JUNO EVIDENCE ALLIANCE

The State of the Field for Research on Agrifood Systems

JUNO Transforming Evidence for Agriculture, Food and Climate

CONTRIBUTING AUTHORS

Porciello, Jaron[1,2]; Skidan, Volha[2]; Ambikapathi, Ramya[3]; Boonabaana, Brenda[4]; Guerra, Jill[5]; Lidder, Preetmoninder[6]; Piñeiro, Valeria[7]; Phillips, Lauren[8]; Savilaakso, Sini[9]; Schuster, Monica[10]; Sheikh, Hafsa[2]; Tufan, Hale[11];Witkowski, Kelly[12].

1 University of Notre Dame, Lucy Family Institute for Data and Society, Notre Dame, Indiana, USA

2 Havos, Inc., Ithaca, New York, USA

3 Cornell University, Department of Global Development, Ithaca, New York, USA

4 University of Texas, Austin, USA

5 Global Affairs Canada, Global Issues and Development Branch, Agriculture and Food Systems Division, Ottawa, Canada

6 Food and Agriculture Organization of the United Nations (FAO), Office of the Chief Scientist, Rome, Italy

7 International Food Policy Research Institute (IFPRI), Washington, D.C., USA

8 Food and Agriculture Organization of the United Nations (FAO), Inclusive Rural Transformation and Gender Equality Division, Rome, Italy

9 University of Helsinki, Department of Forest Sciences, Helsinki, Finland

10 Food and Agriculture Organization of the United Nations (FAO), Agrifood Economics and Policy Division (ESA), Rome, Italy

11 Cornell University, School of Integrative Plant Sciences, Ithaca, New York, USA

12 Inter-American Institute for Cooperation on Agriculture (IICA), San Jose, Costa Rica

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JUNO Transforming Evidence for Agriculture, Food and Climate

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

EXECUTIVE SUMMARY

Science is called upon in times of significant change and uncertainty to respond to global challenges and opportunities. Novel approaches are needed to connect science with policy targets so that we can dedicate some of the scientific knowledge that we've accumulated over the course of human history on being able to save the world—while we still have a world left to save. Converging crises of hunger, climate, and political unrest remind us there is no time to waste. The impacts of climate change are increasingly evident worldwide, particularly affecting farmers and rural communities in regions that already struggle with poverty, hunger, and access and affordability of nutritious diets.

Governments, funders, and public and private sectors are investing significant energy and resources to promote and identify evidence-based solutions across agrifood systems. A proliferation of research published over the past 15 years encourages agrifood systems to contribute towards a broader set of outcomes beyond productivity, and embrace nutrition, women's empowerment, environmental sustainability, resilience, and inclusion. There is a profound sense of urgency for all actors, and especially global institutions, to innovate and adapt in response to an ambitious set of targets while paying attention to potential trade-offs and unintended consequences that come with integrating multiple objectives simultaneously.

'The State of the Field for Research on Agrifood Systems' uses artificial intelligence (AI) to analyse global research distribution from the past 13 years. This report provides a macro-level review of more than six million summaries of scientific papers and reports. It offers a snapshot across agrifood systems research, highlighting where progress has occurred, and where significant gaps remain. The findings of the report are presented in separate sections to facilitate navigation, but we encourage readers to explore the connections more holistically.

Artificial intelligence offers a powerful set of innovative technologies, including generative AI. Generative AI optimizes knowledge and data to identify patterns and, where appropriate, combines data from diverse sources to generate new insights. In an increasingly interconnected science and policy landscape, it is crucial to have a comprehensive understanding of how past and future research contributes to broader goals.

What did we find?

Despite 60% growth in research publications across agrifood systems in the past 13 years, there are extremely low levels of scientific research targeting the poorest, hungriest, and most vulnerable to climate change countries. Some countries are supported by an evidence base of fewer than 1,000 publications spread across more than 35,000 journals. Research involving various stakeholders in the agriculture value chain—such as small and medium enterprises and small-scale farmers—accounts for only 8% of global agrifood systems research.

Not all areas where there is a dearth of research can be treated equally or with the same urgency—especially when it comes to issues of healthy diets and climate change. While the issues of nutrition and diet are critical for every population, children and mothers remain a highly vulnerable demographic, yet only 6% of research focuses on these populations. Research on fruits, vegetables, and legumes, which are critical for improved diet and nutrition outcomes, is much lower compared to literature on staple crops. This creates challenges to potentially scaling-up solutions across these value chains. And overall, research focused, on crop, livestock, aquaculture, forestry, and food processing and storage interventions requires more investment and attention to ensure that inclusivity and gender equity outcomes, including women's empowerment, are prominently represented.

Research focused on environmental sustainability, including climate adaptation, must also be increased in order for agriculture and food systems to play a part in reducing global emissions. In some cases, the lack of outcomes related to environmental sustainability is a symptom of greater problems in research, such as poor data collection methods and a lack of access to newer technologies that measure water consumption, water quality, and soil health as part of agricultural research. Fisheries, livestock, and forestry are not highlighted in as much detail as crop research despite their critical role in agrifood systems, and underscoring the need for increased research focus on these vital sectors.

Some bright spots do emerge. Researchers working and publishing in the countries most impacted by climate change and hunger are twice as likely to engage with local communities as part of their research compared to researchers from high-income countries. In addition, efforts focused on sustainable economic growth outcomes, as well as food security, are consistently represented across many intervention areas. And the integration of inclusivity and gender equity outcomes across social and behavioural communication change and advisory and extension services is also encouragingly high.

But overall, the trends are worrisome. There is simply a lack of research on critical outcomes and communities that are at the heart of agrifood system transformation—women, children, and small-scale farmers and producers—in the countries most impacted by hunger and climate change.

Resolving this requires a systems approach and challenging long-standing norms regarding power dynamics across science and policy, including publication and funding norms. Doing so has the potential to generate more context-specific solutions for complex issues like hunger and climate change that require targeted interventions to achieve long-lasting change.

As we look towards the research and policy agendas for the future, the combination of AI and the collective intelligence already generated by millions of researchers and practitioners represents a way forward. It gives us the tools to refine how we work together to solve problems and establish priorities.

INTRODUCTION

The transformation of agriculture and food systems is necessary for creating resilience to climate change, fostering inclusivity, and ensuring environmental and economic sustainability, thereby guaranteeing access to affordable and nutritious food for all. This requires a concerted effort across various global and national agendas and systems to support the overarching goal of food system transformation.

The recent COP28 UAE Declaration on Sustainable Agriculture, Resilient Food Systems and Climate Action underscores the importance of reaffirming commitments to international targets such as the 2030 Agenda for Sustainable Development, the United Nations Framework Convention on Climate Change and the Paris Agreement, the Kunming-Montreal Global Biodiversity Framework, and the United Nations Convention to Combat Desertification.

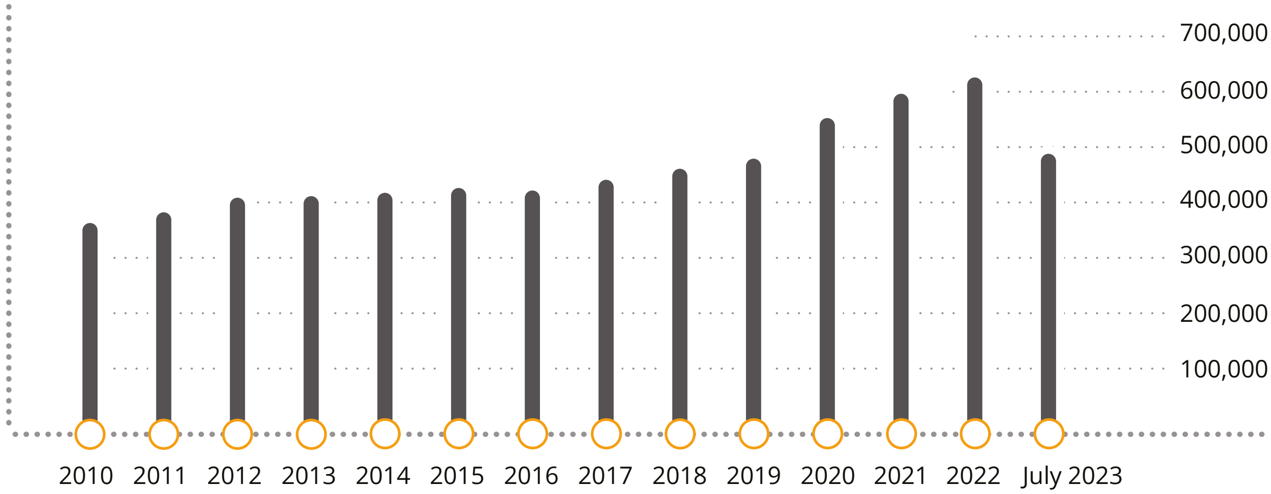
Science plays a pivotal role in achieving international targets. It is unique in its contribution to society by taking a systematic approach to solving complex problems (United Nations, 2023). The United Nations Secretary General created a scientific advisory board in 2023 to solicit expert advice on the opportunities and the risks of scientific breakthroughs. As part of the Food and Agriculture Organization of the United Nations (FAO) Science and Innovation Strategy, the Office of the Chief Scientist recently released draft guidance for strengthening science–policy interfaces (SPIs) for agrifood systems at the national level.

The guidance stresses that decision-making is informed by the best available evidence, and it is necessary to have both high-quality scientific evidence and robust SPIs that support the co-creation and mobilization of knowledge, as well as the use of evidence by policy-makers (Stewart and Patiño-Lugo, 2024; Welch et al., 2024).

Identifying the relationships between science and societal progress is complex. Governments, funders and public and private sectors are investing significant energy and resources to promote and identify evidence-based solutions across agrifood systems that emphasize numerous outcomes (Davis et al., 2022). They are also moving swiftly towards outcomes-based models of assessment and results-based management, which measure the impact of investments rather than only evaluating activities and money spent, with the hope of improving accountability and assessment of agriculture and food systems (Global Affairs Canada, 2022).

These ambitious plans require new tools and approaches. Currently, there is no simple way to synthesize the world's accumulated published knowledge (Porciello et al., 2023). The sheer volume of scientific publications exacerbates this challenge, where research output in agriculture and related domains has increased approximately 60% in the past 13 years, with an average of 440,000 publications per year across more than 35,000 journals and technical reports (Figure 1).

FIGURE 1: ANNUAL PUBLISHING TRENDS IN AGRICULTURE AND FOOD SYSTEMS FROM 2010 TO JULY 2023



MOVING TOWARDS EVIDENCE-BASED APPROACHES FOR AGRIFOOD SYSTEMS

Outcomes-based strategies, or results-based management (RBM), helps governments, donors, non-governmental organizations (NGOs) and other implementing agencies in agricultural development articulate the specific results they seek to achieve or contribute to through their investments. In the context of agriculture and food systems, this means prioritizing outcomes that lead to food system transformation, such as improved food security and nutrition, sustainable economic growth, environmental sustainability, and improved practices to support inclusivity and equity, especially gender equity (von Braun et al., 2021).

Assessing the real impact of outcomes and interventions occurs as part of evidence-informed decision-making (EIDM) processes. These processes are designed to identify whether policies and decisions are grounded in the best available research and informed by relevant contextual factors (Gurevitch et al., 2018). There are many different methodologies for carrying out evidence-informed decision-making assessments captured under the umbrella term of evidence synthesis, which brings together information from primary studies to draw high-level conclusions (Tricco et al., 2018). Many people know evidence synthesis by more specific terms, such as evidence gap maps, rapid evidence assessments, systematic reviews, or scoping reviews.

Evidence synthesis play a crucial role in understanding multifaceted problems and identifying critical knowledge gaps. It involves integrating diverse data sources, triangulating evidence, employing rigorous evaluation methodologies, and utilizing mixed method approaches. It requires careful consideration of contextual factors, and an acknowledgment of the inherent complexities and limitations associated with attributing outcomes solely to specific interventions (Haddaway et al., 2020).

BOX 1: EVIDENCE SYNTHESIS METHODS

Evidence synthesis has a long history in health and medical sciences, most notably through Cochrane and other established groups, including education and social interventions supported by The Campbell Collaboration, environmental and natural resources management supported by Collaboration for Environmental Evidence, and international development interventions supported by 3ie—among many others.

Evidence synthesis refers to the process of combining information from multiple studies investigating the same topic to provide an overview of current scientific knowledge. The three most common types of evidence synthesis are systematic reviews, systematic maps and rapid evidence assessment. Systematic reviews typically answer the question 'What works?', i.e. they are focused on effectiveness of management or policy intervention. Systematic maps are broader in scope and answer 'What is known?' types of questions. Rapid evidence assessments can be of either type, but follow streamlined methods to produce the review rapidly.

High-quality evidence synthesis can be recognized by the use of pre-defined, rigorous methods, and transparent conduct and reporting designed to reduce bias. One hallmark of genuine systematic reviews is appraisal of study quality. By assessing included primary studies for potential bias, conclusions can be drawn about their risk of bias and, further, confidence on study results.

When synthesizing evidence on the effectiveness of interventions, three key questions arise: Does the intervention work (significance)? How large is the effect (magnitude)? Are there factors that influence effectiveness (variation)? Systematic reviews often include meta-analysis to assess the significance and magnitude of outcomes across primary studies and to analyse causes of variation. This can be supplemented with a qualitative synthesis (e.g. thematic analysis) to provide deeper understanding of intervention complexity, contextual variations and factors linked to implementation, in essence providing insights into the 'why' and 'how' intervention works. Where necessary or desirable, evidence synthesis can be combined with expert or stakeholder insights to fill knowledge gaps in published literature or to seek further insights into practice.

These methods encourage collaboration between researchers, policy-makers, and practitioners to translate actionable policies and programmes, including feedback that informs future research priorities (Avey et al., 2022). Box 1 provides more details about evidence synthesis methods.

Artificial intelligence has the potential to significantly enhance evidence-informed decision-making in agrifood systems. It can enable poorly developed systems to leapfrog—advancing rapidly by adopting modern technologies without intermediary steps—to reflect approaches found in more mature and established evidence synthesis systems. For example, missing from agrifood systems are standardized approaches to facilitate EIDM, especially when compared to well-established practices in the health and medical sector. The World Health Organization (WHO) maintains an International Classification of Health Interventions (ICHI), a common reporting tool for defining and analysing health interventions. Cochrane, a long-standing leader in evidence-informed decision making, produces evidence synthesis that supported 76% of WHO recommendations in 2021. AI can help agrifood systems catch up on methods, guidance, and streamline the production of 'what works' analysis to improve production of evidence synthesis to ensure decisions in agrifood systems get better over time.

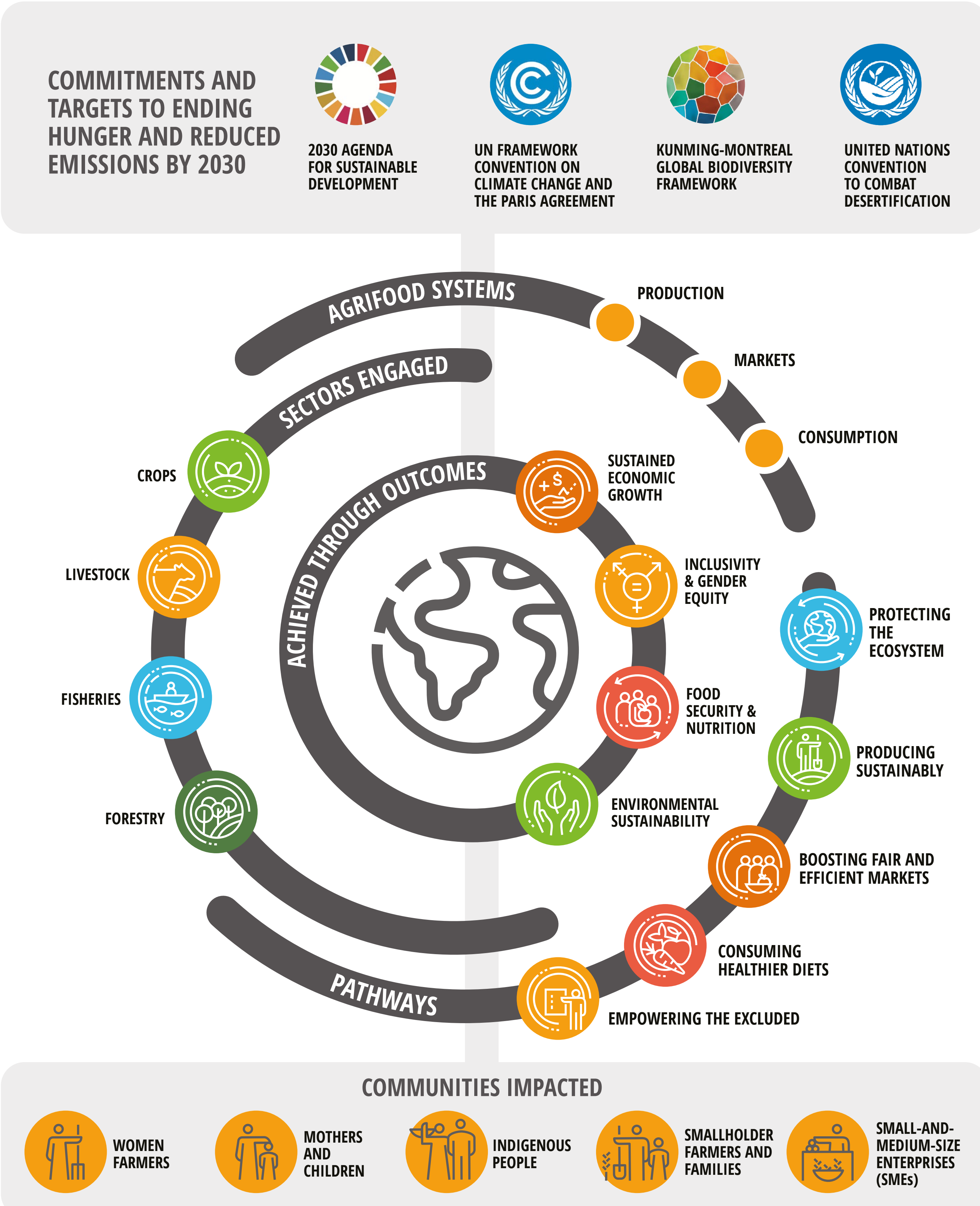
REPORT DESIGN AND METHODS

' The State of the Field for Research in Agrifood Systems' uses AI, including large language models (LLMs) and generative AI, to connect existing research findings to actionable insights across policy targets. Using a global dataset provided by CABI of 6.3 million scientific summaries covering 35,000 journals and grey literature reports from 2010 to 2023 across agriculture, forestry, human and animal health, natural resources and more, the report promotes opportunities to learn from collective knowledge and research already in place. CAB Abstracts remains a premier resource covering agrifood-related domains when compared to similar databases like Scopus and the Web of Science Core Collection for both geographical and subject-related analysis. There are limitations to this report. First, the report does not include analysis that would consider the effectiveness of specific interventions across any outcome, appraisal or assessment of the overall quality of the research, or an exhaustive look to identify all possible interventions and practices. It is also a novel use of AI that will be improved over time as models and methods are developed. In addition, Figure 2 and Figure 3 should be considered indicative and not prescriptive.

Some of the limitations result from type of data selected for this report. The analysis is based on title, abstract, author, and publisher's metadata. While some research indicates that considering an entire article doesn't consistently improve analysis compared to search and retrieval based on abstracts alone, there is some evidence that including paragraph-sized segments of full-text articles has the potential to perform better than abstract-only search (Lin, 2009). Additional experiments suggest that summary data performs well in isolation from full text for certain AI tasks yet is not relevant for others. We constrained the use of summary data to mirror the first steps in any evidence synthesis, which is to screen titles and abstracts for potential interventions, outcomes, populations, and geographies—as well as other data points, such as names of crops.. Given that this is a standardized approach across all types of evidence synthesis, it is reasonable to create a broad mapping of agrifood systems using a generalized LLM that has been fine-tuned for use in agriculture and related domains.

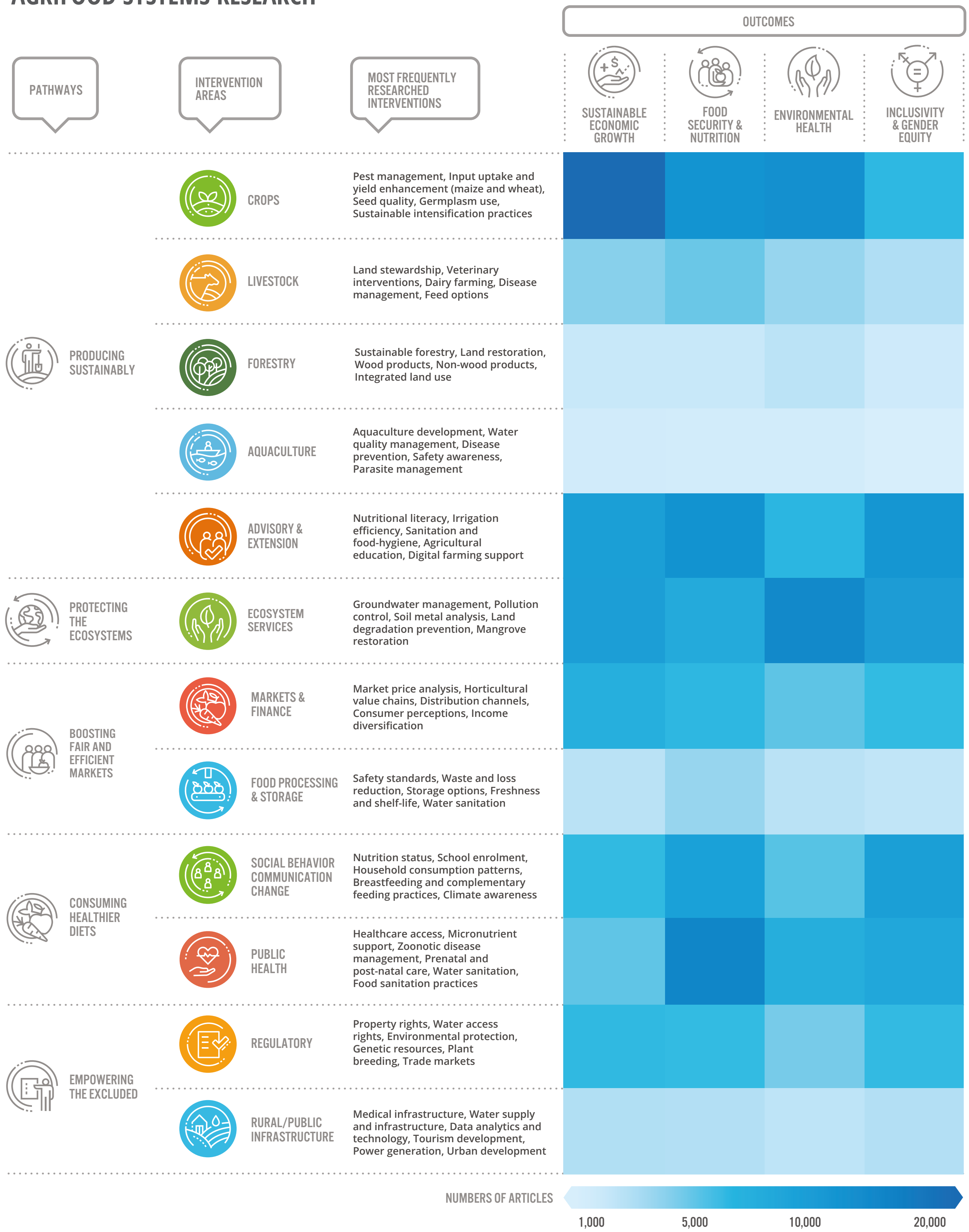
Food systems are characterized by multiple interactions between food production, processing, distribution, and consumption (Lipper et al., 2020). Numerous visual representations of food systems have been designed since 2015 to describe the complexity of the food systems. A simplified analytical framework (Figure 2) highlights some of the important dimensions that are relevant for an evidence-informed system supporting agrifood systems, though stops short of attempting to characterize all of the linkages and external drivers of food system. In the centre of Figure 2, four-high level outcomes (sustainable economic growth, inclusivity and gender equality, food security and nutrition, and environmental sustainability) are reached through multiple intervention pathways (empowering the excluded, producing food sustainably, boosting fair and efficient markets, protecting the ecosystem, and consuming healthier diets). Some of the main areas and sectors of aid support for agriculture as named by the OECD Development Assistance Committee (DAC) are highlighted: Agriculture, Forestry, Livestock, and Fisheries, as well as populations such as small-scale farmers, rural communities, and small-and-medium-size enterprises that are that are frequently targeted by policy targets (shown at the top of Figure 2).

FIGURE 2: CONCEPTUAL FRAMEWORK OF OUTCOMES-BASED ASSESSMENT



CONCEPTUAL FRAMEWORK

FIGURE 3: EVIDENCE ANALYSIS COMPARING OUTCOMES AND INTERVENTIONS ACROSS AGRIFOOD SYSTEMS RESEARCH



This evidence gap map reports on overall frequency of the research reporting interventions and outcomes using AI. There are 12 broad intervention areas mapped by four outcomes, as shown in the conceptual framework, Figure 2.

Associated with each of the 12 intervention categories are most frequently researched interventions. The gaps in the evidence are depicted in terms of the number of articles reporting.

RESEARCH INSIGHTS

1. INTERVENTIONS AND OUTCOMES

Identifying, communicating, and ultimately measuring the effectiveness of outcomes across interventions is a hallmark of evidence-based practice.

Outcomes are the short-term and medium-term effects of an intervention's outputs (OECD, 2022). They help measure how interventions lead to change in knowledge or behaviour. Identifying outcomes helps ensure effectiveness, accountability, and comparability and contribute towards enhanced learning and evidence-based decision-making (Davies, 2012). It helps hold groups and agencies accountable for achieving results and ensuring that resources are used efficiently and effectively to deliver tangible benefits to target populations.

An intervention is an intentional activity or effort that is being evaluated, and can include strategies, policy advice, technical assistance, financing mechanisms, programmes, institutions, or projects (OECD, 2022). Interventions often target at least one specific population.

We identified the occurrence of outcomes and interventions as they appear in the literature using a novel AI architecture (Porciello et al., 2020; Porciello et al., 2023, Edwards et al., 2023). Each article in the dataset was analysed to identify any instance of an outcome or an intervention before determining how to classify using the categories shown in Figure 2. More details are provided in the Annex.

The findings of outcomes and interventions are visualized using an evidence gap map layout (Figure 3), which is designed to identify research priorities, gaps in knowledge, and areas where further investigation may be warranted (Snilstveit et al., 2016). An important consideration is that, unlike a traditional evidence gap map, no quality assessment or effectiveness of the underlying literature is conducted in this report. The detailed evaluation across all of these interventions is still best conducted by smaller teams of experts and methodologists experienced with evidence synthesis who can meticulously assess whether results can be combined for statistical significance concerning the impacts of interventions on specific populations.

Ten key insights came from a review that used both AI and a detailed look at the literature. The assumption is that the amount of research on an intervention is closely related to how frequently that intervention is implemented.

1

Interventions supporting the sustainable production of food – crops, livestock, aquaculture, and forestry – result in higher rates of outcomes related to sustainable economic growth, but fewer outcomes fostering inclusivity and gender equity.

Addressing this through farm-level interventions and investments in other areas alongside agrifood production systems that include women and other marginalized communities could provide a valuable opportunity to improve women's overall economic empowerment. For instance, involving women in participatory processes to determine crop breeding traits has resulted in improved crop varieties, increased adoption by women farmers and consumers and increased levels of income (Acevedo et al., 2020; Occelli et al., 2024).

2

More research on interventions related to livestock, fisheries, and food storage and processing is needed—especially as farmers face new challenges, many of them due to erratic weather patterns. Environmental health outcomes across these areas is weakly represented, including adopting environmentally friendly pest and disease management strategies (Chandler et al., 2011).

Additional research on interventions are needed that will promote household and community level resilience. Early warning systems are an important adaptive measure for resilience to climate change (Vaughan et al., 2019). There is demand for increased intelligence around weather data that contributes to early-warning systems for all actors, and the development of these approaches is improved when undertaken in partnership with local communities (Leow et al., 2023).

3

Research supporting crop-focused interventions is significantly more abundant than aquaculture, livestock, and forestry. Promotion of various integrated and diverse farming systems may improve both productivity and ecological benefits of a farm, but scaling-up is hampered in part by a lack of research outside of crop-focused research.

Integrated farming systems of all types can offer benefits to food and nutrition security, ecosystem services, and environmental sustainability. They may reduce costs or enhance economic benefits at the farm level through residue recycling and improved land-use efficiency (Rosa-Schleich et al., 2019).

4

Continued development of agricultural value chains, including horticultural value chains, has traditionally emphasized production opportunities that support increased incomes of value chain actors (Devaux et al., 2018). This is evidenced in the higher levels of economic outcomes identified in the studies related to market and finance-based interventions. Additional research is needed to ensure other outcomes are equally emphasized, including food security and nutrition and environmental sustainability for a wider range of agrifood value chains (McMullin et al., 2021).

Improvements and updates across value chains have potential for improving production and consumer-related challenges. Nutrition outcomes, for example, can be improved for market-based interventions when they are paired with other interventions to explore win–win scenarios, including consumption of fresh fruits and vegetables (Cooper et al., 2021).

5

Food processing and storage interventions are often aimed at reducing food loss incurred due to poor infrastructure, including storage and processing facilities, training, safety, and handling methods (Stathers et al., 2020). Environmental outcomes are studied with less frequency compared to other outcomes such as food security and nutrition.

Food loss (and waste) also has an impact on natural resources, many of which are scarce. More research is needed on the environmental impacts of food loss, including opportunities to reduce greehouse gas emissions. There are underlying issues in data capture and collection on food loss and waste that must be addressed first (Delgado et al., 2021).

6

Environmental health outcomes are not consistently prioritized across social and communication behaviour change interventions and advisory and extension services. While some studies focus on farmers' perception and awareness of climate change, the interventions that the studies evaluate are designed to offer services or education that can help promote environmental sustainability and/or climate adaptation.

Linking current efforts around climate change awareness with agricultural education and behaviour change programmes presents an opportunity for enhancing understanding and improving services related to climate adaptation (Born et al., 2021). Studies reporting environment and climate adaptation outcomes as part of advisory and extension services research do not necessarily collect data or information that is distinctly different from other outcomes, especially economic growth (Porciello et al., 2020). Improving data collection methods and strengthening data collection instruments would allow better measurement of environmental health outcomes.

7

Interventions to address food security and nutrition outcomes for youth and children focus on improving dietary intake through nutrition programming, such as school feeding. Increasingly, more studies encourage these programmes to take food preferences and health and wellness outcomes into consideration as drivers for adoption (Biesbroek et al., 2023).

Understanding common drivers of food choice, such as taste, colour, price, affordability, availability, and vendor and product properties, can inform strategies to improve nutrition and health outcomes (Constantinides et al., 2021). Research targeted at drivers and the overall demand side of agrifood systems affords more opportunities to understand heterogenous needs of all actors across agrifood systems.

8

Interventions designed to improve food sanitation and safety practices are identified across multiple categories, including food processing and storage, regulatory, and public health, with a primary focus on food security and nutrition outcomes.

Food safety is a fundamental component of efforts to modernize food supply chains in low-income countries and interventions are needed to ensure there are more mechanisms to enforce food safety standards. Otherwise, food safety threats such as pesticide residues and aflatoxin contamination can remain hidden from buyers and sellers (Visser et al., 2020).

9

Research focused on crop breeding technologies is intertwined with review and the status of regulatory aspects. Research primarily highlights how these technologies impact economic growth and food security and nutrition, with less emphasis on environmental outcomes.

Currently, unresolved policy and regulatory issues create bottlenecks that impact the development and sharing of diverse crop varieties and regional seed production. This includes developing relevant seed systems for introduced seeds, ensuring they comply with regulatory practices while assessing and addressing impacts on related outcomes, including nutrition (Nabuuma et al., 2022).

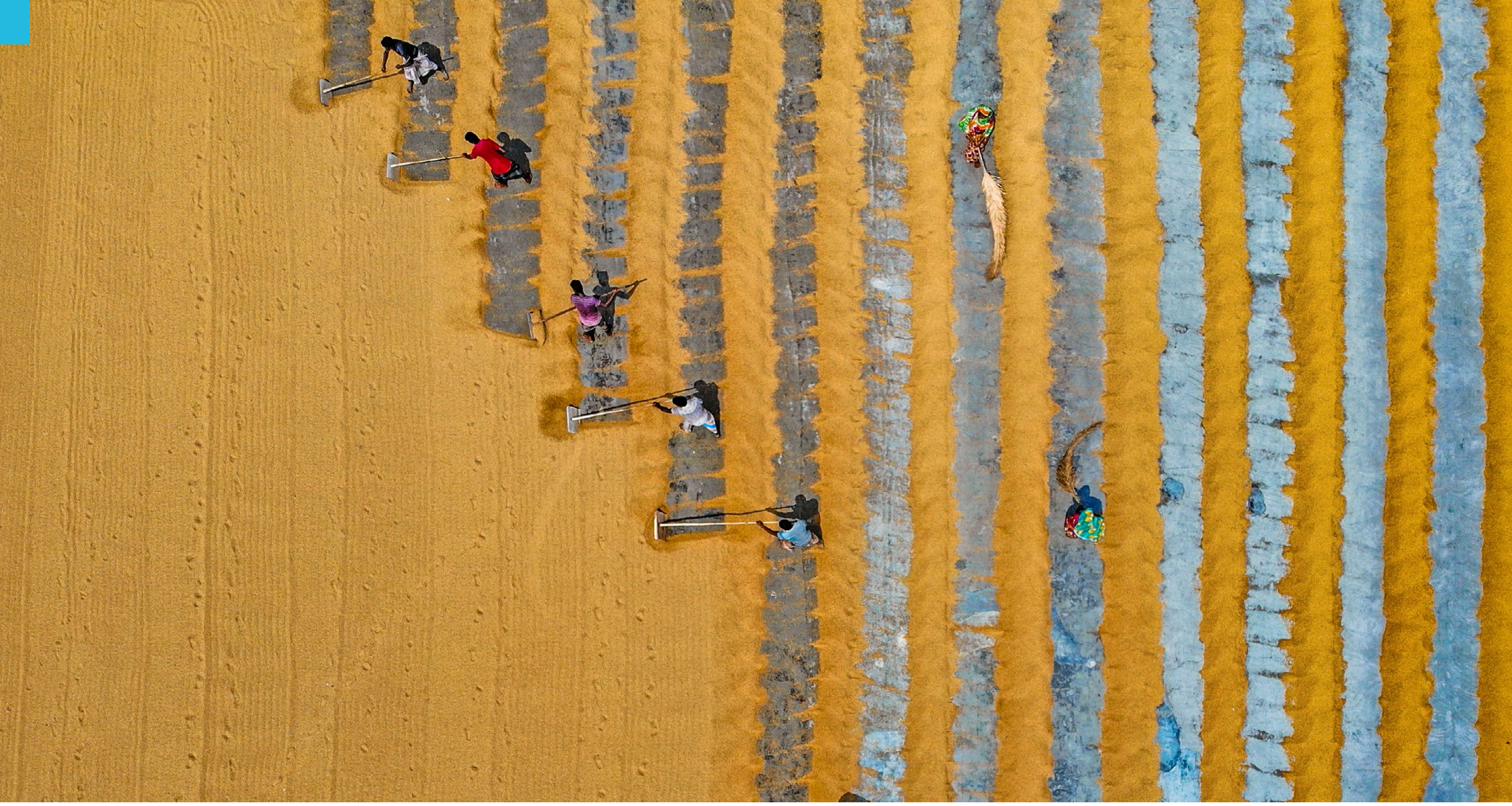
10

Rural and public infrastructure interventions include evidence on some of the underlying issues that inhibit use of 'big data' and/or data analytics to improve on-farm support and other data-enabled services for rural communities, including digital agriculture (Mehrabi et al., 2021).

Identifying and scaling up decision-support tools that can take advantage of near- and real-time data can optimize resource use, reduce environmental impact, and improve farm productivity. Currently, many of these approaches lack investments that promote underlying access to big data of all kinds, including satellite data, and security standards and protocols, all of which limits interoperability and data-sharing (Lobell et al., 2018).

Overall, care should be taken to interpret this analysis not to conclude that less should be done in certain areas, like sustainable food production and economic growth where there is more research, but rather increased efforts are needed across all research areas so that all outcomes are equally prioritized and considered as part of an overall path towards transformation. Reducing efforts in well-researched areas is not the answer nor the goal of this analysis; it is to highlight the need to sustain progress where gains have been made and drive progress further across all areas of importance.

In an increasingly interconnected science and policy landscape, it is crucial to have a comprehensive understanding of how research aligns with agrifood system outcomes, and the opportunity to identify persistent systemic gaps.



2. CROPS

To tackle climate and nutrition targets, increased investment is needed across fruit, vegetable, and legume value chains.

Global food demand is expected to increase by more than 50% by 2050, and climate change and other environmental stressors are expected to drive crop productivity down (Fredenberg et al., 2024; Jägermeyr et al., 2021; van Dijk et al., 2021). Enhancing food security while advancing nutritional, environmental, and social equity goals necessitates a heightened commitment to investment throughout the entire agrifood value chain. This entails bolstering research and development efforts aimed at addressing key challenges like food processing, storage, and transportation, alongside promoting greater consumption of nutrient-rich foods (FAO, 2022).

We identified the distribution of crop research by extracting the scientific and common names of more than 300 individual crops across seven categories (Figure 4). The full list of crops and categories is available in the Annex.

Currently, research on cereals is more than twice that of any other food group (Figure 4), and most of the research on agricultural climate impacts focuses on yields of the major staple crops (Ortiz-Bobea et al., 2021). Yet a quarter of the world's deaths are caused by dietary risk factors such as low intake of whole grains, fruits, and vegetables, higher intakes of sodium, sweet and sugary beverages, and low physical activity (Afshin et al., 2019).

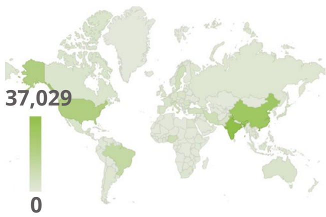
There is growing support for research and development to advance a diverse set of crops essential for food security and nutrition that can provide communities with a source of local resilience in the face of changing weather patterns (Fredenberg et al., 2024; van Zonneveld et al., 2023). For example, existing research on legumes highlights a capacity to play a dual role to support nutrition and other important ecosystem benefits, including improving soil fertility through enhanced nitrogen fixation (Kumawat, 2022). They are also an important source of protein. A major CGIAR project, Tropical Legumes, has helped to support 266 improved legume varieties from 2007 to 2019 (Varshney et al., 2019). Intercropping strategies, where legumes are mixed with cassava, groundnut, cowpea, and soybean, already play an important role across multiple countries to help enhance productivity, food security, and combat declining soil fertility.

Nutritional inequalities are largely driven by rural status, where one-third of children in rural areas display stunted growth compared to a quarter of children in urban areas, and where children in rural areas have less diverse diets that rely on staple cereals (Ambikapathi et al., 2023). And while this analysis has limited data on livestock and fisheries, animal-based protein is an important source of both nutrition and livelihoods for millions of families.

FIGURE 4: THE OVERALL DISTRIBUTION OF CROP-LEVEL RESEARCH BY COUNTRY

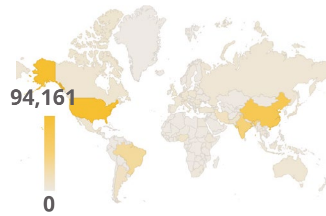
RESEARCH BY CROP GROUPS ACROSS COUNTRIES

VEGETABLES



Vegetables are considered a major source for combating micronutrient deficiencies. High value underutilized crops, such as amaranth, can increase income on small farms and help alleviate poverty.

CEREALS

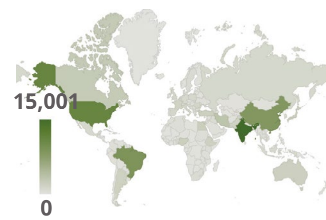


Cereals such as wheat, maize, and rice are essential dietary energy sources and many are also sources of B-complex vitamins, vitamin E, zinc, and magnesium, making them important for enhanced nutrition.

FRUITS

Fruits contribute significantly to economic welfare and poverty alleviation among households by providing income and profits from sales of fresh and value-added fruit products.

LEGUMES

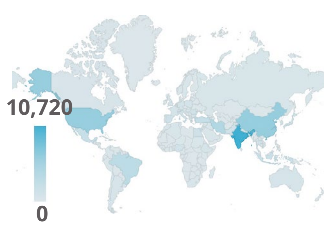


Legumes play a crucial role in adding nitrogen to the soil, **reducing the need for chemical fertilizers, and mitigating greenhouse gas emissions.**

NUTS

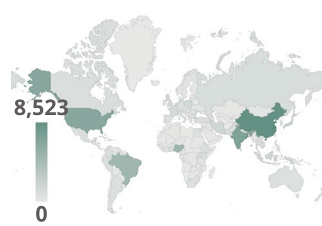
Nuts are important for food security in poor countries due to their nutritional value and sustainability, making them a valuable source of essential nutrients and protein. They are especially valuable during the lean season.

SPICES



Spices such as pepper, ginger, turmeric, black cumin, and korarima can play an important role in **diversifying livelihoods and increasing income potential for smallholder farmers.**

ROOTS & TUBERS



More than **200 million farmers in developing countries grow root and tuber crops,** such as cassava, banana, and yams for food security and income. These crop are especially important in areas with marginal soil fertility.

A lack of investment in specific crop value chains shows up in the research gap that has widened in recent years.

3. GEOGRAPHY

There is a lack of research focused on countries vulnerable to climate change and hunger.

Among our main findings was a concerning lack of research focusing on the world's poorest and hungriest countries, which are also most vulnerable to climate change. In 2022, 691–783 million individuals grappled with chronic hunger, while 3.1 billion couldn't afford a nutritious diet; and by 2030, close to 600 million people are projected to still face chronic undernourishment (FAO, IFAD, UNICEF, WFP and WHO, 2023).

The geography of a country plays a crucial role in evidence-informed decision-making. Many issues in agriculture, food, and climate require localized solutions that consider distribution and availability of natural resources, access and availability of food, and the ability to prevent and respond to risks and hazards.

We measured how scientific literature incorporates geography using two dimensions. First, we examined the geographical focus of research articles independent of the authors' affiliation to find out where research attention is focused. Second, we used author affiliations irrespective of whether their research focused on the geography of the country where they are based.

Yet no matter how we measure it, only a small percentage of global scientific research focuses on regions vulnerable to climate change and hunger.

FIGURE 5: VOLUME OF RESEARCH COMPARED TO GEOGRAPHIC REGIONS

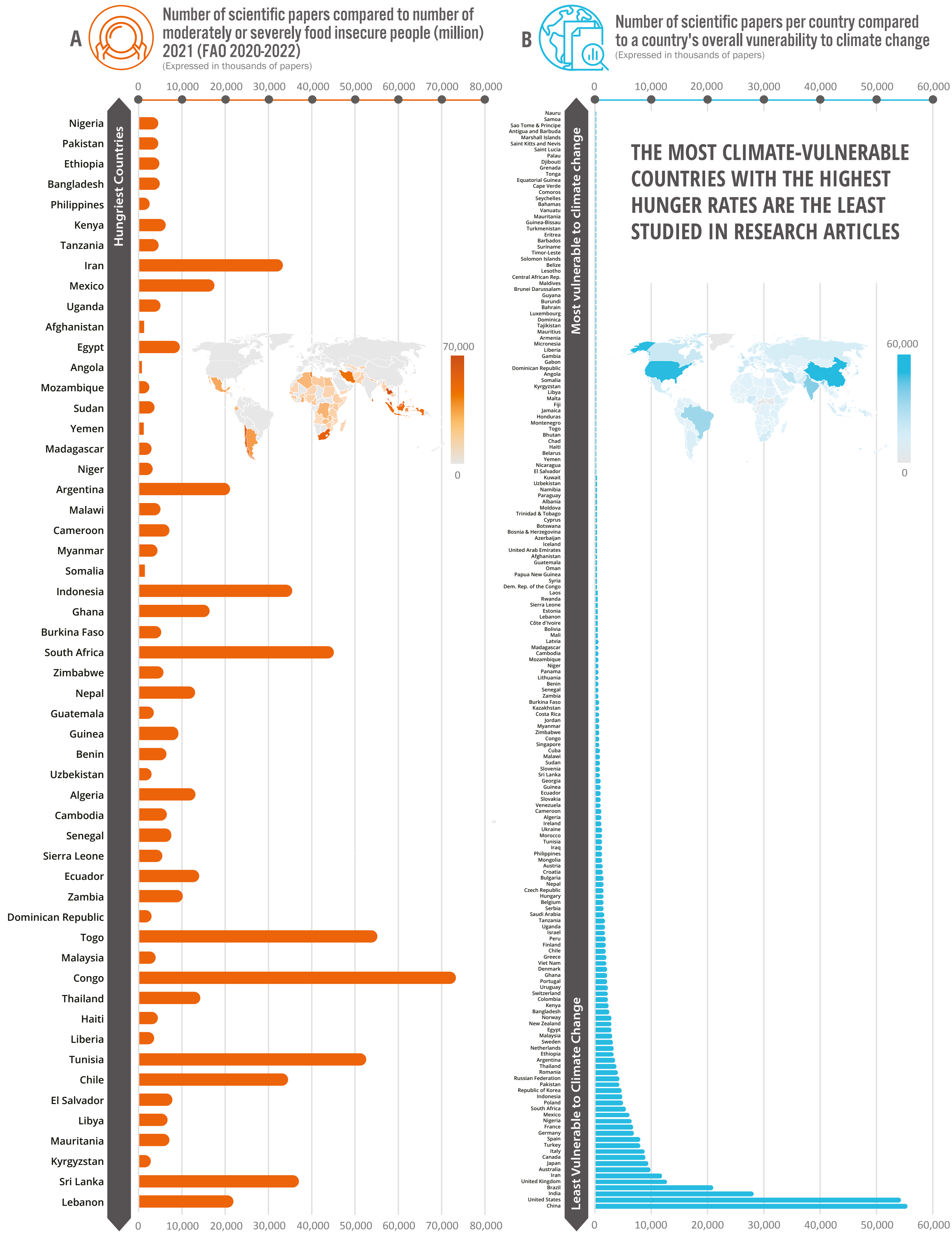


Figure 5A (in orange) is an overview of research volume per country for 54 countries that are classified as low and lower-middle income by the World Bank and further refined by FAO data reporting moderately to severely hungry people (in millions, 2021) reporting more than two million hungry people. (Note that China and India are excluded due to data unavailability from FAO.)

Country names appear across the Y-axis whereas the X-axis shows the total volume of scientific research papers, by thousands, per one million hungry people. The ordering on the Y-axis is calculated by research volume comparing each country's hunger levels. For example, in Angola, there are 63 papers per one million hungry people based on FAO moderate to severe hunger numbers of 27 million people. Yemen has 121 papers per one million hungry people based on hunger numbers of 22 million. In contrast, a high-income country like Poland (not shown in Figure 5A), that has more than two million hungry people, has nearly 25,000 scientific papers per one million hungry people.

Agriculture and food systems are a principal contributor to climate change, accounting for a third of anthropogenic greenhouse gas emissions along the entire value chain from production to consumption (Crippa et al., 2021). Figure 5B (in blue) is a global picture of country level research for 184 countries. We map volume of research to each country's position on the global adaptation initiative (ND-GAIN). ND-GAIN measures a country's readiness and vulnerability to adapt to climate change using numerous underlying indicators. Countries most vulnerable to climate change, including many smaller island nations, have an evidence-base of scientific papers in the low hundreds. A country like Djibouti, for example, is the ninth most vulnerable/least ready to adapt to climate change and the subject of approximately 400 articles from 2010 to 2023.

Next, we looked at publication trends coming from researchers in each country. Publications by authors in low- and middle-income countries comprise only 12% of overall research as compared to 65% of research coming from just ten of the richest countries (Figure 6). The remaining 33% of research (not highlighted in Figure 6) is published by scientists in upper-middle-income countries.

Global R&D expenditures have risen substantially since 2000 to an estimated $2.4 trillion in 2019 (National Science Board, 2022). A country's scientific productivity, measured by the volume of published and cited scientific articles, reflects its overall economic wealth—suggesting poorer countries will always produce less scientific research compared to wealthier nations due in part to a lack of supportive policies and institutions for science, including PhD programmes, as well as competitive funding and access to publishing resources (Jaffe et al., 2020). This correlation should not be viewed as deterministic, however, as there are numerous other avenues for countries to engage with scientific advancements and innovations through strategic partnerships, technology transfer, and knowledge-sharing initiatives.

FIGURE 6: AUTHORS' AFFILIATION OF PUBLISHED RESEARCH

ONLY 1 OUT OF EVERY 8 SCIENTIFIC STUDIES IS LED BY SCIENTISTS FROM THE POOREST COUNTRIES

4. PEOPLE

The heart of agrifood systems transformation lies in working with communities of small-scale farmers, producers, processors, traders, and consumers.

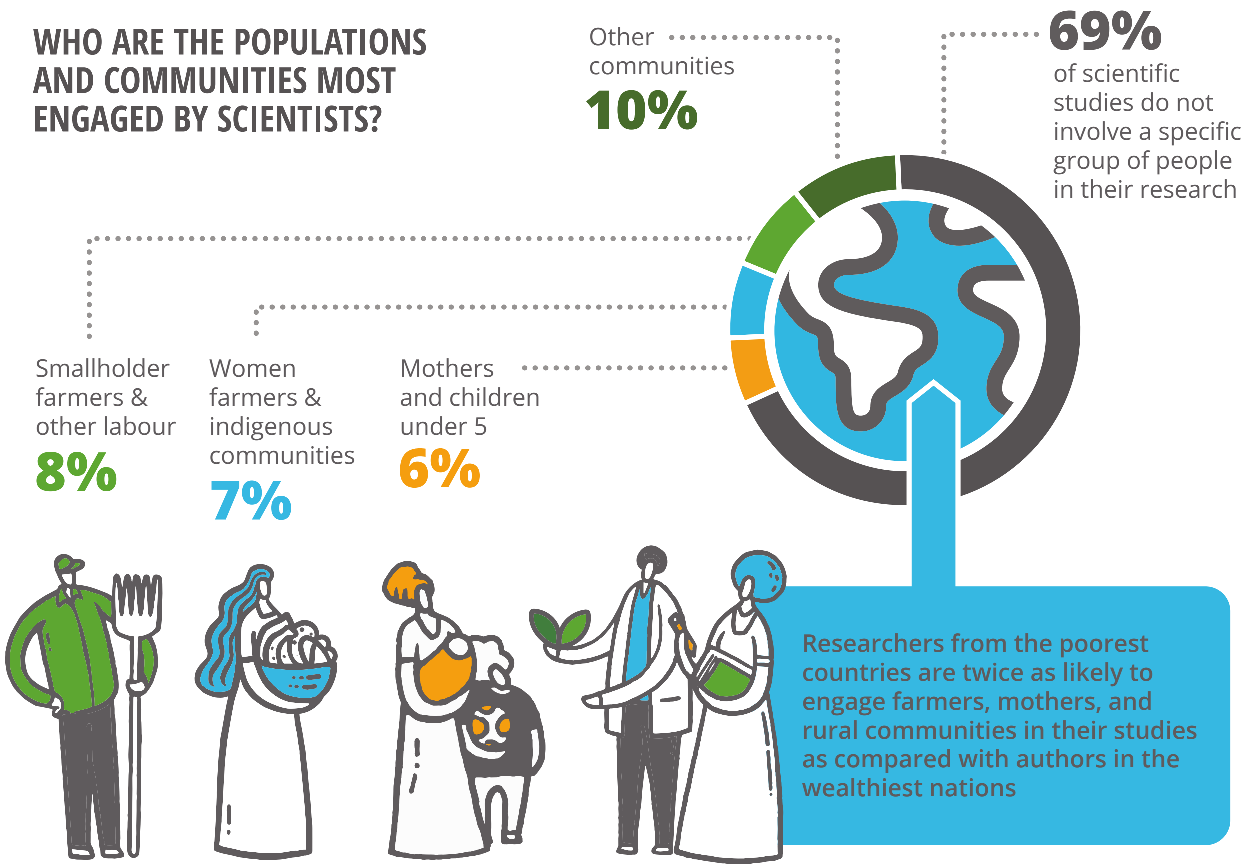
Identifying and communicating diverse needs, preferences, and priorities of multiple groups of people is an important foundation for an effective and evidence-informed system. The number of poor people dependent on agriculture and food systems in low- and lower-middle-income countries is large – 1.23 billion people are estimated to be employed in agrifood systems and about 3.83 billion people worldwide live in households linked to agrifood-system-based livelihood.

Assessing how researchers work with and describe various populations is a complex task. Scientists prefer to capture and report their own experimental data, and there is limited guidance on naming conventions, with some notable exceptions such as plant and animal species. For example, a recent evidence synthesis assessing plant breeding traits describes taxonomic challenges that inhibit coordination across plant breeding that would be streamlined if, for example, trait prioritization data collection was standardized (Occelli et al., 2024).

We identified communities typically engaged by scientists by analysing the words used to describe study populations. This includes many variations of words and phrases describing small-scale farmers, including producer, smallholder, or rural or family farmer, in addition to more specific sub-communities including livestock keeper and fish farmer. It was also important to capture that small-scale farmer have intersecting identities; after all, a small-scale farmer may also be a woman, a business owner, a seed distributor, and more.

Four overarching categories were selected to describe study populations found within research (Figure 7). There is some overlap between the categories presented in Figure 7. Currently, 25% of abstracts and titles indicate some type of direct engagement with rural communities. Engagement with farmers, livestock keepers, extension agents, agribusiness dealers, market owners, and seed producers is present in 8% of the literature; mothers and children under 5 are the focus in 6% of studies; Indigenous People's groups and women in a capacity other than mothers or pregnant women feature in 7% of the literature; and another category captures other multiple communities and individuals, including commercial growers, students, senior citizens, and youth boys and girls over the age of 5, which are represented in 10% of the literature. The remaining 75% of the literature does not identify a study population.

FIGURE 7: THE CATEGORIES AND FREQUENCIES OF STUDY POPULATIONS ENGAGED BY SCIENTISTS



Similarly low numbers of studies focusing on small-scale farmers and women have been reported in other synthesis studies—and those were not constrained by looking at titles and abstracts, but instead thousands of underlying high-quality scientific papers (*Nature,* 2020).

A lack of literature about the needs of specific communities poses a significant challenge to understanding and shaping more services and interventions within agrifood systems. Any shift towards more equitable interventions must begin with an understanding of local conditions, cultural and social issues, and the availability and affordability of food options (Ambikapathi, 2022).

Lower levels of engagement are especially a concern regarding women. Women account for 43% of the agricultural workforce, and they are also responsible for ensuring household food security and diets (FAO, 2023). The 2023 report 'The status of women in agrifood systems' highlights that women's empowerment is growing too slowly, particularly for rural women, and if half of small-scale producers benefited from development interventions that focus on empowering women, it would significantly raise the incomes of an additional 58 million people. It would also increase the resilience of an additional 235 million people compared with a gender mainstreaming approach (FAO, 2023).

Participatory and inclusive research methodologies, which capture the needs and preferences of diverse populations, can significantly enhance decision making at all levels (Occelli et al., 2024; Asante et al., 2023; van Etten et al., 2023; Johnson et al., 2004). Maximizing engagement with farmers and other community members through participatory research design has the potential to improve intervention design and implementation, fostering greater understanding about the communities being engaged (Neef & Neubert, 2011; Klerkx et al., 2012).

A bright spot does emerge within this data. We find that scientists from poor countries have higher levels of engagement with farmers and rural communities. Researchers from the poorest countries are twice as likely to engage with farmers, mothers, and rural communities compared to authors from high-income countries (Figure 7).

Researchers from low- and middle-income countries may offer invaluable firsthand insights for food systems transformation, and it is crucial to hear more from researchers in these countries about the challenges they encounter and the methods they employ to tackle complex issues (Marks et al., 2023). Yet contributions by researchers from low- and middle-income countries can often get overshadowed or ignored amidst the overwhelming volume of publications released annually, as well as publication bias by high-impact journals favouring more theoretical research that is frequently picked up by the media (Subramanian & Kapur, 2021). Female scientists face additional barriers, given the gender gaps in scientific research, where a recent study identified that just 17% of papers are led by women scientists (*Nature*, 2024).

CONCLUSION

Moving towards an evidence-informed agrifood system requires finding new ways to measure tacitly held truths, such as poorer countries receive far less attention across research and science. Some of the findings of this report may not be altogether surprising, but just as measuring something signifies its importance, an absence may signal the opposite. Developing and strengthening effective mechanisms and processes for actively connecting knowledge and research with actions for greater policy coherence, shared ownership, and collective action remains a challenge.

Responses to global challenges are often rooted in domain-specific fields such as agriculture and livelihoods, environment and natural resource management, nutrition and health, and human capital and education. Approaches to synthesizing the evidence are useful to make sense out of all of the domain knowledge, interpret it in light of today's conditions and evaluate it for trade-offs regarding on-the-ground priorities. Scientific research must be assessed for use in diverse settings and communicated to non-academic audiences—primarily policy-makers, donors, and journalists—in ways that will ensure understanding, support, and public accountability. Strengthening evidence systems at all levels to support the use of evidence in policy-making is fundamental.

Some of the challenges identified extend beyond the boundaries of agrifood systems and result from enduring bias underpinning scientific publishing and funding systems. Addressing these issues requires continuous and concerted efforts with multiple partners, including funders and scientific publishers, to take action to unmute and empower more researchers, as well as practitioners, who produce research and scholarship.

As we look towards the research and policy agendas for the future, combining AI and the collective intelligence already generated by millions of researchers and practitioners represents a way to refine how we work together to solve problems and establish priorities. Yet given the magnitude of many of the decisions that need to be made across agrifood systems, care should be taken to avoid autonomous decision-making and instead ensure that understanding the evidence and creating recommendations regarding 'what works' is still done by human experts. After all, the success of any technology hinges on coordination and cooperation among partners. We can maximize the benefits of AI so that decisions in agrifood systems get better over time to support a more inclusive, informed, and sustainable agrifood system.

RECOMMENDATIONS

- **Invest in collaborative and multi-dimensional solutions.** Current research remains largely siloed, and sustainable solutions that consider the ecological, social, and economic dimensions of food production, distribution, and consumption are needed. Continuous fragmented approaches will lead to inefficiencies and less progress. Resources must be allocated towards collaborative science-policy projects that bring together stakeholders with diverse viewpoints.

- **Invest in comprehensive solutions in low- and middle-income countries.** Many countries and communities grappling with hunger and climate change lack sufficient support from research and scientific initiatives in generating practical solutions. We encourage funders and governments to prioritize investments that offer direct benefit to the most vulnerable populations and countries afflicted by poverty and hunger, as well as allocate resources towards research endeavours that specifically address the needs and challenges of marginalized communities.

- **Increase investments in AI and outcomes-based frameworks.** Clear and standardized language and data are essential for collaboration and accountability in food systems transformation. The intervention and outcome framework, designed using a bottom-up approach based on a global assessment of scientific contributions, exemplifies this need. Additional investment in AI can drive the development and widespread adoption of clear research and policy agendas, enhancing information exchange and analysis, and facilitating near real-time decision-making.

- **Support participatory, inclusive agrifood systems research.** Interventions addressing the multifaceted challenges encountered by farmers, women, and other stakeholders must integrate multiple outcomes. To address this gap, more efforts are needed to support participatory research methods, ensuring a comprehensive understanding of the complexities involved and promoting more inclusive interventions.

- **Support scientific research that reflects diversity.** To reform the politics of scientific research and publishing, funders of agricultural research must prioritize and finance studies from low- and middle-income countries, fostering inclusive networks and ensuring their work is valued equally to that from high-income nations. Additionally, scholarly and commercial publishers should diversify their editorial boards and publishing practices to support a more diverse and equitable system. Innovative solutions and new models for accessing and disseminating scientific information are crucial to addressing underrepresented regions and topics, reforming the knowledge sector.

- **Invest in better data collection practices for scientists.** Greater investment is needed to update training, education, and communication platforms, enabling practitioners and scientists to incorporate diverse stakeholder perspectives, including those of local communities and smallholder farmers, into research and data collection practices. Without these new investments, the development of an evidence-based system that adapts to changing norms and values will stagnate.

- **Prioritize women-led research investments.** To address gender disparities in scientific research, funders should prioritize financial investments in women-led research projects and publications, especially from the Global South. This support will help amplify the voices and representation of women scholars, who are often marginalized. Additionally, acknowledging and addressing the unique gender constraints that women face in scientific leadership will foster a more inclusive and equitable research environment.

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ANNEX

Interventions and Outcomes

We used a customized AI approach of extracting and classifying interventions and outcomes from scientific abstracts, first relying on advanced natural language processing (NLP) techniques to automate the processing of our large text datasets. Our aim was to identify and extract specific phrases or sentences that describe interventions and outcomes from the abstracts of scientific papers. For our purposes, an intervention is an intentional activity or effort that is being evaluated, and includes strategies, policy advice, technical assistance, financing mechanisms, programmes, institutions, or projects. In addition, interventions often target at least one specific population, usually human, though in agrifood systems these may be participatory action research focused on crops or animals. Outcomes are the short-term and medium-term effects of an intervention's outputs (OECD, 2022). They help measure how interventions lead to change in knowledge or behaviour. (OECD, 2022).

A pre-trained labelled dataset of interventions and outcomes, created by experts as part of international development and evidence synthesis projects, supported fine-tuning GPT-3.5 models to perform named entity recognition (NER) tasks using the definitions of interventions and outcomes. Parameters were adjusted to enhance precision and recall. Extracted phrases were identified as either an outcome or an intervention before being classified as part of *a priori* categories identified in Tables 1 and 2.

A category of 'suspicious' was also available, which was used to support when the model identified outcomes or interventions but could not identify a relevant category. Reviewing the 'suspicious' extractions was also useful to identify if an entire category was missing. And while each extracted phrase can belong to only one category, multiple interventions and outcomes can be identified from one single study.

The outcome and intervention category descriptions are not exhaustive, nor are they prescriptive. They are designed to represent a snapshot and give the model enough information to explore scientific summaries written by millions of different humans, each with their own writing style and conforming to a journal and/or report publication format. Within each of the intervention and outcome categories are hundreds of specific phrases. Each of the broad categories listed can be 1) realigned / adjusted based on adding new data; 2) repurposed in favour of other classification or strategic frameworks; 3) be expanded to identity much more granular interventions within each category.

Some of the categories (especially the Producing Sustainably categories) are based in part on a review of some of the areas noted in the OECD Development Assistance Committee (DAC) sector codes, which are used to record information on the purpose of individual aid activities from bilateral donors.

TABLE 1: INTERVENTIONS

PATHWAY	INTERVENTION AREA	DESCRIPTION
PROTECTING THE ECOSYSTEMS	ECOSYSTEM SERVICES	Interventions related to the benefits that people derive, directly or indirectly, from natural ecosystem functions. Ecosystem services represent the goods and services derived from the functions and utilized by humanity. These interventions focus on regulating and supporting functions such as clean air, nutrient cycling, pollination, erosion control, carbon storage and sequestration, planting of trees on farms, reforestation, afforestation, avoiding deforestation, water resource management, land management for conservation purposes, conservation and management of biodiversity.
PRODUCING SUSTAINABLY	CROP MANAGEMENT AND TECHNOLOGY	The use of practices, activities, and technologies to support agricultural production and quality of agricultural products. This includes underlying technology such as biotechnology or gene-editing, improved seeds, crop breeding, irrigation, and mechanization. It includes use and monitoring of inputs such as fertilizer, pesticide, insecticide, herbicide, and more through traditional or digital agriculture and precision agriculture technologies. Interventions supporting agricultural practices such as integrated crop management and sustainable agricultural intensification are also included in this category.
	LIVESTOCK MANAGEMENT AND TECHNOLOGY	The use of practices, activities, and technologies to improve the health, feed, fodder, and productivity of all livestock and pasture-based animals. This includes all produce, including eggs, meat, milk, cheese, honey, and fur. (Livestock interventions do not include wild, domestic, or zoo animals.) Livestock interventions include technology such as artificial insemination, vaccines and vaccination programmes, and other disease management and surveillance. This category captures husbandry and other livestock management practices, including feed supplements and grazing.
	FORESTRY MANAGEMENT AND TECHNOLOGY	These activities include the formulation and management of forestry policies, afforestation, sustainable exploitation and conservation practices, educational and training programmes, research initiatives focused on artificial regeneration and genetic improvement, and the provision of forestry services aimed at both utilization and preservation of forest resources.
	AQUACULTURE AND FISHERIES MANAGEMENT AND TECHNOLOGY	Aquaculture interventions support the development of fish, fisheries, and aquaculture farms. These interventions involve developing and implementing fishing policies, capacity building within the fishing sector, sustainable exploitation and management of fishery resources, educational programmes, research programmes supporting marine and freshwater fish culture, and the provision of fishery services including harbours, markets, transportation, and cold-storage facilities.
	ADVISORY AND EXTENSION SERVICES	Agricultural advisory services are the entire set of organizations that support and facilitate people engaged in agricultural production to solve problems and to obtain information, skills, and technologies to improve their livelihoods and well-being. This includes extension and advisory services; informal farmer training, including peer-to-peer diffusion, and demonstration plots; on-farm research and participatory action research; vocational training; access to information such as market, weather, climate data; and early warning systems.

BOOSTING FAIR AND EFFICIENT MARKETS	MARKET CHANNELS AND FINANCE	These interventions support farmers and small- and medium-sized enterprises (SMEs) with financial instruments, services, and incentives made available to farmers and other agricultural development value chain actors. These include services that provide access to markets, credit (all types), insurance and other financial safety nets to promote agricultural development, whereas incentives encourage cash, trade, or other in-kind services to or between producers. The interventions are often distinguished according to who is providing the service—formal, semi-formal, and informal actors. These include cooperatives, membership organizations and microcredit lenders offering market linkages, finance, credit or insurance, formal bank or contract lenders providing savings, credit, and loan services, land rental agreements, insurance services, warehouse receipts and other collateral programmes, prices of input and output, compensation for work or income transfer.
	FOOD PROCESSING AND STORAGE	Interventions that are designed to support the safe storage, transportation, and processing of food and animal products, including dairy-processing facilities and techniques, primary food processing (e.g. threshing, drying, smoking, etc.), secondary food processing (transformation, blending, canning), tertiary food processing (e.g. processed foods into meals), and post-harvest loss technologies (e.g. silos, bagging, cold storage).
CONSUMING HEALTHIER DIETS	SOCIAL BEHAVIOUR AND COMMUNICATION CHANGE	Interventions that use communication strategies, programmes, activities, and platforms to promote intrinsic and extrinsic behaviour change about nutrition, health, climate change, or other issues. The strategies include education, training, social media, radio messaging, and face to face interaction through educational or marketing campaigns. Programmes include school feeding programmes, nutrition counselling, nutrition education, and other community-based programmes.
	PUBLIC HEALTH	Interventions that provide basic and primary care, disease prevention, malnutrition and feeding programmes, support sanitation measures and sanitation services; water services and access to safe drinking water; access to hospitals, healthcare, and community health care workers; and water, sanitation and hygiene (WASH) interventions.
EMPOWERING THE EXCLUDED	REGULATORY AND TRADE	These interventions support food safety, certification, and quality assurance, as well as land policy and environmental management. Trade interventions are designed to develop and manage trade policy and infrastructure, streamline international trade procedures, support regional and multilateral trade negotiations and agreements, provide adjustment assistance for trade policy reforms, and enhance trade education and training.
	RURAL / PUBLIC INFRASTRUCTURE	Rural and public infrastructure interventions include improved or new roads, bridges, dams, large irrigation schemes, and water supply services, including sewage. They also support development of disaster risk-reduction programmes and other services that can support urban and rural communities. This includes large-scale data infrastructure within government, public, and private sector groups, as well as renewable energy services such as wind, solar, and water that are intended to support a town, village, city, province, or state.

TABLE 2: OUTCOMES

OUTCOME CATEGORY	OUTCOME DESCRIPTION
SUSTAINABLE ECONOMIC GROWTH	Economic growth outcomes emphasize production, yield, productivity, income, labour, and market growth. These outcomes improve the lives of farmers and food systems actors and their families through increases in income, productivity, employment, yield, and labour, both on-farm and off-farm.
INCLUSIVITY AND GENDER EQUITY	Outcomes that improve the terms of social and economic participation in society, particularly for people who are and have been historically disadvantaged, through enhanced opportunities, access to resources, voice and respect for rights. These outcomes are measured from the support and inclusive design of all people of any gender, through increased decision-making, increases in earned income, education, policy, and social standing.
ENVIRONMENTAL HEALTH	Outcomes that emphasize environmental and planetary health, often achieved through environmental sustainability. These outcomes are measured through change in capacity to adapt and/or mitigate to the impacts of climate change, biodiversity, water usage, reduced emissions, water quality, soil health, forest management, and land use change.
FOOD SECURITY AND NUTRITION	These outcomes emphasize food safety, utilization of food, access to food, consumption, nutrition outcomes including wasting, stunting, and malnutrition, dietary outcomes such as dietary diversity, or preferences of consumers and farmers. Food security is defined as ensuring reliable access to a sufficient quantity of affordable, nutritious food and food consumed is represented by different food groups.

Crops

Each title and abstract in the dataset was reviewed for crop names, both scientific and common, using a controlled list of common names (column 2). A named entity recognition model was trained and extraction performed on all titles and abstracts. Care was taken to avoid false positives. An online visualization is available to accompany the graphic in the report.

TABLE 3: CROPS

CATEGORY	CROPS WITHIN CATEGORY		
CEREALS	barley	oats	sweet sorghum
	coarse grains	rice	teff
	feed cereals	rye	triticales
	foxtail millet	sorghum grain	wheat
	maize	sweet corn	winter wheat
	millets		

CATEGORY	CROPS WITHIN CATEGORY
FRUITS	akee akee apple alligator pear apples apricots avocado pear avocados bananas berries bird chillies cantaloupes carambola cherimoyas cherries chinese gooseberry citrons citrus citrus fruits coconuts cucurbit fruits damsons dragon eye dragon fruits durians figs gages grapefruits greengages guavas hip rose jabuticaba jack fruit kaki kiwifruits lemons litchis longans loquats lucuma lychees mandarins mangaba mangoes mangosteen melons murici nectarines olives oranges papayas passion fruits pawpaw peaches pears persimmon pineapples pitaya plums pome fruits pomegranates quinces rambutans rose hips safou star fruit stone fruits strawberry pear temperate fruits watermelons wine grape
LEGUMES	adzuki beans broad beans bush beans carob beans carobs chickpeas common beans fava beans field bean field pea haricot beans horse bean kidney beans lentils mung beans navy beans pea beans peas pinto beans pole beans soybeans wax beans yard long beans
NUTS	almonds bitter almonds brazil nuts cashews chestnuts filberts groundnuts hazelnuts kola nuts macadamia nuts peanuts pecans pistachios queensland nut shea nuts sweet almonds walnuts
ROOTS & TUBERS	beetroot cassava cocoyam cooking bananas cooking plantains irish potato plantains potatoes radishes subtropical fruits sweet potatoes taro tuber yams yuca

CATEGORY	CROPS WITHIN CATEGORY		
SPICES	alkaloid	cilantro	oregano
	allspice	cinnamon	paprika
	anise	cloves	parsley
	aniseed	coriander	pepper
	aromatic herb	cumin	persian cumin
	balm	dill	Petawali
	basil	garden chervil	roman chamomile
	bay laurel	garlic	rosemary
	black pepper	ginger	saffron
	caraway	horseradish	sage
	caraway thyme	hot peppers	savory
	cardamom	hyssop	sweet bay
	chamomile	juniper	tarragon
	chervil	kohlrabi	thyme
	chicory	mace	turmeric
	chili	mint	vanilla
	chillies	mustard seed	white pepper
	chives	nutmeg	
VEGETABLES	amaranth	drumsticks	parsnips
	artichokes	edible fungi	pimiento
	asparagus beans	eggplants	pumpkins
	asparagus spears	endives	red beet
	bamboo shoots	fennel	red peppers
	bean sprouts	field mustard	rhubarb
	bell peppers	fluted pumpkin	runner beans
	bengal gram	garden pea	rutabagas
	black gram	garden rhubarb	salsify
	black salsify	gherkins	shallots
	borecole	golden gram	sitao
	brassica	green gram	snap beans
	brinjal	green peppers	sour cherry
	broccoli	green vegetables	southernpea
	brussels sprouts	horse gram	spinach
	bulbous vegetables	indian colza	spinach beet
	cabbages	indian rape	sprouted beans
	calabrese	inflorescence vegetables	squashes
	cardoons	kales	stalk celery
	carrots	kulthi beans	stem vegetables
	catjang	lady fingers	string beans
	cauliflowers	leaf celery	swedes
	caupi	leafy vegetables	swedish turnip
	cayenne peppers	leeks	sweet peppers
	celeriac	lettuces	swiss chard
	celery	limes	taioba
	chard	locust beans	tick beans
	chilli peppers	madras gram	tomatoes
	chillies	manioc	turnip rooted celery
	collards	mushroom logs	turnips
	corchorus olitorius	mushrooms	urd
	cowpeas	Nalta jute	watercress
	cucumbers	okras	zucchini
	cucurbit vegetables	onions	
	dasheen	palm hearts	

Geographies

Each title and abstract in the dataset was reviewed for geographical names, including countries, provinces, and state names using libraries such as sPacy, a versatile and fast NLP library that provides built-in support for named entity recognition, and Stanford NLP Group's software. These toolkits are based on machine learning and come with pre-trained models that are capable of detecting geographies with high accuracy. Similar to crop names, care was taken to reduce 'false positives,' e.g. articles with Aspergillus Niger were not associated with the country Niger. Low- and middle-income countries were mapped using 2023 classifications using lending categories available from the World Bank.

Populations

We used a Word2Vec approach to identify the populations and communities within agrifood systems literature. Word2Vec, a foundational model, maps words into a high-dimensional vector space, enabling the discovery of words with similar meanings or content. This technique is particularly useful in uncovering associated and specialized terms throughout the dataset. For example, researchers use various terms to refer to 'small-scale farmers.' In the absence of controlled dictionaries, definitions, or trial databases for pinpointing specific populations or communities in agrifood systems, Word2Vec is a useful approach for the comprehensive capture of relevant terminology. We utilized this approach to identify the different populations and communities that scientists are studying. These lists are often extremely long; for example, a community like 'elderly' is identified using some of the following terms: ageing, aging, care home resident, community-dwelling elder, elderly, frail, geriatric, grandmother, grandfather, late life, later life, mature adult, nonagenarian, nursing home resident, octogenarian, old age, older adult, pensioner, retiree, senior citizen, and more. Word2Vec captures all associated terms within the dataset. Many of the populations mapped for the exercise are identified below.

TABLE 4: POPULATIONS

CATEGORY	ASSOCIATED COMMUNITIES AND POPULATIONS
SMALLHOLDER FARMER AND OTHER LABOURS	Smallholder farmers, small-scale producers, beekeepers, livestock keepers, agro-entrepreneurs, fish keepers, extension agents, agrobusiness owners, small- and medium-size enterprises, contract farmers
WOMEN FARMERS AND INDIGENOUS COMMUNITIES	Women farmers, female-headed households and businesses, pastoralists, tribal communities, Indigenous People
MOTHERS AND CHILDREN UNDER 5	Pregnant (post and prenatal) women, breastfeeding women, mothers, infants, children under 2, children under 5 (including malnourished/undernourished)
OTHER COMMUNITIES	Elderly, school age, youth boys and girls, college age, farmer's organizations and groups

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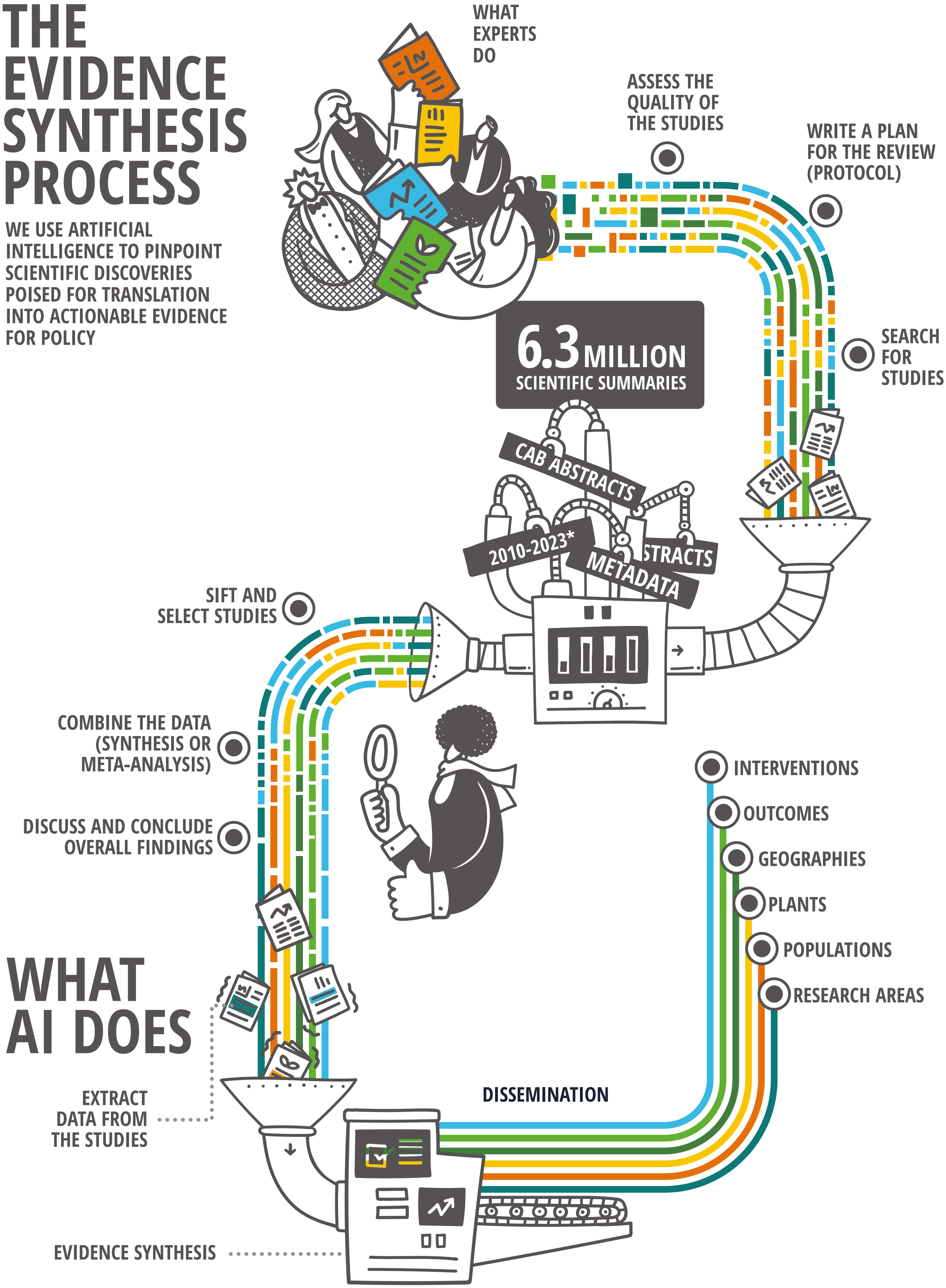

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