use of crop residues. The literature shows a bias toward understanding the technicalities of livestock feeding while not paying enough attention to how technologies fit into farm practices (Baltenweck et al., 2020).

EVIDENCE FOR EFFECTIVE INTERVENTIONS ON THE FARM

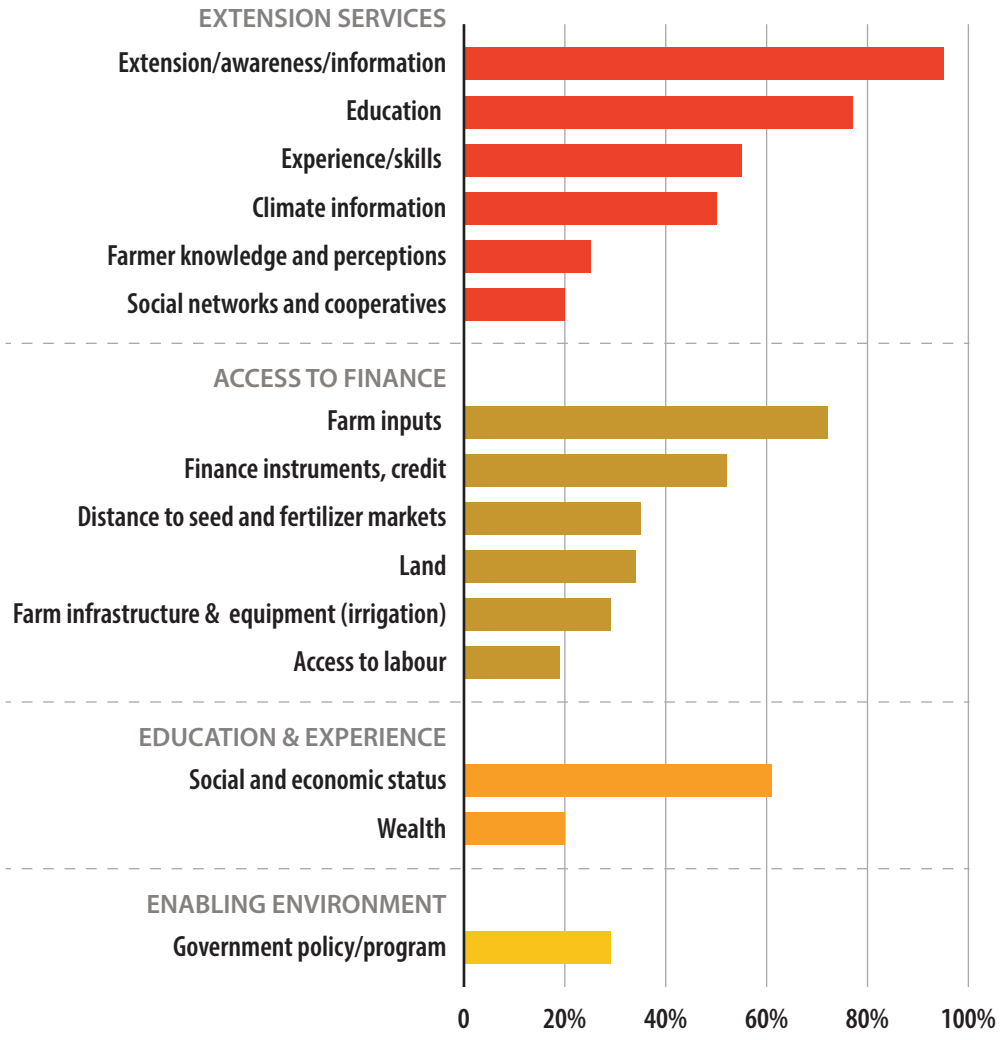
Despite the importance of small-scale producers and their contribution to global food systems, the evidence teams found that research into how interventions affected small-scale producer income and well-being was scarce. Several of the research teams did find that interventions are more successful if they meet more than one objective simultaneously (e.g., paying attention to the marketability of a crop and not just its climate resilience or resistance to pests) (Acevedo et al., 2020; Baltenweck et al., 2020; Piñeiro et al., 2020). To increase their effectiveness, regulatory measures are often linked to economic incentives, such as short-term financial support to incentivize the participation of farmers. If environmental conditions on the farm improved with the intervention, the evidence shows farmers were more likely to persist with the more sustainable practices (Piñeiro et al., 2020).

A variety of interventions exist to encourage more sustainable on-farm practices. Market and non-market regulations and cross-compliance incentives that are linked to short-term economic benefits have been more successful at improving the environment than the interventions that focused only on ecological services (Piñeiro et al., 2020). Successful incentive programs are correlated with market conditions, farmers' attitudes to the environmental problems being addressed, and the structure of the programs offered. For example, legal regulations have proven to be relatively effective for environmental outcomes, but they are a relatively complex and inflexible instrument—and unpopular with farmers, especially if the regulations do not make any provision for increased on-farm costs (Piñeiro et al., 2020).

Climate variability exposes food systems to greater risk and increases farmers' costs. These risks threaten domestic food production in many low- and middle-income countries and disrupt international markets. Significant public investment has gone into successfully developing climate-resilient crops and crop varieties; the evidence shows that where they can access them, small-scale producers use climate-resilient crops to cope with stresses such as drought, heat, flooding, salinity, and changes to the growing season (Acevedo et al., 2020). They also adopt crops adapted to cope with the pests associated with changes in weather and climate patterns. Yet the evidence shows important barriers to adoption, too. They are best overcome in the presence of additional factors: the most important determinants of adoption of climate-resilient crops are the availability and effectiveness of extension services and outreach followed by education levels, farmers' access to inputs, and socioeconomic status (see Figure 3). Nearly 50% of the studies on climate-resilient crops identify extension services as a factor for successful adoption. The evidence also suggests these factors do not work in isolation, but rather are mutually reinforcing. The most successful climate-resilient crops are accessible through a variety of distributors, reliable, affordable, easy to grow, and produce a crop for which there is market demand (Acevedo et al., 2020).

Nearly 50% of the studies on climate-resilient crops identify extension services as a factor for successful adoption

FIGURE 3. IMPORTANCE OF EXTENSION SERVICES FOR CLIMATE-RESILIENT CROPS



Source: Acevedo et al., 2020

Climate change is increasing the incidence of extreme weather events that pose a risk to agricultural production and small-scale producer livelihoods, including both droughts and floods (IPCC, 2012; 2019). Estimates suggest that over 4.8 billion people worldwide will face at least one month of water scarcity each year by 2050 (Ricciardi et al., 2020). The creation of a map of small-scale farms (less than 5 hectares) overlaid with the availability of irrigation infrastructure showed a paucity of interventions where they are most needed.

Over a billion people depend on livestock for their livelihoods. Their animals are not just a food source for the household or an asset to be sold; the animals also serve vital roles on-farm, including draft power for plowing and high-value compost for crops. The demand for animal-sourced foods is increasing as both populations, and income levels rise. These foods are an important source of nutrition and income for the families that care for them and can be especially important for small-scale producers with limited access to land. However, dairy yields (litres of milk per cow) from livestock in Africa are up to 20 times below what they are in developed countries (Baltenweck et al., 2020). Increasing the productivity of livestock through improved feed, veterinary services and breeding programs are powerful interventions that support the goal of access for all to sufficient healthy food grown more sustainably. Such interventions can simultaneously reduce GHG emissions, for example by raising the yield of milk per animal (reducing the number of animals needed overall), or by switching to feeds that produce lower levels of methane as they are digested, while also increasing access to nutritious food and improving livelihoods (Baltenweck et al., 2020).

The evidence also provides reminders that small-scale producers are not a homogeneous population. For example, interventions to improve feed quality that target small-scale, semi-commercial farmers are particularly effective, as these farmers have the resources and the business interest to make better feed a priority. The evidence also shows that the use of crop residues as a means of feed improvement remains relatively underexploited. Access to improved crop residues could reduce dependence on purchased feed, thereby lowering costs. Making better use of crop residues is a good compromise solution for small-scale livestock producers, as they are close at hand, cheap, and effective, making them attractive for wider adoption (Baltenweck 2020).

FOOD ON THE MOVE

MAIN FINDINGS

- **Reduce post-harvest losses by expanding the focus of interventions beyond the storage of cereals, to include more links in the value chain and more food crops.** The evidence base confirmed that several storage interventions, including the use of airtight bags and containers, are effective at reducing post-harvest losses for cereals and pulses. Other technology interventions were effective at reducing losses of fruits and vegetables: these included better handling practices, improved packaging, more careful timing of the harvest, and cold storage. There is a need to look at the effect of combining interventions and the need for more interventions for users other than farmers, as well as to investigate the potential of post-harvest training, finance, marketing, organization, governance, policies, and infrastructure interventions (Stathers et al., 2020).
- **Invest in the infrastructure, regulations, services and technical assistance needed to support SMEs in the value chain.** The evidence shows that SMEs[8] are successfully serving farmers in low- and middle-income countries, particularly in Africa, and are correlated with technology adoption and higher productivity. They are typically more accessible to small farmers than larger enterprises (such as supermarkets) and small-scale producers value the mix of services that SMEs provide (Liverpool-Tasie et al., 2020).

EVIDENCE FOR EFFECTIVE INTERVENTIONS FOR FOOD ON THE MOVE

Small-scale producer productivity and income depend in part on access to post-harvest services such as storage, marketing information, processors, and food retailers. Drivers such as urbanization, population growth, and rising incomes in many low- and middle-income countries, have transformed both how much and what people eat (FAO, 2017; HLPE, 2017). These trends are transforming markets in which small-scale producers, changing what they need to know and the risks and opportunities they face.

The researchers looked at effective interventions to reduce post-harvest losses for 22 food crops with a focus on Africa and the low- and middle-income countries of South Asia. Interventions that increase the use of airtight containers (including hermetic bags) or admixture of a range of protectants are effective at reducing post-harvest losses for cereals and pulses. These measures kept quantity losses below 2% for maize, rice and sorghum, and below 5% for wheat during a 6-month storage period

[8] For the purposes of this paper, the term "SMEs" refers to cooperatives, traders, processors, logistics firms, and other value chain actors.

(Stathers et al., 2020). Simple improvements in handling practices such as choosing the right time to harvest combined with good drying and sorting practices reduced losses in cereals and pulses. For example, simple improvements in handling practices for cereals (excluding rice) and pulses, such as drying, early harvesting, and sorting kept losses at or below 5%. Without these measures, cereal losses were between 11% and 20%. The use of improved handling methods (such as careful and timely harvesting for fruits, or curing for onions), transport packaging containers, and evaporatively cooled and cold storage reduced losses in the focal fruits and vegetables. Evaporatively cooled, cold, or well-ventilated structures or improved pits kept quantity and quality losses of potato below 16% and 9% during storage, respectively (Stathers et al., 2020). Harvesting rice at the recommended time kept losses below 1% and damage below 10%, while harvesting rice too early or too late led to losses of up to 20% and up to a third of the crop sustaining damage (Stathers et al., 2020).

The researchers looking at post-harvest losses found the evidence base to be skewed toward cereal crops (particularly maize), as opposed to a wider variety of foods. Other biases included a focus on technologies rather than training, finance, policy, infrastructure, or market interventions—let alone combinations of these elements. The evidence base is also scarce on food losses outside of storage, such as during harvesting, transportation, and processing, and on non-farm actors in the food chain. There is almost nothing on the socioeconomic and environmental outcomes of post-harvest loss interventions, nor on farmers' understanding and knowledge (Stathers et al., 2020).

The growth of food systems has created huge market and employment opportunities for farmers along supply chain segments, including food processing, wholesale, and retail. The extent to which these opportunities are available to small-scale producers has not been well established. These segments are often the farmers' immediate interface with the market, through which they sell their products, obtain logistics and intermediation services, and purchase farm inputs. Where accessible, they could potentially improve the revenue-generation opportunities for small-scale producers. Researchers reviewed 202 studies on market interactions between small-scale producers and a variety of market channels (including product traders, logistics firms, processors, and retailers) through the use of non-formal contractual arrangements. These services were primarily offered by SMEs (Liverpool-Tasie et al., 2020).

The evidence shows SMEs are flourishing in rural areas, providing farmers with a host of linked services, including the provision of inputs (especially credit and training), buying crops, connecting farmers to processors, and offering market information. This economic activity has not been well understood to date. Actors in the midstream of crop value chains are sometimes mistakenly referred to as the "missing middle" in descriptions of food systems in developing countries. In fact, the evidence shows they are very much present—and active and dynamic. They are not so much missing as "hidden" in the policy debate (Liverpool-Tasie et al., 2020). Yet the coverage SMEs can provide is uneven and usually informal. As a result, economic risk is fairly high for the actors involved, and it is hard to protect the standards that buyers along the value chain impose. Tin addition, the evidence suggests

government agencies often fail to make the most of the services provided by SMEs. For example, they are inclined to set up competing services rather than complementing existing activity. The evidence synthesis identified weaknesses in the SME sector that governments might address, including limited technical capacity, weak managerial and organizational skills, and poor coordination within the sector (Liverpool-Tasie et al., 2020).

Farmers appreciate the complementary services that SMEs provide, which are also correlated with technology adoption and higher productivity among farmers (Liverpool-Tasie et al., 2020). Services found to be offered together include: providing credit along with transport and processing services (the case of 22% of traders and 31% of processors studied); inputs coupled with training or extension services (the case of over 40% of cooperatives and 19% of processors); logistics service providers also acting as buyers (the case of 44% of logistics service providers) and input providers also acting as buyers (the case of 25% of cooperatives) (Liverpool-Tasie et al., 2020).

WHAT IS THE FUNDING GAP?

The second question the Ceres2030 project sought to answer was, what will it cost governments to end hunger, double the incomes of small-scale producers, and protect the climate by 2030? The additional cost is distributed across the three categories of interventions: empower the excluded, on the farm, and food on the move.

The results from the model show that donors need to contribute an additional USD 14 billion per year on average until 2030 to end hunger and double incomes of small-scale producers in low- and middle-income countries. The investment achieves these goals while maintaining greenhouse gas emissions for agriculture below the commitments made in the Paris Agreement (see Figure 4).

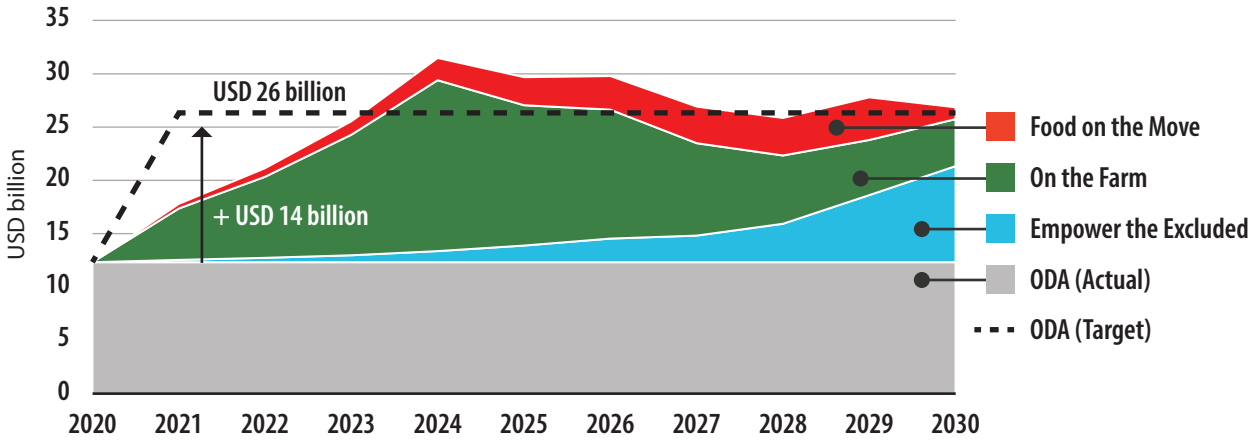
Donors currently spend USD 12 billion per year on food security and nutrition and therefore need to double their contributions to meet the goals. However, ODA alone will not be enough. Additional public spending of USD 19 billion per year on average until 2030 will have to be provided by low- and middle-income countries through increased taxation.

Together, the additional public investment from donors and low- and middle-income countries will prevent 490 million people from experiencing hunger, double the incomes of 545 million producers and their families on average, and limit greenhouse gas emissions for agriculture to the commitments made in the Paris Agreement.[9] Importantly, the additional public spending will, on average, spur an extra USD 52 billion in private investment per year.

[9] The results from the modelling should be interpreted as an estimate of the scale of resources needed at the big-picture level. This is useful to inform resource allocation decisions from the global level down to the national level but is insufficient to inform strategy, planning, and programming at the subnational level.

The current level of donor spending averages USD 12 billion per year, only half of what is needed to meet the goal of ending hunger by 2030

FIGURE 4. THE FUNDING GAP OVER TIME AND BY CATEGORY OF INTERVENTION

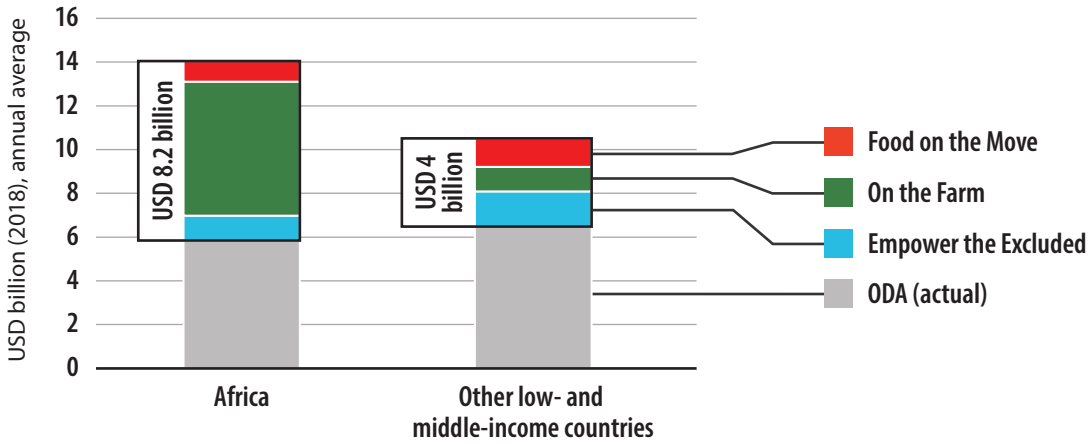


Source: Author's calculations.

By far the region with the greatest need for additional resources is in Africa. Figure 5 shows the donor contribution needed in Africa compared to other low- and middle-income countries and distributed across the three categories of interventions. The need in Africa is particularly high since more than half of the global undernourished population will be concentrated on this continent by 2030.

Two thirds of the additional public spending is needed in Africa to achieve the targets

FIGURE 5. FUNDING GAP BY REGION AND BY CATEGORY OF INTERVENTION*



Funding gap by region and by category of intervention

Source: Authors' calculations.

** Funding gap for global R&D is not included in the regional breakdown.*

There are two instruments used to generate an estimate of the donor contribution needed for empowering the excluded: income support through food subsidies (social protection programs) and vocational training programs. The donor contribution for these instruments is an additional USD 3 billion per year on average.

To estimate the donor contribution needed for interventions on the farm, the modellers used 10 policy instruments that directly affect the technologies available for small-scale producers and what and how they produce: investment subsidies, fertilizer subsidies, capital endowments, production subsidies, national R&D, international R&D, extension services, irrigation infrastructure, agroforestry, and improved forage. The donor contribution for this category is an additional USD 9 billion per year on average. Interestingly, each instrument's investment follows a different time profile to achieve the targets by 2030, with spending on core public goods—especially R&D, which has a long lag before payoff but a high return—to be prioritized first.

The modellers used two policy instruments to estimate the donor contribution needed to support moving food to market. Both instruments contribute directly to increased income opportunities for farmers while reducing overall costs for consumers. The two instruments are increased rural infrastructure and storage opportunities, both of which contribute to a reduction in post-harvest losses. The donor contribution is an additional USD 2 billion per year on average.

4. CROSS-CUTTING LESSONS

SUCCESSFUL INTERVENTIONS DEPEND ON HUMAN, SOCIAL, FINANCIAL, AND KNOWLEDGE CAPITAL.

Effective technology interventions rely on interdependencies among human, social, financial and knowledge capital. To protect the 2030 Agenda commitment to leave no one behind, governments must underwrite all these forms of capital. The lack of information on complex outcomes has to be addressed to build a knowledge base on how to nurture different facets of sustainable development (Bizikova et al., 2020; Liverpool-Tasie, 2020; Stathers et al., 2020)

IT IS IMPORTANT TO BUILD AN INTEGRATED PORTFOLIO OF POLICY INTERVENTIONS.

The evidence synthesis researchers found that integrated portfolios of policy interventions work better than isolated fixes. SMEs, in particular, are providing farmers with a range of services. In addition to linking them to markets, SMEs are an important source of credit and capacity building on product standards. The research shows these "wraparound" services are one of the things small-scale producers most appreciate about SMEs (Liverpool-Tasie et al., 2020). The adoption of climate-resilient crops, too, showed the importance of extension services, education about climate change, and the great importance that farmers that attached to ensuring crops also have good sales markets (Acevedo et al., 2020). In addition, incentives for sustainable agricultural practices showed both the usefulness of

meeting farmers' short-term financial constraints with the incentives schemes, and the importance of farmers' understanding the environmental benefits to sustain participation in the program in the longer term (Piñeiro et al., 2020).

GENDER-DISAGGREGATED STATISTICS FOR AGRICULTURE AND RURAL DEVELOPMENT REMAIN SCARCE.

Gender-disaggregated datasets are slowly being built. Researchers and policy-makers know more now than they did 10 years ago. However, although they are becoming more available for health and nutritional outcomes, gender-disaggregated statistics for agriculture and rural development are still sparse (Bizikova, 2020). Among the evidence that synthesis teams counted, just 10% or so of the reviewed papers considered gender differences in the outcomes of the interventions. The team researching SMEs found that only 12% of the 202 studies they reviewed included a focus on gender. However, gender matters—first as a human rights issue and also for the effectiveness of interventions. For example, the findings from the papers reviewed for the livestock study found two-thirds of livestock keepers in low- and middle-income countries are female (Baltenweck et al., 2020). Gender and marital status also affect membership in farmers' organizations, with married women less likely to join (Bizikova, 2020). Data collection is necessary to better understand social gendered differences between and within households, yet the research teams found little evidence of socioeconomic outcomes, including gender-disaggregated outcomes (Acevedo et al., 2020; Ricciardi et al., 2020; Stathers et al., 2020).

EVIDENCE-BASED POLICY IS ONLY AS GOOD AS THE EVIDENCE BASE AVAILABLE.

The data gaps are not confined to gender. The evidence teams found large gaps in the research to support answers to the kinds of questions that donors and governments are asking. Based on our studies and a review of 20 other systematic reviews, less than 2% of the available evidence base is pertinent for the questions donors typically want to investigate, such as the cost of an intervention (Porciello et al., 2020a). Most challenging for calibrating the model with outcomes from the evidence, almost none of the published evidence considers the cost of the technology—or who should pay. For example, the research on livestock interventions found that very few studies (6 out of 73) reported combined evidence of adoption, productivity, and livelihood effects (Baltenweck et al., 2020).

Large areas of the world are invisible in the literature. The researchers found many of the widely shared beliefs and assumptions about agricultural development rest on a geographically incomplete database. In addition, Decision-makers are increasingly asking for policy prescriptions that mix interventions. However, the researchers did not find a lot of evidence that looked at the system effects of multiple interventions. Investments in developing standardized frameworks and indices for links between livelihoods and the environment, livelihoods, and youth, similar to the Women's Empowerment in Agriculture Index (WEAI), is one approach that can fill critical gaps in the evidence base. There is an urgent need to invest in the development of standardized frameworks to improve the quality and availability of research over time.

For a number of intervention areas reviewed, the evidence shows governments are investing in proven technologies. This was true of post-harvest management and loss reduction, for example, and climate-resilient crops. Amid the proliferation of published research, however, the results showed significant blind spots. There was a lot of evidence on yield effects, but with very little consideration of effects on farm income, nutrition, or environmental cost (Liverpool-Tasie et al., 2020; Ricciardi et al., 2020; Stathers et al., 2020). There was also a lot of evidence on the effectiveness of technologies; for example, on whether and by how much GHG emissions were reduced or water quality improved. But broader ecosystem effects were captured much less often. Even less evidence has been published on whether a proven technology is actually used on the farm, whether it increases incomes, and if it changed on-farm practices or expanded market opportunities.

SPENDING MORE AND BETTER IS VITAL.

Total ODA for agriculture increased significantly in response to the 2007–2008 international food price crisis. New institutions were built, bridging spending to reduce poverty and social exclusion with investments in raising agricultural productivity. However, agricultural spending is still a relatively small share of the ODA budget (since 2014, G7 donors have each disbursed between 3% and 7% of their total ODA budget on agriculture[10]) (Eber-Rose et al., 2020). We estimate that spending needs to double to meet the ambition of SDG 2, and yet actual disbursements to agriculture are faltering. ODA flows are predicted to decrease because of the global economic slowdown associated with the COVID-19 pandemic—the International Monetary Fund (IMF) has predicted a global growth decline of 5% that will reduce fiscal space in donor countries, which is likely to reduce ODA flows (IMF, 2020).

Nowhere is ODA playing as central a role as it does in Africa. Total ODA spending is increasingly concentrated in Africa and Asia; Africa has been the main recipient of agricultural ODA since 2011 (Eber-Rose et al., 2020). In 2017, the share of ODA in the foreign finances received by African countries south of the Sahara was 36%, compared to 31% from overseas personal remittances and 23% from FDI (OECD, n.d.b).

[10] Data extracted from the OECD Development Assistance Committee (DAC) Creditor Reporting System (CRS) database (OECD, n.d.a). Spending on agriculture is defined by the DAC codes for agriculture, forestry and fishing total (sector code 310) and rural development (purpose code 43040). Percentages calculated relative to total ODA, all sectors. Values refer to total disbursements in constant 2018 US dollars.

6. CONCLUSION

Governments have 10 years until 2030. The sooner the investments are made in the 2030 Agenda, the less it will cost the public purse and the more sustained the outcomes are likely to prove. Building resilient and inclusive economies is a much better basis for ending hunger than providing a social safety net; social protection is necessary for the resilience of a society, but it is not sufficient in and of itself. There is a further reason for urgency, beyond the rising costs associated with inaction: the need to act now to limit irreversible damage to the earth's ecosystems. For the environment, too, waiting means foreclosing options, some of them permanently.

Ceres2030 was an experiment, an effort to make better use of the available evidence in policy decisions. A multidisciplinary team equipped with a variety of research tools and some relatively clear—if broad—questions was able to use machine learning, teams of researchers, and a highly sophisticated cost model to answer complex questions. The experiment is ripe for reiteration, improvement, and new frontiers.

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Ceres2030
Sustainable Solutions to End Hunger

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ABOUT CERES2030

Ceres2030 brings together three institutions that share a common vision: a world without hunger, where small-scale producers enjoy greater agricultural incomes and productivity, in a way that supports sustainable food systems. Our mission is to provide the donor community with a menu of policy options for directing their investments, backed by the best available evidence and economic models.

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