Sustainable Agricultural Productivity to Address Food Systems Challenges

Measurement, Data, Drivers and Policies

Proceedings from the OECD Conference
28 October 2024, Paris

Sustainable Agricultural Productivity to Address Food Systems Challenges

Measurement, Data, Drivers and Policies

Comments are welcome and may be sent to TADcontact@oecd.org.

Please cite these proceedings as:
OECD (2025), *Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies*, Proceedings from the OECD Conference, 28 October 2024, OECD Publishing, Paris.

Photo credits: Cover © Bizi88/Shutterstock.com.

Foreword

Sustainable productivity growth (SPG) in agriculture has become a cornerstone of the global policy agenda. SPG stands for innovating to do more with less, and hence plays an essential role in overcoming the challenges food systems face in ensuring food security, while supporting livelihoods and improving environmental sustainability.

However, it remains difficult to assess progress towards SPG. Finding ways to measure sustainable agricultural productivity is urgently needed to help design policies leading towards the desired path. SPG measurement is essential to provide an overarching overview on where the sector stands, shed light on emerging trade-offs between the objectives food systems face and help guide innovation efforts to overcoming them.

In response to this issue, the OECD, the European Commission's Directorate-General on Agriculture and Rural Development, and the United States Department for Agriculture's Economic Research Service co-organised the conference "Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies". Held on 28 October 2024 at the OECD in Paris, this international conference brought together over 160 policymakers, researchers, and practitioners to discuss ways forwards that are both rigorous and pragmatic for advancing the measurement of SPG. The OECD Global Forum on Agriculture followed on 29 October and served to exchange experiences and distil policy implications from this event.

Several messages emerged from the conference. Measuring SPG is not an easy task, but not an impossible one either. Policymakers to date mostly relied on total factor productivity (TFP) to understand agriculture's performance. While TFP remains an important and robust indicator, it does not capture environmental and social dimensions which are vital for sustainability. The good news is that there are already ways to incorporate environmental indicators into traditional TFP measures, enabling to track environmentally sustainable agricultural productivity growth. The inclusion of the social dimension is more challenging, but lessons learnt from combining environmental and economic indicators can guide these efforts.

The measures we have on tracking SPG performance can and should be brought into the policy discussion. These indicators can already provide policymakers with information on how to steer policies towards SPG, though they should certainly be perfected and completed over time.

These proceedings provide a summary of the conference discussions and short papers from experts and practitioners that contributed to the event. They are intended to encourage further discussions to advance SPG measurement and help deliver on OECD Agriculture Ministers' 2022 Declaration that committed to achieve sustainable productivity growth and called on the OECD to facilitate its measurement.

Catherine Geslain-Lanéelle
European Commission

Marion Jansen
Organisation for Economic Co-operation Development

Spiro Stefanou
United States Department of Agriculture

Acknowledgements

This publication was prepared by Jesús Antón and Ágnes Szuda of the Agriculture and Resource Policies Division of the OECD Trade and Agriculture Directorate, with support from Michèle Patterson, OECD Trade and Agriculture Directorate.

The authors of the respective sections are as follows: Section 1.1: OECD Secretariat, Section 1.2: Wilfrid Legg (formerly OECD), Section 1.3: Jesús Antón and Ágnes Szuda (OECD), Section 1.4: Jesús Antón (OECD), Section 2.1: Johan Swinnen (IFPRI), Section 2.2: Moriah Bostian (Lewis & Clark College), Section 2.3: Kelly Cobourn (Virginia Tech), Section 2.4: Arne Henningsen (University of Copenhagen), Section 2.5: Bernhard Dalheimer (Purdue University), Section 2.6: David Kenny (Teagasc), Section 2.7: Adrian Müller (FiBL), Section 2.8: Marc Müller (Brightspace Project, Wageningen Research), Section 2.9: Allison Thomson (Foundation for Food and Agriculture Research), Section 2.10: Maria Vrachioli (Technical University of Munich), Section 2.11: Uris Baldos (Purdue University), Section 2.12: Yvonne Pinto (IRRI), Section 2.13: Mikitaro Shobayashi (Research Institute for Humanity and Nature), and Chapter 3 and the Annexes: OECD Secretariat.

This publication builds on presentations and discussions held during the international conference “Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies” that took place at the OECD Headquarters on 28 October 2024. The conference was organised by the OECD Trade and Agriculture Directorate, in collaboration with the European Commission’s Directorate-General on Agriculture and Rural Development and the United States Department of Agriculture and its Economic Research Service. It was funded by the European Union and through a conference sponsorship granted by the OECD Co-operative Research Programme. Olaf Heidelbach and Gijs Schilthuis (European Commission’s Directorate-General on Agriculture and Rural Development) and Spiro Stefanou and Elise Golan (United States Department for Agriculture) participated in the steering committee to prepare the conference. Subsequent discussions held during the Global Forum on Agriculture (GFA) on 29 October 2024, entitled “Steering Policies towards Sustainable Agricultural Productivity” also supported the findings in this publication. Chairs, speakers of the conference and the GFA (as named in the Annex), as well as participants and moderators contributed significantly to this work.

The organisation of the October 2024 international conference and Global Forum on Agriculture involved a large team from the OECD Trade and Agriculture Directorate, led by Jesús Antón and Ágnes Szuda under the guidance of Marion Jansen (Director) and Guillaume Gruère (Head of Division). This included contributions and inputs from Julia Nielson, Lee Ann Jackson, Roger Martini, Mercedes Campi, Helene Bombrun, Francesco Vanni, Adriana Garcia Vargas, Urszula Ziebinska, Lauren Lee, Ada Ignaciuk, Theo Jesover, Daniela Rodriguez, Juan Pablo Rosado, Lorena Rivera Orjuela, Florian Freund, Jibran Punthakey, Hugo Valin, Tarja Mard, Helena Rasch, Lorenzo Díez-Picazo, Helen Maguire, Martina Abderrahmane, Marina Giacalone-Belkadi, Marie Russel, Nathalie Elisseou Leglise, Janet Schofield, Koen Deconinck, Caitlin Boros, Sydney Scott, Marc Regnier, Michèle Patterson, Jerome Mounsey, Laura Quintin, Ida Christensen, Linda Moran and Paul Schwenk.

The publication of these proceedings is financially supported by the OECD Co-operative Research Programme.

Acronyms

AEI	Agri-environmental indicators
AI	Artificial intelligence
AWD	Alternate Wetting and Drying
BNI	Biological nitrification inhibition
CEJA	European Council of Young Farmers
CGIAR	Consortium of International Agricultural Research Centers
CIFOR-ICRAF	Center for International Forestry Research and World Agroforestry
DEA	Data envelopment analysis
EC	European Commission
EEA	European Environmental Agency
ELPS	European Livestock Production Systems
Embrapa	Brazilian Agricultural Research Corporation
ESPI	Environmentally Sustainable Productivity Index
EU	European Union
FAO	Food and Agriculture Organization
FFPI	FAO Food Price Index
FiBL	Research Institute of Organic Agriculture
FLAN	Farm Level Analysis Network
GASL	Global Agenda for Sustainable Livestock
GHG	Greenhouse gas
GPS	Global Positioning System
IAM	integrated assessment model
IICA	Inter-American Institute for Cooperation on Agriculture
IFPRI	International Food Policy Research Institute
IRRI	International Rice Research Institute
JIRCAS	Japan International Research Center for Agricultural Sciences
JRC	Joint Research Centre of the European Commission
LEAP	Livestock Environmental Assessment and Performance Partnership
LULUCF	Land Use, Land-use Change and Forestry
mDSR	Mechanised Direct Seeded Rice
MMRV	Measurement, Monitoring, Reporting and Verification
MRD	Mekong River Delta
MRV	Measurement, Reporting, and Verification
NDC	Nationally Determined Contribution

PB	Planetary Boundaries
R&D	Research and Development
SCAR	Standing Committee on Agricultural Research
SDG	Sustainable Development Goal
SEEA AFF	System of Environmental-Economic Accounting for Agriculture, Forestry, and Fisheries
SJOS	Safe and Just Operating Space
SLCA	Social lifecycle assessment
SPG	Sustainable Productivity Growth
STEP UP	Sustainable Livestock Systems Transition and Evidence Platform for Upgrading Policies
TAD	OECD Trade and Agriculture Directorate
Teagasc	Agriculture and Food Development Authority, Ireland
TFP	Total Factor Productivity
TFPI	Total Factor Productivity Index
TFPN	OECD Network on Agricultural Total Factor Productivity and the Environment
UNSD	United Nations Statistical Division
USDA ERS	Economic Research Service of the United States Department of Agriculture
WHO	World Health Organization

Table of Contents

FIGURES

BOXES

1 KEY MESSAGES, SUMMARY AND BACKGROUND

1.1. Key messages

Sustainable productivity growth (SPG) in agriculture is a high priority objective in the global policy agenda as a means to reconcile economic productivity with environmental and social sustainability.

Developing measurements for SPG

- SPG measurement needs to be developed to determine whether agriculture and agricultural policies are progressing in the right direction. Such measure can inform policymakers on potential trade-offs and guide policy and innovation efforts. It can also facilitate cross-country comparisons and learning from success stories on how to incentivise innovation and facilitate the adoption of sustainable practices.
- Significant progress has been made to measure agricultural productivity and environmental sustainability. There are cutting-edge measures of agricultural total factor productivity (TFP) that give important information on the economic performance of agriculture. Over the last 30 years, the development of agri-environmental indicators has been impressive in terms of resource use and measuring environmental externalities.
- Methodologies to measure environmentally sustainable agricultural productivity are being developed. Several approaches have been applied to combine the international agricultural TFP dataset by USDA-ERS with the OECD agri-environmental indicators dataset.
    - o An index-based approach that compares "good outputs" (agricultural products), "bad outputs" (e.g. greenhouse gas emissions), and resource inputs has been developed, and gives decision-makers the possibility to attribute weights to environmental impacts. This index approach can be used to calculate an environmentally sustainable productivity index (ESPI).
    - o Broadening traditional TFP metrics to reflect environmental values through social shadow prices, incorporating both market and non-market impacts of agricultural production, has emerged as another possible avenue.

There is reasonable confidence in comparisons of trends in SPG across countries and over time using these methods, but the comparison of absolute levels should be undertaken with caution and would benefit from further efforts.

- There remain significant challenges in measuring environmentally sustainable productivity performance. Total factor productivity (TFP) calculations remain constrained by limitations on inputs accounting and aggregation. National environmental performance indicators are insufficient in some areas, incomplete in others and unable to capture the spatial heterogeneity of farming and their positive or negative effects on local ecosystems.

- Advances in incorporating environmental performance in the measurement of TFP can guide efforts to include the social dimension in SPG measurement. While the social pillar is an essential element of sustainability, its inclusion in SPG measurement is complex, and even more so given that priorities and components vary across countries, as do current data limitations.

Linking SPG performance measurement with innovation and policies

- Co-creation is essential for developing SPG indicators. To develop and interpret meaningful indicators requires academic experts with different backgrounds, in addition to the participation of decision makers and practitioners - including farmers – working in the agricultural sector. This conference is a good example of interactions amongst a multitude of actors involved in making measurement a useful and timely tool.
- SPG is above all innovating to do more and better with less. Measuring SPG draws attention to potential trade-offs and synergies between increased agricultural output and improved environmental performance. Innovation can transform some of the trade-offs into win-wins if efforts are focused on overcoming them. To track progress in SPG and identify its drivers, it is essential to measure the performance of innovation and to understand if innovation efforts are directed towards a path of sustainable agricultural productivity growth. It is concerning that policies in the public sector have tended to underfund these services compared to other support to producers despite the high returns they can deliver.
- While measures of SPG can be perfected over time, they should be brought into the policy discussion. Agriculture must urgently deliver on meeting the UN Sustainable Development Goal 2.4. and, with appropriate interpretation, SPG indicators can already provide useful information to policymakers on where agriculture is headed to adjust policy decisions. Delaying the discussion of SPG measures in the policy arena risks bringing a “data winter” that hinders the advancement of policy and performance towards SPG.

Progressing pragmatically towards SPG measurement

- A pragmatic approach is needed to progress on SPG measurement, combining further work on existing indicators of SPG with improvements and considerations for extensions.
    - Investment is needed to overcome data gaps without placing undue data collection efforts on practitioners.
    - Methodological advancements are also essential to overcome difficulties in measuring SPG across geographical scales.
    - Evidence-based studies should continue to be undertaken, recognising that context matters.
    - Multi-disciplinary approaches are needed to reflect the plurality in paths towards sustainability

Such efforts are crucial to measure the outcomes of practices and technologies in the field and comparing their contribution to sustainable productivity performance across countries.

- The OECD is well-placed to advance the measurement of SPG. Through the Total Factor Productivity and the Environment Network and the OECD Agri-environmental Indicators, it supports governments in their efforts to steer policies towards sustainable agricultural productivity with both data and analysis. This conference and the accompanying high level Global Forum on Agriculture have demonstrated the unique capacity of the OECD to convene experts, practitioners, and policymakers in a constructive and stimulating environment.

1.2. Summary of the conference

Wilfrid Legg[1]

Background and context

The conference Sustainable Agricultural Productivity to Address Food System Challenges: Measurement, Data, Drivers and PulkPolicies took place on 28 October 2024 at the OECD Headquarters, organised by the OECD's Trade and Agriculture Directorate, in collaboration with the European Commission's Directorate-General on Agriculture and Rural Development and the United States Department of Agriculture and its Economic Research Service. It was funded by the European Union and the OECD Co-operative Research Programme. The conference also benefited from the work of the Network on Agricultural Total Factor Productivity and the Environment through which the OECD has convened world class experts for more than seven years.

The event, which was also livestreamed, brought together around 160 participants representing a wide range of diverse interests, including academia and research, business and industry, policy advisors and international organisations. The exchange among experts and policymakers focused on the current and evolving state of sustainable agricultural productivity performance, measurement, and data, as well as on the main challenges to reconcile productivity and sustainability, in particular on the environmental aspects.

Session 1. Measuring the unmeasurable: Learning from the cross-country benchmarking and measurement experience of other OECD Directorates

The session included a discussion between OECD Directors on lessons that can be learnt from the OECD's benchmarking and measurement experience in other domains to facilitate the measurement of sustainable agricultural productivity.

In welcoming participants, Director of the OECD Trade and Agriculture Directorate (TAD), **Marion Jansen**, noted that OECD has over many years been developing agri-environmental indicators and measuring agricultural productivity. Producing more with less while reducing the environmental burden implies reconciling agricultural productivity and environmental sustainability. While combining agri-environmental indicators and agricultural productivity to measure sustainable productivity growth in agriculture (SPG) is complex, work undertaken elsewhere in the OECD in measuring and benchmarking in other economic sectors can provide lessons for agriculture.

In this respect, the Director of the OECD Statistics and Data Directorate, **Steve MacFeely**, pointed out that productivity is a complex abstraction as very little is directly measured, and it is necessary to communicate results in ways that resonate and are understood by policymakers and the public. One example where the OECD has succeeded in "measuring the unmeasurable" is the OECD Better Life Index, which provides a composite dashboard that helps policymakers interpret the results of different policy areas together and individually to drive policy action. The challenges faced when measuring SPG are similar to questions on national accounts and it is important to have conceptual consistency when developing measurement methods. One of the expected big changes in the 2025 edition of national accounts to be agreed by the UN Statistical Commission is netting out environmental degradation from GDP, and the development of the system of environmental-economic accounting (SEEA), to understand what the real cost of growth to the planet is.

Comparisons across countries, sectors and time require conceptual and measurement consistency, so agreed protocols and standards are crucial to ensure robust, valid and verifiable data. In this area the

[1] This summary reflects the Rapporteur's perceptions of the conference presentations and discussions.

OECD is at the forefront with quality assurance criteria. The first OECD manual on measuring productivity was launched in 2001 and updated in 2009. It is necessary to keep working on improving these methodologies and data through a co-creation mechanism, together with Member states, experts, institutions and actors who have “skin in the game” such as policymakers. But there are trade-offs as time pressures for results can conflict with providing high quality data. In this respect it is important to establish priorities for work as some data, such as on economic structures, change only slowly. Moreover, in the case of agriculture – a biological activity – some elements that influence productivity are outside the control of farmers, so caution needs to be exercised in the interpretation of results. Governments need to outline what data is needed, why it is needed and by when, which are essential to design better policies. There is unlikely to be a single “perfect” indicator, so the OECD can help in experimenting with a suite of indicators and getting feedback from global experts as a practical way of going forward. It is useful to have a diversity of methods and indicators, with multiple but limited options, in order to avoid decision making paralysis.

Efforts are being made to revisit the “infrastructure” of data collection. There is a plethora of data, but it is often not well organised. A common classification system across countries, consistency in definitions (such as “labour” as defined by the International Labour Organization) to enable spatial and temporal comparability, and linking data sets related to people, place and production are essential. Collecting data using newer technologies, including GIS, are valuable, especially for agriculture. “Citizen science” whereby the public participate in the collection and analysis of data on the natural world at the local level can be a useful, but scaling up to the national level is difficult. It is increasingly recognised that data in both the public and private domains have value, but often commercial enterprises protect data by paywalls. Governments need to incentivise companies to keep sharing that data because otherwise we risk facing a “data winter” until companies maximise the profit from the data. As systems of data collection are constantly evolving forward planning is needed to anticipate future requirements for policy design and implementation.

Session 2. Sustainable agricultural productivity and food systems

As a panel discussion, the session explored how sustainable agricultural productivity growth can help address the triple challenge food systems face, underlining the importance of its measurement.

Marion Jansen highlighted that in the 2022 Declaration on *Transformative Solutions for Sustainable Agriculture and Food Systems*, OECD Agriculture Ministers committed to take action to achieve sustainable productivity growth and called on the OECD to facilitate its measurement. The OECD has been at the forefront on measuring sustainable agricultural productivity, including through the work of the OECD Network on Agricultural Total Factor Productivity and the Environment (TFPN) and the Farm Level Analysis Network (FLAN). Through this expertise on measurement, the OECD can help countries steer policies towards sustainable agricultural productivity.

How can the measurement of sustainable agricultural productivity growth help decision-makers address the triple challenges of ensuring food security, while supporting livelihoods and improving environmental sustainability? In response, **Spiro Stefanou**, Administrator of the Economic Research Service (ERS) in the United States Department for Agriculture focused on work on the measurement of Total Factor Productivity (TFP). He highlighted that the role of data is critical and emphasised the importance of drawing on new data collection methods for advancing measurement. He pointed out that in tracking and anticipating trends, local decisions at the farm level aggregate to those at the national and global levels, which in turn feedback to the local level. Four steps are needed in undertaking sustainable agricultural productivity measures: identifying the relevant questions; communicating concepts and context; implementation and reporting; and establishing a process of verification through monitoring and making corrections if necessary. The notion of granularity is key and no one framework or sets of indicators are relevant for all countries and cases, so multiple measures are needed, which are likely to be different for each country. There is no one size fits all, but time has come to join forces to assemble data for TFP measurement and put them in an existing framework. USDA’s MMRV (Measurement, Monitoring, Reporting and Verification) process can help inform these efforts. Revising and reforming frameworks is crucial due to the diversity of economic data which is what are used for cross-country comparable SPG measurement, as well as for tracking progress within countries over time. When expanding TFP to SPG, people need to be open to multiple measures to track SPG. The efforts of the TFP Network are a good start for this and for broadening the environmental dimension needed for SPG measurement.

Catherine Geslain-Lanéelle, Director of Strategy and Policy Analysis in the Directorate-General for Agriculture and Rural Development of the European Commission stressed that increasing productivity is a key objective in the European Union. Increasing the productivity of agriculture has been and remains an important objective and OECD countries have already made progress. Countries have been using TFP as a useful and robust metric to measure progress domestically, but also to benchmark and compare performance across countries. However, TFP does not capture all elements that are important to policymakers. Policymakers aim to create policies that support farmers not only to be more productive, but also to help restore nature, protect soil and water, so that efforts to improve productivity are not ruined in the future by not paying attention to the environmental impact of farming and practices. She stressed that “if you are not able to measure, you cannot progress”. Therefore, if policymakers are to do a better job in designing policies to improve the sustainability of farming systems, there is a need to enrich TFP with other elements, including environmental metrics, and later with social dimensions when it becomes technically feasible. As the 2022 Ministerial Declaration says, OECD should continue to help measure SPG. Indicators need to be robust and reliable, but policymakers and stakeholders should not delay by looking for perfection. If we already have metrics that capture at least the environmental and economic dimensions of productivity, we should start using them to avoid the unintended effects of productivity on the environment. But it is also important to co-create these indicators in collaboration and agreement with other countries.

The academic community has played an important role in advancing the measurement of sustainable productivity growth in agriculture. **Paloma Melgarejo**, Professor of Research at the Spanish National Institute for Agricultural and Food Research and Technology in the Spanish National Research Council (INIA-CSIC) and a Member of the Scientific Advisory Board of the OECD Co-operative Research Programme (CRP), noted that the measurement of SPG requires multi-faceted, collaborative solutions involving producers, agribusinesses, transporters, retailers, and policymakers. Several measures of sustainable productivity are being developed: partial factor productivity (such as yields - the ratio of output per hectare), and total factor productivity (TFP, the ratio of all marketable outputs commodities to all marketable inputs. In parallel, databases assembled by the OECD, FAO, the UN and WORLD KLEMS initiative are collecting data on the environment and productivity and using it to advance the measurement of sustainable productivity. Nevertheless, there are data gaps, including soil health and biodiversity, and the need for disaggregated information given the diversity of agricultural systems and natural conditions. Newer technologies, such as GPS, AI, Robotics and Digitalisation can help the collection and management of data.

Farmers are at “the sharp end” in striving to achieve sustainable productivity growth because it is on farms where actions to achieve SPG begin, therefore decisions by farmers are crucial. **Rūdolfs Pulkstenis**, a cereal farmer in Latvia and Vice-President of the European Council of Young Farmers (CEJA) representing 2 million young farmers, argued that sustainability is not an end goal, but a journey. Moreover, farmers have different visions of sustainability. Farmers need clear directions from society and policymakers to ensure economic and environmental viability, as well as necessary tools, including access to land, innovation, and knowledge. Complying with regulations, financial providers and the supply value chain are difficult challenges. A key requirement is “strategic dialogue” with other stakeholders, benchmarking to judge performance, and certainty to make good decisions in an industry that is dependent on weather. But there are trade-offs across financial and environmental aims, such as whether farmers should keep cover crops for the time required by EU eco-schemes to receive payments or plough them at the time dictated by weather to ensure good quality crops next year.

Box 1.1. Words associated with "sustainable agricultural productivity"

Given that "sustainability" can mean different things to different people, participants were asked to use a digital application to share which words come to mind when they hear the term "sustainable agricultural productivity". The most frequently cited were "environment", "efficiency", "trade-offs", "biodiversity", and "innovation" (Figure 1.1).

Figure 1.1. Words conference participants associated with sustainable agricultural productivity

Session 3. Keynote speech: Why is the sustainable productivity of agriculture important and why do we need to measure it?

In his keynote speech, **Johan Swinnen**, Director General of the International Food Policy Research Institute (IFPRI), reminded the conference that a decade ago the evidence suggested that global poverty and hunger were on the decline. But since 2018 (i.e. before COVID-19 and Russia's war of aggression against Ukraine) that decline has been reversed and correlated with a slowdown in productivity growth. While global agricultural growth has been driven by productivity growth since the 1970s (although by area expansion in Africa) it has slowed down in the last decade. But TFP has not come with zero external cost and several environmental factors challenge the sustainability of agricultural productivity. Globally, agriculture is a significant consumer of energy (30%), freshwater (70%), generates over 20% of greenhouse gases, and contributes to biodiversity loss and environmental and human health hazards from excess applications of chemical inputs.

There is a need for sustainable productivity growth. Measurement has a key role in this respect for several reasons to: i) assess the current situation and performance (and the need for change), ii) understand trade-offs and potential win-wins, iii) compare the impact of a variety of policies, regulations and innovations, vi) guide decisions through the food system, and v) coordinate efforts. Significant progress has been made in measuring sustainable productivity growth conceptually, in data availability, and in policy analysis and evaluation. The OECD has been a central player in this respect and measuring SPG is technically feasible, but there are trade-offs between the complexity of measurement and the usefulness for policymakers.

Sustainable productivity growth requires innovation and policy reform. Public investment in agricultural R&D for innovation and sustainability has been downward trending during the last decade, which is correlated with the slowdown of TFP. R&D spending in most African countries is below 1% of agricultural GDP. While over USD 800 billion each year is spent on government support to agriculture, much of this does not assist sustainable agricultural growth: according to a study in 2023, among various options studied, shifting to R&D and incentives for green innovations would create the most win-win outcomes by raising farm output, reducing the cost of a healthy diet and significantly reducing GHG emissions. A major concern of governments - and society in general - are the distributional effects of reforms so an efficient outcome from the sustainability perspective may not viewed as equitable.

Session 4. Towards the cross-country benchmarking of environmentally sustainable agricultural productivity: Where do we stand with indicators?

Jesús Anton, Head of the Productivity, Sustainability and Resilience Benchmarking Unit in TAD and Moderator for the session highlighted the increasing recognition of the need to measure sustainable agricultural productivity. Progress to date has been made on adjusting TFP measures to incorporate various agri-environmental outcomes and several approaches emerged, in particular combining the OECD Agri-environmental indicators dataset and the USDA-ERS international agricultural productivity dataset. The panel discussed the state of the art in measuring in successive steps: first, calculating total factor productivity agriculture; then measuring the environmental performance of the sector; and finally combining both economic and environmental performance in an index of environmentally sustainable productivity growth.

Are there available calculations of sustainable productivity growth in agriculture that are comparable across countries?

Keith Fuglie, an economist in the Economic Research Service of the United States Department of Agriculture introduced the discussion by addressing the issue of comparing TFP figures across countries using the USDA-ERS dataset. Comparisons across countries are possible if inputs and outputs are defined consistently to produce indices of total output, total input and TFP. The ERS has calculated annual series for every country and world region for 1961-2022, which are updated annually. The sources of output growth have significantly evolved over time: in the 1960s and 1970s a greater application of inputs dominated, whereas improvements in TFP became increasingly important from the 1980s to 2010. But the global downturn in agricultural output and TFP growth in the latest decade is worrying, although TFP remains the principal driver. However, environmental effects are not factored into these calculations.

Simone Pieralli from the Joint Research Centre (JRC) of the European Commission focused on the use of indicators in policy decisions and the way forward in developing policy relevant indicators. He presented the methodological comparisons between JRC calculated TFP values for European countries and those of the ERS. There are differences in sources of data, methods and scope, resulting in different TFP values. He stressed the importance of comparability in the calculations across countries in the European Union, given the common application of agricultural policy across EU countries, but also the need of consistency with non-European countries for appropriate benchmarking. However, regarding “fair benchmarking”, quality differences and weather need to be borne in mind as agriculture is a biological activity. Therefore, adjusting for quality differences in inputs (soil, weather) and outputs (positive and negative environmental externalities) should be considered when expanding these TFP calculation to include agri-environmental performance.

How advanced are we in measuring agri-environmental performance?

The panel discussion with leading researchers in the field focused on where we stand in terms of the global benchmarking of agricultural productivity and agri-environmental sustainability. **Francesco Tubiello**, Senior Statistician and Team Leader in Environmental Statistics in the FAO, focused on progress on the UN Sustainable Development Goals, agreed in 2015 to be met by 2030. He argued that there has been good success in measuring the *proportion of agricultural area under productive and sustainable agriculture* (Indicator 2.4.1, to measure progress towards SDG Target 2.4.). FAO originally developed an indicator in 2017-18 spanning the three dimensions of sustainability based on farm level surveys, but data availability and response rates were low. Therefore, a proxy indicator was developed instead based on seven economic, environmental and social sub indicators at national level. For example, “soil quality” is measured by “nitrogen use efficiency”. Using these proxies, FAO now reports on the status and trends globally and regionally on the status of SDG 2.4. This highlights the importance of developing indicators from available data showing that sometimes proxies can be more helpful than developing the “perfect” indicator.

The OECD has pioneered the development of agri-environmental indicators, starting in 1993. **Guillaume Gruère**, Head of the OECD Agriculture and Resource Policies Division in TAD, reminded the conference that it took seven years for the first indicators to be published, but now there are 60 indicators covering 54 countries, which attract very high views on the Internet. The OECD has produced a “dashboard” to improve communicate results, with the next update to be released in 2025. The focus is on trends rather than absolute levels given the diversity of country situations, but no country is at the top of the league table across all the indicators of agri-environmental performance. The challenge now is to develop biodiversity indicators, although good progress is being made.

Bruno Alves, a Researcher at the Brazilian Agricultural Research Corporation (Embrapa) gave a perspective from a major agricultural producing middle-income country. He explained how agri-environmental indicators have been adapted to the Brazilian context. He illustrated this with respect to the nitrogen and phosphorus balances in Brazilian soils as the inputs from biological nitrogen fixation are not constant over time, while Brazilian soils trap phosphorus more intensely than elsewhere and a positive balance indicates increased soil fertility rather than a loss to the environment. This is important for the calculations of the environmental effects of meat and dairy output, which is pasture-based. Brazil has embraced technology that has led to a tripling of grain production over the last three decades while the area has only doubled. While GHG emissions have risen, TFP has increased more, resulting in a better balance of economic growth in agriculture and its environmental impacts.

In commenting on the panel presentations, **Moriah Bostian**, Jr. Professor of Economics at Lewis and Clark College, noted that differences between the measurement in TFP in the European Commission and the ERS are mainly due to the input component. Therefore, consistent measurement and consideration of input quality differences are important in making cross-country comparisons. In addition, there are also differences in resource constraints and in environmental quality, while changes in the environment (such as soil health or biodiversity) have feedback impacts on production. At present, databases on ecosystem services mainly include quantities of natural assets while qualitative measures are restricted to management practices. Accounting for ecosystem services requires qualitative as well as quantitative indicators. Technical guidelines for ecosystem accounting have been developed by the UN System of Environmental Economic Accounting (SEEA-EEA) to reflect the overall quality of an ecosystem in terms of its characteristics. Aggregation and weighting can be used to construct indices of, for example, soil and water quality, wetland conditions, and biodiversity, while valuation methods, including shadow pricing, can be used. Models integrating changes in production inputs/outputs alongside ecosystem services present opportunities going forward (as the data and methods to measure changes in input quality exist), starting with GHG emissions and biodiversity (environmental outputs).

The perspectives outlined by the panel speakers generated much comment and discussion among conference participants. Issues raised included adjusting for differences in the quality of inputs and outputs (and their categorisation), valuation of environmental outputs, weighting of land, labour and capital inputs, and whether some environmental outputs should be considered as feeding back into production inputs, such as improved biodiversity or soil quality. Crucially, the context needs to be recognised in making comparisons across countries. For example, where water availability is abundant in mountainous temperate zone countries, water stress is much reduced but its quality can still be of concern. While there was a broad consensus that good progress has been made on measuring both productivity and environmental sustainability of agriculture, there is still work to be done in the OECD, in academia, and in other fora to improve this measurement and cross-country comparability.

Can we combine productivity and environmental sustainability performance?

Combining agricultural productivity and environmentally sustainable performance through the calculation of an Environmentally Sustainable Productivity Index (ESPI) is already possible as outlined by **Kelly Cobourn**, Associate Professor at the Virginia Polytechnic Institute and State University. The proposed index integrates environmental externalities (GHG emissions, and N and P surpluses) and the depletion of natural resources into a measure of TFP, using OECD agri-environmental indicators and USDA TFP data for 28 countries from 1990-2018. Illustrative results for three countries and the OECD as a whole show improved performance as commodity output increased more than environmental externalities. The framework is flexible, but agreeing data, estimation of weights to aggregate outputs and inputs, and environmental externalities remain challenging.

Another approach was described by **Arne Henningsen**, an Associate Professor at the University of Copenhagen, which extends the traditional measure of productivity to include social valuation of environmental performance (sustainable TFP), both beneficial and harmful. Whereas traditional TFP generates a ratio of market values of outputs to inputs over time, the proposed index of environmentally sustainable TFP calculates a ratio of value of benefits and costs to society using social shadow prices. Preliminary results of TFP trends in the European Union show that EU TFP growth is higher when factoring in GHG emissions. Overall, the availability of good and harmonised data on non-market costs and benefits is limited, although the scientific literature on methods to measure non-market goods is extensive.

Where do we stand in measuring sustainable agricultural productivity?

In responding to the presentations, **Bernhard Dalheimer**, Assistant Professor in the Department of Agricultural Economics at Purdue University recognised the significant progress that had been made in the methods to measure environmentally sustainable agricultural productivity, but gaps remain to be filled on identifying and measuring externalities and combining all the components in practice in a harmonised way. Illustrating the trade-off between biodiversity and production in palm oil in Indonesia, although deforestation helped to reduce food insecurity, biodiversity has been lost. However, values differ: the (private) price of conserving one species in Indonesia is high in terms of lost producer income whereas it is much lower in relation to per capita income in Europe. But the *societal* benefit of biodiversity is estimated to be much higher than *private* producer benefits, and there are already methods available for measuring SPG that can help inform policymakers in this respect.

Several comments from participants (Box 1.2) recognised that significant progress has been made in integrating economic and environmental performance in agriculture, including in OECD, in terms of concepts, methods, and applications. But scale is a key issue: how meaningful is it to aggregate, say, nitrogen surpluses or GHG emissions from individual farms to the national level given the great diversity whereby averages mask the farms that are underperforming. Another issue is the robustness or asymmetry of the price signals to farmers to take remedial action to reduce environmental damage when they do not internalise externalities, and many are distorted through policy measures and market imperfections.

Another issue of growing relevance is the increasing value of data itself, including highly disaggregated data, and data confidentiality, particularly in the private sector, which can be restrictive for researchers. Overall, questions were asked as to whether TFP is really growth if it does not take account of external costs, underpinning the pertinence of measuring SPG. **Jesús Anton** noted there is already a lot of work done with different indicators and needs to be shared and interpreted together with those with "skin in the game", including policymakers. At the same time, there is scope for a lot more work, and data and methodology improvements, which needs to be at once rigorous and pragmatic, and ensuring communication with those who are involved in taking decisions and have interests in making progress.

Box 1.2. Main messages from the group discussions on measuring SPG

Group 1: Integration can inform trade-offs to ensure general sustainability (profitability), regional land use decisions, and consensus of values for policymakers and farmers.

Group 2: Integration fosters better understanding, measurement and projections of food security; motivates farmers to introduce improvements; and improves trust with stakeholders. The way forward should be for more granularity (balance); and taking into account differences in technology.

Group 3: Integration can ensure increased engagement with countries, adapt TFP measurement to the situation of each country, and work closely with farmers to provide them with the right incentives for SPG.

Group 4: Integration can take stock of existing knowledge, enhance collaboration and communication to improve data quality and verification. The way forward should include the social dimension in the medium to long term.

Group 5: Integration can leverage data at different scales across actors and all sustainability domains using new technologies to bring science into policy.

Group 6: Integration can find a balance in the level of data used (farm, sector, or national).

Group 7: Integration can aid the calculation of a single number to inform policy discussion (but this should not replace the wider set of environmental, economic, and social indicators). The way forward is to harmonise data.

Group 8: Integration should encourage more efforts to understand the social component as very little work exists on this, while in developing countries there is a need for scenarios to engage governments if there are data on relevant investments.

Group 9: Integration can provide useful environmental SPG indicators, but there needs to be proper balance between the sub-indicators used.

Group 10: Integration means that researchers and policymakers have a mutual interest and will gain from identifying drivers of change, but need to ensure the data are correct and replicable.

Group 11: Integration can provide more evidence to the ideological debate (e.g. conventional vs organic), but there is a challenge to correctly price inputs and outputs, although it may be better to avoid comparing absolute values/results.

Group 12: Integration can ensure stability in policy and farmer decision making, while accounting for quality of inputs and outputs and more data, including remote sensing, helps to design better policies. The way forward is to gather input from society and policymakers, and provide better data, especially on filling gaps, especially on biodiversity.

Session 5. Lessons from the field: How to achieve environmentally sustainable productivity in agriculture? Specific practices, processes and technologies and results

While the objectives of sustainable productivity growth (SPG) in agriculture, which encompass food and nutrition security, farmer and farmworker wellbeing, and environmental health, are universal, the specific practices, processes, and technologies used on the ground to achieve it can vary widely, illustrating there is no single best solution for every situation. The diversity of approaches, practices and technologies underscores the importance of careful assessment of success in advancing sustainable productivity growth in different contexts.

How to identify production practices that are environmentally sustainable and increase productivity: Measuring outcomes at the project level

Peter Minang, Director for Africa at the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF), presented a project (2017-2023) on *Regreening Africa* through the natural regeneration and agroforestry for sustainable agriculture productivity. Trees are incorporated into croplands, communal and pastoral lands. There has been a good uptake of participation (65% of households in the areas targeted, in countries broadly across the centre of the African continent). Agroforestry has economic and environmental benefits over the long term but there are upfront costs and measuring the impacts of diverse practices in variable conditions as well as scaling up (such as on soil organic carbon) are challenging. Opportunities exist to adopt the lessons learned for the next phase of the project, stronger collaboration with other stakeholders, and use of innovative tools like citizen science and bioeconomic modelling.

Presenting the Sustainable Livestock Systems Transition and Evidence Platform for Upgrading Policies project (STEP UP) **David Kenny,** Head of the Animal and Bioscience Research Department in the Animal and Grassland Research and Innovation Centre of the Agriculture and Food Development Authority (Teagasc) in Ireland, said the overall aim is to provide policymakers with evidence on the impacts and externalities and their valuation of livestock farming. This involves identifying data gaps and different livestock production systems, using a holistic methodology to quantify impacts, scenario modelling, and providing livestock system foresight. It is a pragmatic experience-led project covering 20 pan-European livestock production systems in seven countries, with over ten indicators to measure the externalities, and a user-friendly assessment tool that recognises planetary resource boundaries.

Organic agricultural systems globally account for small shares of areas and production only but, particularly in some European countries, contribute with larger shares. **Adrian Müller**, Senior Scientist in the Department for Food System Science at the Research Institute of Organic Agriculture (FiBL) highlighted several observations on the relationship of organic agriculture and SPG measurement. Improving the performance of organic systems could focus on improving yields or addressing harvest losses, as ultimately what matters is how much food reaches consumers. For organic agriculture, it is not annual yields that add a meaningful picture but yields over a number of years so that the performance of crop rotation systems – critical for plant protection and to preserve soil fertility – can be captured. He highlighted that organic agriculture produces several ecosystem services and it is important to take these into account in measuring agricultural performance. He argued that it is not organic yields that are “too low” to ensure food security, but rather conventional yields are “too high” to ensure sustainability. It is necessary to bridge the “ideological debate” and learn which specific practices from various production systems are effective while allowing to remain within the carrying capacity of the planet.

Allison Thomson, Scientific Program Director at the Foundation for Food & Agriculture Research in the United States remarked that sustainability is diverse and the context - whether local, regional or national - is key. The results of farming systems that aim for environmental sustainability often have their results manifested after several years, rather than in a yearly TFP value. There is a need to take a long-term view and look beyond primary agriculture to the whole food supply chain to generate consumer support for environmental outcomes. Existing policies can help or hinder sustainability but may benefit sectors in the food chain (such as seed companies) rather than farmers. She stressed the importance of engaging farmers who are the experts on what matters for SPG.

How to develop technologies that contribute to SPG: Measuring outcomes

Jiro Ariyama, International Water Expert at FAO spoke about the WaPOR database that monitors agricultural water productivity through remote sensing. There are multiple water productivity definitions, and WaPOR reports water productivity as ratio of biomass production to water consumption. Studying an irrigation scheme in Sudan, it was possible to find which areas are best (or worst) performing ones in terms of high (low) water productivity, measured by high yields and/or low water consumption. WaPOR has been used for farmer advisory application development and national/international level reporting as well. Decision makers also must keep in mind that increasing water productivity does not always lead to water saving or improved water sustainability but may lead to expanded irrigated areas.

Tadashi Yoshihashi, Project Leader in the Biological Resources and Post-harvest Division of the Japan International Research Center for Agricultural Sciences (JIRCAS) described work on improving the nitrogen cycle via biological nitrification inhibition (BNI) – the natural ability of some plants to supress soil nitrification. Through conventional breeding, a wild wheat chromosome containing the BNI-trait was introduced into an elite wheat variety in India. Relative to the control crop, BNI enabled crop yields increased, but nitrate formation in soil and nitrous oxide emissions were supressed so contributed to higher productivity and sustainability, reducing the need for fertiliser use.

Everton Capote Ferreira, Postdoctoral Scientist, at The Sainsbury Laboratory, 2Blades, Norwich, United Kingdom explained work on delivering rust-resistant soy in Africa. Soybean rust leads to defoliation and up to 90% yield loss. Transferring traditional resistance genes from other legumes to soybeans reduces defoliation and increases yields. Fewer fungicides are needed, GHG emissions are reduced, soil health and water quality are improved, and biodiversity conserved. In addition, smart technologies (GPS, AI) enable the prediction of incidences of weather and disease.

The challenge of assessing the performance of practices and technologies

In commenting on the projects presented, **Marc Müller**, Project Coordinator of the Brightspace Project at Wageningen University & Research, noted the projects illustrated that win-win outcomes are possible, but trade-offs are more likely between increased production and improved environmental performance. Achieving sustainable agricultural production requires motivation, investment, affordability, and knowledge. Context is crucial in that policies, social norms and property rights related to land use can facilitate investment, while respecting planetary boundaries: measuring stocks/changes in natural capital play a role in this respect.

Maria Vrachioli, Senior Research Staff at the Technical University of Munich, in summarising the discussion with participants (Box 1.3), schematically outlined the stages from inputs, production systems, agricultural outputs to socio-economic and environmental outcomes. However, the flow is not linear but circular with feedback. In this respect a question arises as to whether “biodiversity” (genetic, species, ecosystems) is an “input” contributing to sustainable agriculture, or an “outcome” of sustainable agriculture? The case studies generated discussion on scale (the extent to which aggregation is possible in scaling up indicators from the local to national level), the need to revise indicators from experience in use, and the value of including changes in natural capital (the flow of ecosystem services) in national accounts. But with budget and data constraints, while researchers and governments can do *anything*, they can’t do *everything*!

Box 1.3. Main messages from the group discussions on SPG approaches

Following the panel discussion, participants were asked to reflect on which environmental outcomes should be measured (e.g. GHG emissions, biodiversity); how can these be combined with the measurement of economic productivity; whether there are trade-offs between different objectives; and whether win-win solutions are possible.

Group 1: Determining what should be measured should be informed by both goals of policymakers, communities, farmers and scientists. System boundaries, technologies and investments to remove barriers for farmers are necessary to identify possible win-win options.

Group 2: It would be necessary to measure all environmental outcomes, recognising the complexity and difficulty of doing this. Priorities are GHG emissions and biodiversity. Important to harmonise how different outcomes are measured. There are win-win situations, but also some trade-offs and need safeguards for any losses.

Group 3: Proritise GHG emissions (including LULUCF + pre and postproduction), water quality, soil health, nutrient surpluses, pollinators. Biodiversity is difficult to measure. We need outcome-based measures, and a suite of indicators to manage trade-offs between productivity and GHGs, water, biodiversity, etc.

Group 4: Need to measure as many outcomes as possible (e.g. biodiversity), and fill data gaps. There are always trade-offs, but win-win solutions are possible, they are most apparent when measured over time.

Group 5: Key dimensions should include water, biodiversity and soil carbon as a proxy for soil health and climate mitigation. Win-win options exist with well-chosen practices.

Group 6: Soil health improvement is win-win in many dimensions (rom biodiversity to human health) - ONE health. Trade-offs: economic vs social aspects.

Group 7: Win-win solutions are possible, but trade-offs are more likely. Win-win solutions are harder to reach when we have more indicators. We need cost-benefit evaluations which requires the measurement.

Group 8: More evidence is needed in terms of understanding biodiversity/soil microbiology. However, efforts should also focus on “positive impacts”, such as new biodiversity that emerges.

Group 9: Context is crucial and determines priorities. Need to identify local versus global public goods; trade-offs and win-win outcomes, for example drip irrigation if water is free.

Group 10: Cannot get a fast, good, cheap measure. Ideally all measurements should be at the farm level. Important to have input and output measures. Multiple trade-offs between objectives (productivity, profits, environmental sustainability). All measures have trade-offs, but a win-win solution could be possible in the long-term (context).

Group 11: Priorities depend on what the measurement is for. Need to agree on global public goods, starting with few indicators, e.g. GHG easier for international comparison, while biodiversity and overall environmental performance is contingent at local/national levels. Win-wins are possible (e.g. biodiversity and yields) and the time perspective is relevant.

Group 12: Priorities are water, GHG, nitrogen but biodiversity is difficult (both an input and output, affecting soil health), and not everything can be monetised. Biodiversity can be a trade-off and win-win outcome with agricultural production.

Session 6. Measuring innovation efforts and their impacts driving sustainable agricultural productivity growth

This session included a panel discussion on measuring innovation and understanding how to drive efforts in a way to enhance SPG. **Alessandra Zampieri**, Director of Sustainable Resources of the Joint Research Centre in the European Commission moderated the session, highlighting that sustainable agricultural productivity, innovation and policy reform are inherently intertwined. The question is whether current innovation investments are going in the right direction to enhance SPG, and building on that how innovation and its adoption can be induced to lead to SPG. This session discussed first how to measure innovation and then how to induce this innovation towards SPG.

Measuring innovation and its performance

In the segment on *measuring innovation performance* **Uris Baldos**, Research Associate Professor of Agricultural Economics in Purdue University, pointed out that productivity growth in the long run is largely driven by R&D, which varies significantly across regions and in private/public composition. Most recently, private R&D plays an increasingly important role in driving TFP growth. However, R&D-led agricultural growth in total factor productivity takes time and is uncertain in delivering results. R&D-led models can be coupled with economy wide or agricultural models to assess their environmental impact. According to modelling studies, R&D-led productivity growth contributes to environmental sustainability by preventing cropland expansion and thus preserve biodiversity.

Nevena Alexandrova-Stefanova, Policies and Capacities for Innovation Unit Leader in the FAO Office of Innovation, argued for taking an integrated approach in agri-food innovations, but stressed that innovation is context specific, requires collective and collaborative (including stakeholder) efforts, and takes time to deliver impacts. In practice, establishing innovation policy laboratories, strengthening Agricultural Innovation Systems, providing multiple technological options, engaging in international collaboration, and preparing for disruptive technologies can contribute to the achievement of effective innovation. FAO has an agriculture innovation system indicator framework, some of which looks at innovation inputs (24 indicators), and innovation results (10 indicators), presented as part of a dashboard. There is a shift in trends in innovation, as new innovations must be concurrently sustainable, efficient and democratic. Policy, social and infrastructure innovation can even be more powerful than technological innovation.

Joaquin Arias, Coordinator in the Observatory of Public Policies for Agrifood Systems at the Inter-American Institute for Cooperation on Agriculture (IICA) discussed which policies create incentives for the adoption of innovations that lead to sustainable agricultural productivity. In this respect evidence suggests that moving from input subsidies towards incentives to innovate for long term outcomes through, for example, compensation to improve soil health or the provision of public goods such as ecosystem services, can lead to the adoption of cost-effective sustainable agricultural practices.

As a contribution from the private sector, **Matthias Nachtmann**, Digital Farming - Sustainability Business Development Lead at BASF stressed that the transformation of the agri-food chain is changing the basis for data requirements and evaluation. Measuring sustainable productivity requires the harmonisation of evaluation methods and input data. But both environmental improvement ("reduced footprint") and increases in production ("increased yields/reduced costs") are possible, as win-win outcomes.

Inducing innovation towards SPG

In the segment on *going beyond numbers to induce innovation and its adoption in a direction that ensures sustainable agricultural productivity* **Yvonne Pinto**, Director General of the International Rice Research Institute (IRRI), spoke about the role of genetic innovation in working towards SPG, and highlighted the importance of measurement for understanding whether innovation efforts are going towards the right direction by assessing their impacts. She informed the conference of IRRI's project on sustainable rice production in the Mekong River Delta in Viet Nam, with the aim of increasing rice quality and reducing the carbon footprint. With improved farming practices (Mechanized Direct Seeded Rice, optimal seed density, integrated weed management, fertiliser deep placement), water use, fertiliser applications, methane emissions and pest incidents all decreased, while productivity and profits also increased (a win-win outcome). Moreover, another advantage is that the time needed to develop new rice varieties has dramatically decreased.

Mikitaro Shobayashi, Professor at the Research Institute for Humanity and Nature in Kyoto, Japan spoke of the case of collective action in land use innovation. Based on the example of the Shingai Land Use Improvement Association, there is significant potential for land consolidation that would rationalise land and water use, and maximise output as well as solar power sharing for agricultural and local use, but incentives are needed to achieve this. This is against the background of a deterioration in the net stock of public infrastructure in Japan for irrigation in agriculture since the beginning of the 21st century due to decreasing public investment since the mid-1990s. Social innovations in local decision-making on land and water use can contribute to improve both environmental and economic performance.

Improving policy efforts on innovation for SPG

Jean-Christophe Bureau, Professor at Agro-Paris Tech, commenting on the presentations, stressed that productivity arises from R&D and innovation, but given there are very good returns to R&D, why is there not more investment? The OECD databases on support to agriculture show that only a small share of public support is allocated to "general services", which includes investment on infrastructure and innovation expenditure. Private investment in innovation is low, but public R&D can focus on long term innovation. Innovation can benefit the environment with targeted regulations and subsidies, which could reduce the social costs of improving the agri-environment. However, good data are needed for better policies, as well as to support and direct the work of researchers.

In the discussion, participants noted that environmental regulation was an essential component in the policy toolbox; the often long time scale to undertake remedial actions to improve sustainability can conflict with the time horizon of policymakers; many suggested that interventions impose administrative costs (transfer efficiency) that have to be factored into the evaluation of policy actions; investment in education and skills, training, information, and the extension services play key roles in moving towards sustainability, especially as path dependency can impede change among nascent farm businesses; and the involvement of stakeholders in innovation, policy design, and implementation can encourage buy-in and facilitate conflict resolution.

Session 7. How do the lessons learnt at the conference influence policy agendas?

In the concluding roundtable, **Marion Jansen** reminded participants that the focus of the conference is on measurement and the role of the OECD in creating bridges between technical discussions on measurement and policymaking.

Elise Golan, Director for Sustainable Development at the United States Department of Agriculture, argued that advancing the measurement of SPG can inform policy by *crystallising* information on trade-offs in meeting divers objectives on productivity and sustainability, bearing in mind that the current set of indicators of sustainability are not comprehensive; *incentivising* change to adopt sustainable practices on the ground by ensuring that measurements take into account efforts farmers take for environmental sustainability; *benchmarking* success with flexible measurement so policymakers can make adjustments as necessary; and *mobilising* action by policymakers to engage in cross-country dialogue. She highlighted the importance of the collaboration with the European Commission in this area through the USDA – EC DG AGRI Collaboration Platform on Agriculture, and with both being members of the SPG Coalition that was an outcome from the UN Food Systems Summit in 2022.

Catherine Geslain-Lanéelle (European Commission) reiterated the importance of this collaboration that was also manifested in co-organising this conference. Measuring SPG is indispensable for policymakers for designing better policies and for incentivising action. She stressed that we have the capacity to measure SPG, and the conference showed many examples: we already have methods to track in an integrated way both the productivity and environmental performance of agriculture. Even if indicators are not perfect and complete yet (e.g. on the inclusion of the social dimension), we can build on what we have, avoiding unnecessary data collection burden for farmers and authorities. Policy makers need a robust and pragmatic basket of indicators, building on available data, but cannot wait another decade! She highlighted the importance of the OECD in this work, bringing together all those actors who are needed to co-create this metric.

David Laborde, Director of Agrifood Economics and Policy Division at FAO highlighted that factoring in the social aspects in sustainability is complex: for example, social sustainability related to equity rather than efficiency and integrating it in productivity indicators is challenging and needs to be able to show that there can be conflicts between efficiency and equity. The "hidden costs" of the food system need to be highlighted by identifying the costs of repairing a damaged agri-environment, calculating adjusted measures of productivity gains in a sustainable system, and recognising the need, for instance, to correctly price water and carbon. The work undertaken in developed countries should be relevant and applicable for developing countries. He also highlighted the importance of aligning what both the private and public sector measures.

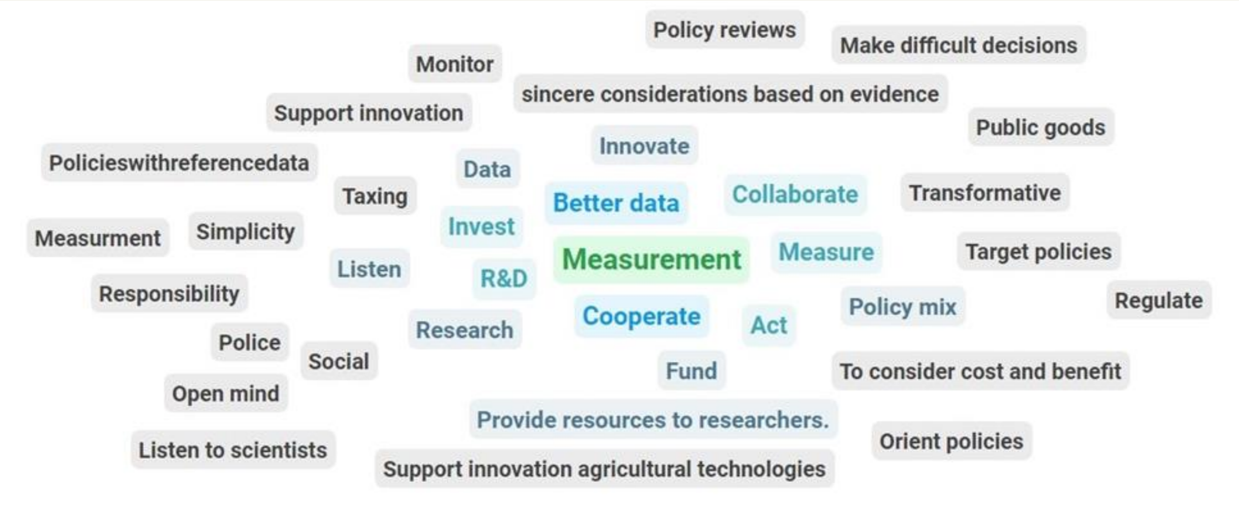
Guillaume Gruère (OECD) noted the progress made so far in OECD work on agri-environmental policy relevant issues, although addressing the social aspects is largely at the conceptual stage. The 2024 *OECD Monitoring and Evaluation of Agricultural Policies* includes analysis and evidence on innovation for sustainable productivity growth, which notes that some innovation is "induced" through subsidies or regulations, that some climate change mitigation policies are ineffective, while other policies not targeted at GHG emissions also affect those emissions. He stressed the importance of continuing the work on measurement.

Johan Swinnen (IFPRI) reminded participants that by far the biggest externality of food systems is the costs to health, not the environment. However, the conference highlighted that despite the challenging nature of measuring SPG, presentations today demonstrated that we are able to do so. There is already more consensus than is thought and discussions on measuring SPG should already move to the policy agenda. While much progress has been made more needs to be done, including cost-benefit analysis, identifying trade-offs, and better communication of often complex relationships with the public and policymakers. Private and public sector collaboration is needed to address the sustainability issues facing food systems, including access to finance and insurance: it is revealing that only 3% of finance to tackle climate change is directed at agriculture, but the sector accounts for over 20% of GHG emissions.

Box 1.4. What key action is needed from policymakers to achieve SPG?

At the end of the conference, participants were asked to use a digital application to share what policymakers can do to achieve SPG (Figure 1.2). The dominant action that participants cited to advance “sustainable agricultural productivity” was “measurement”.

Figure 1.2. Key actions from policymakers to achieve SPG as suggested by conference participants



1.3. Sustainable agricultural productivity growth: Definitions, strategies and policies

Key messages

- Sustainable Agricultural Productivity Growth (SPG) refers to the sector's performance with a holistic view that includes the efficient use of inputs in production and the reduction of pressure on the environment and natural resources. The broadest definition of SPG includes not only economic and environmental dimensions, but also the social dimension of sustainability.
- Many practices, processes and technologies can contribute to SPG, including diverse types of conservation practices, precision agriculture, genetic improvements, and agro-forestry. Scientific research and innovation involving farmers is needed to test and identify the best way forward in each setting.
- Governments are implementing different approaches to encourage SPG**.** These include strategies to advance environmental objectives, as well as a diverse set of policies and regulations that can determine the enabling environment for innovation. The merits and demerits of each approach deserve an assessment based on empirical evidence, thereby underlining the importance of advancing the measurement of SPG.

What is Sustainable Agricultural Productivity Growth?

Productivity improvements have been driving most growth in agricultural production in recent decades (Villoria, 2019[1]; Bureau and Antón, 2022[2]), helping to feed a growing global population.[1] Total Factor Productivity (TFP) growth assesses improvements in the efficiency of resource use and captures the notion of "producing more with less" (OECD, 2022[3]). This can have positive impacts on the environment by producing the same amount of outputs with less inputs and natural resources, e.g. avoiding bringing more land into agricultural production. However, traditional TFP measurements do not include environmental or social outcomes.

The concept of sustainable agricultural productivity aims to take a more holistic view on the performance of agriculture, ensuring that environmental and social dimensions of sustainability are incorporated into the calculation of agricultural productivity. According to the OECD Productivity, Sustainability and Resilience Framework (OECD, 2020[4]), sustainable agricultural productivity growth refers to productivity growth compatible with the preservation of natural capital in the short and long run. The main drivers of SPG are innovation, structural change and better management of natural resource under climate change. Sustainable agricultural productivity growth is also understood more broadly as agricultural productivity growth that "advances social, environmental, and economic development objectives to meet the food and nutrition needs of current and future generations" (SPG Coalition, n.d.[5]). Thus, sustainable productivity growth (SPG) in agriculture plays a key role in ensuring that food systems can deliver on diverse objectives covering economic, environmental, and social sustainability. There has been significant progress on having a common understanding of the economic and environmental dimensions of SPG and on how to measure them. Social issues related to agriculture remain a key policy concern, but there are still significant differences across countries on their definition and measurement (Asai and Antón, 2024[6]).

In recent decades, several alternative terms have emerged as close synonyms of environmentally sustainable agricultural productivity growth, with slight differences in emphasis. For instance, *Green Total Factor Productivity* (GTFP) aims to enhance agricultural productivity, while simultaneously reducing negative environmental impacts (APO, 2002[7]; Ahmed, 2012[8]). Similarly, *sustainable intensification* is

[1] Section 1.3 was presented as Background Note N°1 for this conference, which in turn is based on OECD (2024[46]).

defined as an "agricultural process or system where valued outcomes are maintained or increased while at least maintaining and progressing to substantial enhancement of environmental outcomes" (Pretty et al., 2018, p. 441[9]). It emphasises achieving multiple objectives without bringing more land into cultivation, as well as increasing the overall performance of the system while reducing environmental impacts and increasing contributions to the flow of environmental services (Godfray et al., 2010[10]; Pretty, Toulmin and Williams, 2011[11]; Pretty et al., 2018[9]). *Ecological intensification* aims to ensure both the productivity and sustainability of agricultural systems. However, it specifically focuses on practices that aim to enhance agricultural yields using ecological practices (Kernecker, Seufert and Chapman, 2021[12]) based on nature-based alternatives or ecosystem services (e.g. conservation agriculture, agroecology, organic and nature mimicry) (Bommarco, Kleijn and Potts, 2013[13]; Tittonell, 2014[14]; Kleijn et al., 2019[15]), with the idea is to complement or replace non-renewable or industrially made inputs for agricultural production. Ecological intensification pursuits the same SPG objectives as GTFP and sustainable intensification, but the list of practices and approaches that the concept encompasses is narrower.

How to progress towards sustainable agricultural productivity?

In order to achieve SPG in agriculture, different practices, processes and technologies should be put in place. Finding the best solutions for each location and circumstances requires scientific research, development and innovation, engaging farmers and other players in the Agricultural Knowledge and Innovation Systems (AKIS). Governments are at present developing strategies and approaches that seek to induce changes in practices, technologies, and processes to improve SPG and, in particular, to advance on environmental objectives.

Examples of practices, processes, and technologies for sustainable productivity growth in agriculture

There are many innovative tools that, used in different circumstances, can potentially contribute to sustainable productivity growth. [2] Some of these are relatively new, like robotics and artificial intelligence, while others like conservation tillage have long been used. All of them have seen continued improvement that expand the bounds of what is possible to achieve on a plot of land.

- Conservation practices, such as minimal soil disturbance (i.e. zero-till farming), crop rotation, and cover cropping, aim to improve soil health, reduce erosion, and increase water retention.
- Precision agriculture refers to the use of digital technologies (i.e. GPS, drones, and sensors) to monitor field conditions and apply inputs (water, fertilisers, pesticides) more precisely to increase efficiency, thus, reducing input waste and environmental impacts.
- Organic fertilisation, split fertilisation and bio-fertilisers aim to substitute or reduce inorganic fertiliser use, improve the efficiency of fertilisation and general soil fertility, reducing environmental pollution while improving nutrient availability.
- Crop choice, crop spatial distribution and crop temporal succession management is used to optimise positive interactions and synergies between crops.
- Crop genetic improvement to develop crop varieties with enhanced resistance to pests and diseases, better adaptability to climate stressors, improved nutritional content, and reduce need for agrochemicals.
- Agroforestry integrates trees and shrubs into agricultural landscapes, which can enhance biodiversity, improve soil health, and increase farm resilience to environmental stresses.
- Integrated pest management refers to strategies that use a combination of biological, physical, and chemical tools minimising economic, health, and environmental risks of pest management.

[2] Source: Authors' own elaboration based on Pannell et al. (2006[41]); OECD (2012[42]); Wezel et al. (2013[43]);Steensland and Zeigler (2020[34]), Campi et al. (2024[45]), (OECD, 2016[44]) and OECD (2024[46]).

- Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide (CO_2) in soils, plants, and other organic matter through agricultural practices, which can help mitigate climate change by reducing the amount of CO_2 in the atmosphere.
- Biocontrol agents use natural organisms such as insects, mites, or microorganisms to control agricultural pests and diseases, reducing reliance on chemical pesticides.
- Water-saving irrigation technologies, including drip irrigation and sprinkler systems, deliver water directly to the plant roots, reducing water loss and increasing water use efficiency.
- Robotics and automation can perform tasks like weeding, harvesting, and planting, monitoring crop health, increasing efficiency and reducing labour costs. Artificial intelligence is quickly expanding the capabilities of automated systems.
- Farm management software combines data from several sources (crop performance, soil, weather) to help farmers make better decisions about planting, managing and harvesting crops.

Sustainable agricultural productivity growth is not defined by any particular practice, process or technology. It is the outcome of actions that, when taken together, lead to improved outcomes over time. Finding the best combination of practices or technologies in each farm or location is a learning process that involves all actors in the AKIS.

Examples of some approaches promoted by governments to advance environmental objectives

Governments may choose to promote specific farming practices as part of their sustainability strategies.[3] These can produce some environmental benefits but may also have other effects, including being less productive. The net benefits of these depend on the context in which they are implemented and the particular sustainability characteristics including as related to food security, food prices, farmer income, and particular environmental benefits and their distribution, sought by governments, producers and consumers. These practices include, for example:

- Organic agriculture is a holistic production management system that promotes agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity, using mainly agronomic, biological, and mechanical methods instead of synthetic materials. The main characteristics are the prohibition of most synthetic inputs and the use of mandatory crop rotations. Standards for organic production have been developed by several associations and governments, aiming to differentiate products and segment markets through food labels (Rousset et al., 2015[16]). Organic products command a price premium and market segmentation that reflects consumer's interest in health, safety, quality and environmental protection (Popa et al., 2019[17]; Eyinade, Mushunje and Yusuf, 2021[18]). It offers environmental benefits like lower pesticide residues, richer biodiversity, and greater drought resilience, though its environmental, particularly climate, performance per unit of output is context-dependent (OECD, 2016[19]; Seufert and Ramankutty, 2017[20]; Gaudaré et al., 2023[21]).
- Agroecology is "a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems, seeking to optimise the interactions between plants, animals, humans and the environment while also addressing the need for socially equitable food systems" (FAO, 2020[22]). It gained prominence in the 1990s in the United States and Latin America, it is seen as a science, a set of agricultural practices, and a social movement (Wezel et al., 2009[23]). There are no national or international standards, but the concept is increasingly incorporated in policy. A study of 15 cases in Europe found that agroecological farms tend to enhance biodiversity and water quality compared to non-agroecological farms, though no clear patterns were found regarding soil quality

[3] Source: Based on OECD (2024[46]).

or economic performance (Landert et al., 2020[24]). The study also suggested that while some agroecological practices lead to reduced greenhouse gas emissions, in certain contexts, some practices can increase the energy use of the farms.

- Regenerative agriculture involves various practices and ideas. It can be defined by processes (e.g. using cover crops, integrating livestock, reduced or no tillage), outcomes (e.g. improving soil health, carbon sequestration, increased biodiversity), or both (Newton et al., 2020[25]). According to the European Academies' Science Advisory Council, regenerative agriculture emphasises soil restoration and the interplay of crops and farm animals and is broader and less prescriptive than agroecology and organic agriculture, allowing targeted use of modern technology, tilling, and inorganic inputs (EASAC, 2022[26]). The United Nations Intergovernmental Panel on Climate Change's Special Report on Climate Change and Land lists regenerative agriculture as one of the sustainable land management practices effective in building agro-ecosystem resilience. In the United States, some municipal governments have incorporated it into their climate action plans (The Climate Reality Project, 2019[27]). While no national or international standards exist, private standards are emerging.
- Circular agriculture focuses on using minimal external inputs, closing nutrient loops, regenerating soils, and minimising environmental impact. It is based on the circular economy concept, where re-using and recycling are integral to production and use choices (Philp and Winickoff, 2018[28]). This includes using manure as organic fertiliser and wastewater in irrigation. Circular agriculture is not defined by specific farm practices or standards but is often associated with mixed crop-livestock production, organic production, and agroforestry. Since 2018, the Dutch Government has promoted a transition towards circular agriculture, emphasising ecological principles combined with modern technology, new partnerships, economic models, and social services (OECD, 2023[29]). This approach aims for good yields, resource and energy efficiency, and minimal environmental, nature, and climate impact (WUR, 2018[30]).
- Bioeconomy refers to the sustainable production and use of biological resources (instead of fossil resources), processes, and principles (notably, biogenic instead of fossil resources) to provide goods and services across all economic sectors. Biotechnology and the life sciences contribute centrally to primary production (and industry) through the conversion of biomass into food, materials, chemicals, and fuels. In the last decade, the bioeconomy has outgrown just biotechnology, and it is embedded in the far-reaching transitions that are taking place in energy, transport and industrial production (Philp and Winickoff, 2019[31]). In agriculture and food systems, the bioeconomy focuses on integrating biological innovations and biotechnologies to enhance productivity, environmental sustainability, and economic resilience (Diakosavvas and Frezal, 2019[32]). This includes the use of bio-based fertilisers, advanced plant breeding techniques, and bioprocesses to convert agricultural residues into valuable products such as bioenergy, bioplastics, and bio-based chemicals. The bioeconomy approach aims to reduce dependence on fossil resources, minimise GHG emissions, and promote circularity within agricultural systems. As a holistic concept, the bioeconomy in agriculture not only enhances resource efficiency and reduces environmental impact but also fosters rural development and economic opportunities.

Examples of policy approaches towards sustainable agricultural productivity

Achieving sustainable agricultural productivity requires *policy coherence* which ensures that "various policies are aligned so that efforts in one policy area do not undermine efforts in another area, and even reinforce those efforts where possible" (OECD, 2021, p. 58[33]).

The main policy challenge for governments is to create the enabling environment and the right incentives to optimise resource use from an economic, environmental and social perspective (Steensland and Zeigler, 2020[34]). In doing so, governments should consider potential spillover effects, including transboundary spillovers, and trade-offs. The governance framework, regulations and the set of policies can define the right incentives to direct innovation for SPG. In this context, governments could focus on the following actions:

- Governance can create an enabling environment that supports SPG. It involves the formulation and implementation of comprehensive strategies that prioritise innovation and provide incentives for all stakeholders. It also includes institutional structures (agencies, co-ordinating groups, independent assessment bodies, as well as horizontal and vertical co-ordination in governments) that ensure that strategies are effectively translated into actions and provide stability and continuity in the efforts to enhance SPG. Governance should facilitate stakeholder's engagement and strengthen the AKIS system to integrate research, education, and extension services (OECD, 2013[35]).
- Policies: governments can implement policies to incentivise sustainable agriculture practices and accelerate the transformation of agriculture towards a more productive and environmentally sustainable sector in many ways:
    - Reform or reorient support: Some forms of support have the potential to distort production and trade or can worsen environmental outcomes, though the effects on the environment are not as clear cut as for production and trade. Reforming or reorienting agricultural policy to address those support measures that are harmful to the environment will help move towards more sustainable and productive agriculture and food systems.
    - Targeted subsidies and tax incentives: If well-designed and implemented, such policies can encourage farmers to adopt practices that promote soil health, biodiversity conservation, and resource efficiency. Governments may also use taxes to discourage unsustainable practices by applying the polluter pays principle.
    - Investment in R&D: Funding research initiatives focused on sustainable agriculture can lead to the development of innovative technologies and practices although the impact of R&D can take up to 20 years (OECD, 2011[36]). Governments can support research institutions and collaborate with the private sector to drive progress in sustainable farming methods.
    - Promotion of sustainable certification programmes: Governments can develop or support sustainable certification programmes rewarding farmers for implementing environmentally and socially responsible practices. These programmes can help differentiate sustainable products in the marketplace and promote consumer awareness.
    - Extension services: A traditional source of technical assistance to farmers, extension services help disseminate knowledge and awareness about environmental sustainability. Extension agents can offer guidance on soil management, water conservation, pest control, and other aspects of sustainable agriculture.
    - Public investments: Building rural infrastructure, such as irrigation systems, roads, and market facilities, as well as digital infrastructure and services, can improve access to inputs, markets, and agricultural services while reducing food loss and waste.
    - Regulations: Can encourage the adoption of sustainable practices and technologies to achieve specific environmental goals (Martini, 2023[37]). They include environmental regulations, land use regulation, water resource management, and food safety standards. Regulations are part of an overall policy package to guide the innovation into the direction of both environmental sustainability and productivity growth.

1.4. Sustainable agricultural productivity growth: Technical challenges and opportunities for measurement

Key messages

- Agricultural Total Factor Productivity (TFP) is the ratio of aggregate agricultural outputs to aggregate inputs used. It measures the part of output that cannot be explained by the inputs used by the sector and, therefore, the average economic performance reflecting efficiency gains and technical progress.
- Expanding this methodology to assess the environmental sustainability performance, including non-marketed inputs and outputs, is challenging. The main difficulties relate to data to build meaningful agri-environmental indicators and to methods that can combine economic and environmental dimensions.
- Measuring environmentally sustainable productivity growth (SPG) is technically feasible. There is expertise from different fields as well as databases from which to develop and adopt one or more SPG indexes to monitor performance and analyse policy impacts. Some Environmentally Sustainable Productivity Indexes (ESPI) have already been calculated.
- The OECD has made significant contributions in this area both through its publications and by creating platforms for discussion. It is time to move the discussion beyond experts to facilitate a much-needed discussion amongst policymakers.

How can productivity be measured?

Productivity measures the efficiency in the production of goods and services.[4] It is often expressed as the ratio between total production and the use of a single input. This partial measurement is intuitive and useful. In agriculture, the productivity of land is called yield. It measures the volume of production per hectare, an insightful indicator of the techniques applied to land and other factors. Labour productivity measures the output per worker and its evolution is a good indicator of structural changes in the sector.

$$Productivity = \frac{Production}{Input\ use} \quad [1]$$

These partial indicators of productivity reflect different aspects of the efficiency of the sector. However, they do not provide a full picture of the efficient use of resources because there are many other inputs used in agricultural production and they are not reflected on their calculation. Total Factor Productivity (TFP) is measured as the ratio of aggregate output to aggregate inputs (Bureau and Antón, 2022[2]; OECD, 2022[3])**.** It attempts to expand the coverage to all inputs and outputs in the sector. TFP can be interpreted as an average of productivity across inputs and outputs, reflecting the extent to which the sector is making good use of resources.

$$TFP = \frac{Total\ Outputs}{Total\ Inputs} = \frac{TO(w_i, Output_i)}{TI(s_j, Iutput_j)} \quad [2]$$

TFP calculations face significant challenges, in particular because adding up outputs such as wheat and pears, and inputs such as land, labour and fertilisers, requires technical adjustments. “Weights” (w_i and s_j) are needed to sum up quantities of different outputs “i” or different inputs “j” into total outputs (TO) and total inputs (TI). Index theory and production theory, together with national accounting databases and other micro information provide the technical support to accomplish the task. However, these calculations rely crucially on price data to estimate these weights and aggregates, most often limiting the analysis to marketed inputs and outputs.

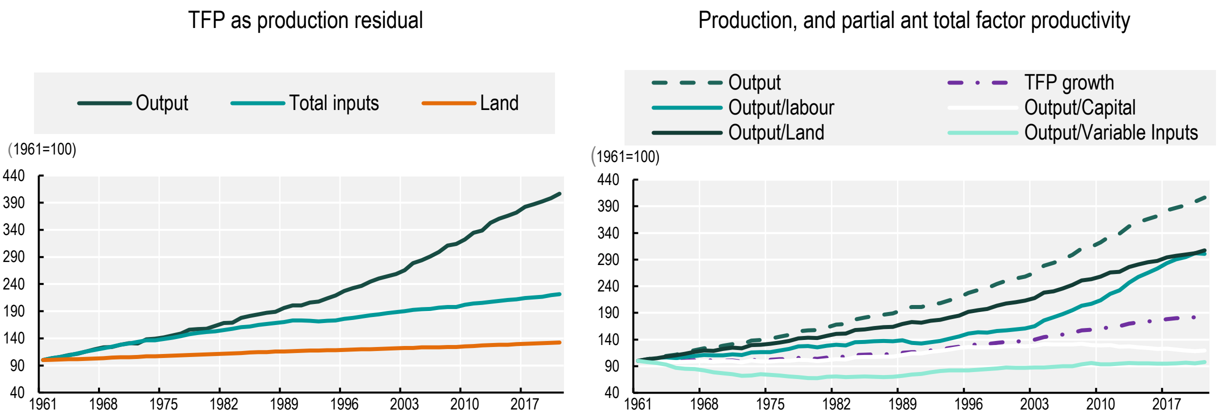
[4] Section 1.4 was originally presented as Background Note N°2 to this conference.

The Growth Accounting Approach is a useful tool to simplify TFP analysis and facilitate its interpretation. The growth in TFP is the residual difference between growth in outputs and inputs. It reflects the additional production that cannot be explained by the use of additional inputs and, therefore, implies gains in efficiency and technological progress. This is a powerful indicator. However, it is calculated as a residual and there is therefore a risk in cumulating all potential measurement errors. It thus requires the careful calculation of inputs, outputs and their weights. Under some assumptions, growth accounting permits a simple calculation of the contribution of each input to output growth and the extent to which TFP grows (g(TFP)), i.e. allows to produce more with less.

$$\mathrm{g(TFP)} = \mathrm{g(TO)} - \mathrm{g(TI)} = \sum_i w_i * g(Output_i) - \sum_j s_j * g(Input_j) \qquad [3]$$

Experts have made efforts to make these calculations by using the economic accounts of agriculture. These calculations are often not comparable across countries. The only openly available database that covers a large number of countries is the International Agricultural Total Factor Productivity database elaborated by the Economic Research Service of the United States Department of Agriculture. The numbers show a significant increase in global agricultural TFP over the last six decades, mainly driven by improvements in the partial productivity of land and labour, while the productivity of capital and variable inputs has fallen, particularly in the most recent decade (Figure 1.3).

Figure 1.3. Global Total and Partial Agricultural Productivity Growth, 1961-2021



Source: Based on USDA (2023[38]) and all countries included in that database.

Can we expand the TFP approach to measure environmentally Sustainable Productivity Growth (SPG)?

Agricultural TFP (or just "productivity") is a good indicator of economic performance of the agricultural sector, but it typically excludes non-market outcomes, thereby neglecting important environmental and social dimensions of sustainability. Producing more with less opens opportunities to deliver more on sustainability, but assessing performance requires measuring the actual sustainability outcomes. To capture the environmental sustainability of agriculture, measuring the use of non-market natural resources and the environmental externalities public goods produced by the sector is necessary. An overall indicator of agriculture's performance should include environmental sustainability performance. For example, when using traditional methodologies to calculate TFP, a reduction in agricultural greenhouse gas emissions (GHG) or in any other form of pollution, holding all other inputs and outputs constant, would imply no increase in productivity growth; the result is that improvements made in the use of natural resources are not revealed.

The framework to measure productivity described in equation [3] can potentially be expanded to measure SPG, including by-products as additional outputs with a positive value (potential positive externalities) or a negative value (pollution), and to include the use of natural resources as additional inputs (e.g. soil degradation).[5] The OECD Network on Agricultural TFP and the Environment has been working on these issues since 2017. An overview of these efforts can be found in OECD (2022[3]) and Bureau and Antón (2022[2]). The focus at this stage is on measuring environmental but not social sustainability reflecting on decades of efforts and convergence on defining and measuring agri-environmental outcomes, while serious difficulties remain to measure social sustainability. Cardenas Rodriguez, Hascic and Souchier (2018[39]) developed an Environmentally Adjusted Multifactor Productivity methodology for the analysis of the whole economy, including the emission of pollutants (environmental bad outputs) and the use of natural capital (environmental inputs). They use calculated "weights" α and β that measure the relative marginal value of emissions and natural capital

$$g(\mathrm{TFP}) = g(\mathrm{TO}) - g(\mathrm{TI}) - \alpha * g(\mathrm{EnvO}) - \beta * g(\mathrm{EnvI}) \qquad [4]$$

The main difficulties in measuring SPG are twofold. First, one must define the relevant areas of agri-environmental performance and, using the scarce data available, calculate the corresponding indicators that reflect very different circumstances across countries. The second difficulty relates to finding commonly-accepted ways to combine economic and different agri-environmental performance into an Environmentally Sustainable Productivity Index (ESPI). These are important technical and methodological challenges, but the current state of the art makes the task feasible. Progress in calculating a widely accepted ESPI is necessary to advance in the policy front.

The OECD has a long experience in measuring the environmental performance of agriculture as reflected in the OECD Agri-Environmental Indicators database**.** This database, which covers OECD countries and emerging economies, is comprised of indicators on GHG and ammonia emissions, nutrient balances, biodiversity, land, soil, water and energy. These indicators are in continuous improvement, and some are more mature than others. For instance, on the one hand, the indicators on GHG emissions have been developed for decades and have agreed methodologies that reflect countries' contributions to the global public good of climate change mitigation. On the other hand, indicators on biodiversity are in their infancy and difficult for cross-country comparisons despite recent efforts including by OECD. An increasing number of agri-environmental indicators could be incorporated to ESPI as they become more mature.

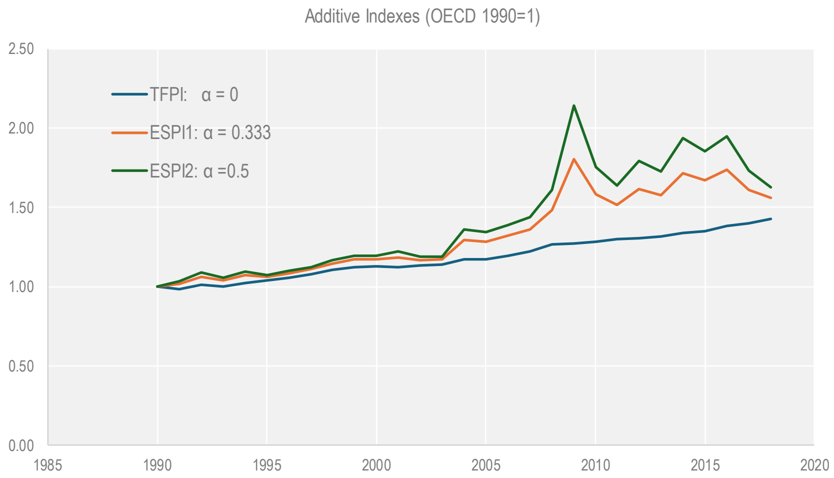
There is no need to choose a single indicator of SPG. Using more than one indicator built through different methodologies is a promising approach. Different options are worth exploring and will certainly help to better understand the trade-offs and synergies between productivity and environmental sustainability. Index theory and production theory provide methods to move forward with the same databases used to calculate TFP combined with the agri-environmental indicators database. The main challenge is calculating or identifying the weights to value agri-environmental performance because there is no market price for most environmental externalities. These weights are at the core of the concept of SPG because they provide the degree to which gains on environmental sustainability are acceptable to compensate weaker economic productivity growth. Using different alternative methods will also help to understand how sensitive are results to these alternatives.

There are already some calculations of ESPIs available. For instance, Cobourn et al. (2024[40]) build an Environmentally sustainable Productivity Index ESPI, which adds GHG emission and nutrient balances to the standard productivity index. ESPI performance worldwide is better than the productivity performance

[5] There are some limitations in applying growth accounting to capture levels of environmental sustainability rather than changes as recognised in Cárdenas Rodríguez, Haščič and Souchier (2018[39]). See also Cárdenas Rodríguez et al. (2023[47]) for further developments and the discussion of the extensions of the accounting framework additional pollutants and natural capital inputs.

in the last decades because the bad environmental outputs have decreased or increased less than the production of agricultural goods. This index allows to give different weights to the environmental performance (reflected by α in Figure 2). If α is zero, the index ignores the environmental performance and becomes the TFP. A higher weight to the environment leads to an index further away from the TFP.

Figure 1.4. An example of Environmentally Sustainable Productivity Index (ESPI) compared to TFP



Source: Cobourn et al. (2024[40]).

The main challenges in moving forward

- Investing in data and in the interpretation and comparison of results. Like TFP, a measurement of SPG would be a residual of the growth on production and on environmental goods that cannot be explained by inputs and use of natural resources. It is sensitive to measurement errors and requires checking the work with different experts in the fields of economics, agronomics and environmental science, including practitioners.
- Bringing the development of policy relevant indicators of SPG beyond the academic discussion into the policy agenda. The conference Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies is a key step in consolidating a forum of discussion in which researchers and experts are encouraged to improve and compare different methodologies, and to test their usefulness with policymakers and practitioners. One or more indicators need to be explored and eventually adopted to assess the performance of different practices and approaches for SPG.

Terms used and their acronyms

Sustainable Productivity Growth (SPG)

A broad concept describing the agricultural sector performance with a holistic view that includes the increasingly efficient use of inputs in production and the reduction of pressure on the environment and natural resources. A broader definition of SPG also includes the social dimension of sustainability.

Total Factor Productivity (TFP)

An economic measurement of productivity calculated as the ratio of aggregate agricultural outputs to aggregate inputs used. TFP seeks to include all outputs and all inputs that are bought and sold in the market and are part of the agricultural production process.

Environmentally Sustainable Productivity Index (ESPI)

A measurement of the agricultural sector performance, including the economic efficiency in producing market goods and the environmental outcomes such as externalities, public goods and use of natural resources.

Further reading

Henderson, B. and J. Lankoski (2023), "Integrated approaches for agricultural sustainability and productivity assessments", *OECD Food, Agriculture and Fisheries Papers*, No. 204, OECD Publishing, Paris, https://doi.org/10.1787/60cfa586-en.

OECD (2023), *Measuring the Environmental Performance of Agriculture Across OECD Countries*, OECD Publishing, Paris, https://doi.org/10.1787/4edcd747-en.

OECD (2022), "Declaration on Transformative Solutions for Sustainable Agriculture and Food Systems", OECD/LEGAL/0483, https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0483.

Network on Agricultural Total Factor Productivity and the Environment | OECD.

References

Ahmed, E. (2012), "Green TFP Intensity Impact on Sustainable East Asian Productivity Growth", *Economic Analysis and Policy*, Vol. 42/1, pp. 67-78, https://doi.org/10.1016/S0313-5926(12)50005-6. [8]

APO (2002), "Green Productivity", *An Approach to Sustainable Development Presented to the World Summit on Sustainable Development September 2002 by the Asian Productivity Organization*, https://www.apo-tokyo.org/wp-content/uploads/2014/07/ind_gp_aasd-2002.pdf (accessed on 14 August 2024). [7]

Asai, M. and J. Antón (2024), "Social issues in agriculture in rural areas", *OECD Food, Agriculture and Fisheries Papers*, No. 212, OECD Publishing, Paris, https://doi.org/10.1787/fec15b38-en. [6]

Bommarco, R., D. Kleijn and S. Potts (2013), "Ecological intensification: harnessing ecosystem services for food security", *Trends in Ecology & Evolution*, Vol. 28/4, pp. 230-238, https://doi.org/10.1016/j.tree.2012.10.012. [13]

Bureau, J. and J. Antón (2022), "Agricultural Total Factor Productivity and the environment: A guide to emerging best practices in measurement", *OECD Food, Agriculture and Fisheries Papers*, No. 177, OECD Publishing, Paris, https://doi.org/10.1787/6fe2f9e0-en. [2]

Campi, M. et al. (2024), "The evolving profile of new entrants in agriculture and the role of digital technologies", *OECD Food, Agriculture and Fisheries Papers*, No. 209, OECD Publishing, Paris, https://doi.org/10.1787/d15ea067-en. [45]

Cárdenas Rodríguez, M., I. Haščič and M. Souchier (2018), "Environmentally Adjusted Multifactor Productivity: Methodology and Empirical Results for OECD and G20 Countries", *Ecological Economics*, Vol. 153, pp. 147-160, https://doi.org/10.1016/j.ecolecon.2018.06.015. [39]

Cárdenas Rodríguez, M. et al. (2023), "Environmentally adjusted multifactor productivity: Accounting for renewable natural resources and ecosystem services", *OECD Green Growth Papers*, No. 2023/01, OECD Publishing, Paris, https://doi.org/10.1787/9096211d-en. [47]

Cobourn, K. et al. (2024), *An Index Theory Based Approach to Measuring the Environmentally Sustainable Productivity Performance of Agriculture*, OECD Publishing, Paris, https://doi.org/10.1787/bf68fb78-en. [40]

Diakosavvas, D. and C. Frezal (2019), "Bio-economy and the sustainability of the agriculture and food system: Opportunities and policy challenges", *OECD Food, Agriculture and Fisheries Papers*, No. 136, OECD Publishing, Paris, https://doi.org/10.1787/d0ad045d-en. [32]

EASAC (2022), *Regenerative agriculture in Europe: A critical analysis of contributions to European Union Farm to Fork and Biodiversity Strategies*, https://www.interacademies.org/sites/default/files/2022-04/EASAC%20Report%20RegenerativeAgriculture_April_2022_WEB.pdf (accessed on 2 May 2024). [26]

Eyinade, G., A. Mushunje and S. Yusuf (2021), "The willingness to consume organic food: A review", *Food and Agricultural Immunology*, Vol. 32/1, pp. 78-104, https://doi.org/10.1080/09540105.2021.1874885. [18]

FAO (2020), *Agroecology Knowledge Hub*, https://www.fao.org/agroecology/overview/en/. [22]

Gaudaré, U. et al. (2023), "Soil organic carbon stocks potentially at risk of decline with organic farming expansion", *Nature Climate Change*, Vol. 13/7, pp. 719-725, https://doi.org/10.1038/s41558-023-01721-5. [21]

Godfray, H. et al. (2010), "Food Security: The Challenge of Feeding 9 Billion People", *Science*, Vol. 327/5967, pp. 812-818, https://doi.org/10.1126/science.1185383. [10]

Kernecker, M., V. Seufert and M. Chapman (2021), "Farmer-centered ecological intensification: Using innovation characteristics to identify barriers and opportunities for a transition of agroecosystems towards sustainability", *Agricultural Systems*, Vol. 191, p. 103142, https://doi.org/10.1016/j.agsy.2021.103142. [12]

Kleijn, D. et al. (2019), "Ecological Intensification: Bridging the Gap between Science and Practice", *Trends in Ecology & Evolution*, Vol. 34/2, pp. 154-166, https://doi.org/10.1016/j.tree.2018.11.002. [15]

Landert et al. (2020), "Assessing agro-ecological practices using a combination of three sustainability assessment tools", *Journal of Sustainable and Organic Agricultural Systems*, Vol. 70/2, pp. 129-144, https://doi.org/10.3220/LBF1612794225000. [24]

Martini, R. (2023), "Towards a taxonomy of agri-environmental regulations: A literature review", *OECD Food, Agriculture and Fisheries Papers*, No. 194, OECD Publishing, Paris, https://doi.org/10.1787/1066cdef-en. [37]

Newton, P. et al. (2020), "What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes", *Frontiers in Sustainable Food Systems*, Vol. 4, https://doi.org/10.3389/fsufs.2020.577723. [25]

OECD (2024), *Agricultural Policy Monitoring and Evaluation 2024: Innovation for Sustainable Productivity Growth*, OECD Publishing, Paris, https://doi.org/10.1787/74da57ed-en. [46]

OECD (2023), *Policies for the Future of Farming and Food in the Netherlands*, OECD Agriculture and Food Policy Reviews, OECD Publishing, Paris, https://doi.org/10.1787/bb16dea4-en. [29]

OECD (2022), "Insights into the Measurement of Agricultural Total Factor Productivity and the Environment", https://www.oecd.org/agriculture/topics/network-agricultural-productivity-and-environment/. [3]

OECD (2021), *Making Better Policies for Food Systems*, OECD Publishing, Paris, https://doi.org/10.1787/ddfba4de-en. [33]

OECD (2020), "OECD Agro-Food Productivity-Sustainability-Resilience Policy Framework: Revised Framework", https://one.oecd.org/document/TAD/CA/APM/WP(2019)25/FINAL/en/pdf (accessed on 28 June 2024). [4]

OECD (2016), *Farm Management Practices to Foster Green Growth*, OECD Green Growth Studies, OECD Publishing, Paris, https://doi.org/10.1787/9789264238657-en. [44]

OECD (2016), "What does organic farming mean for green growth?", in *Farm Management Practices to Foster Green Growth*, OECD Publishing, Paris, https://doi.org/10.1787/9789264238657-5-en. [19]

OECD (2013), *Agricultural Innovation Systems: A Framework for Analysing the Role of the Government*, OECD Publishing, Paris, https://doi.org/10.1787/9789264200593-en. [35]

OECD (2011), *Fostering Productivity and Competitiveness in Agriculture*, OECD Publishing, Paris, https://doi.org/10.1787/9789264166820-en. [36]

OECD/FAO (2012), "Achieving Sustainable Agricultural Productivity Growth", in *OECD-FAO Agricultural Outlook 2012*, OECD Publishing, Paris, https://doi.org/10.1787/agr_outlook-2012-5-en. [42]

Pannell, D. et al. (2006), "Understanding and promoting adoption of conservation practices by rural landholders", *Australian Journal of Experimental Agriculture*, Vol. 46, pp. 1407-1424, https://doi.org/10.1071/EA05037. [41]

Philp, J. and D. Winickoff (2019), "Innovation ecosystems in the bioeconomy", *OECD Science, Technology and Industry Policy Papers*, No. 76, OECD Publishing, Paris, https://doi.org/10.1787/e2e3d8a1-en. [31]

Philp, J. and D. Winickoff (2018), "Realising the circular bioeconomy", *OECD Science, Technology and Industry Policy Papers*, No. 60, OECD Publishing, Paris, https://doi.org/10.1787/31bb2345-en. [28]

Popa, M. et al. (2019), "Organic foods contribution to nutritional quality and value", *Trends in Food Science & Technology*, Vol. 84, pp. 15-18, https://doi.org/10.1016/j.tifs.2018.01.003. [17]

Pretty, J. et al. (2018), "Global assessment of agricultural system redesign for sustainable intensification", *Nature Sustainability*, Vol. 1/8, pp. 441-446, https://doi.org/10.1038/s41893-018-0114-0. [9]

Pretty, J., C. Toulmin and S. Williams (2011), "Sustainable intensification in African agriculture", *International Journal of Agricultural Sustainability*, Vol. 9/1, pp. 5-24, https://doi.org/10.3763/ijas.2010.0583. [11]

Rousset, S. et al. (2015), "Voluntary environmental and organic standards in agriculture: Policy implications", *OECD Food, Agriculture and Fisheries Papers*, No. 86, OECD Publishing, Paris, https://doi.org/10.1787/5jrw8fg0rr8x-en. [16]

Seufert, V. and N. Ramankutty (2017), "Many shades of gray—The context-dependent performance of organic agriculture", *Science Advances*, Vol. 3/3, https://doi.org/10.1126/sciadv.1602638. [20]

SPG Coalition (n.d.), "Sustainable Agricultural Productivity Growth: What, Why and How", https://www.usda.gov/oce/sustainability/about-spgc (accessed on 30 April 2024). [5]

Steensland, A. and M. Zeigler (2020), "Productivity in Agriculture for a Sustainable Future", in *The Innovation Revolution in Agriculture*, Springer International Publishing, Cham, https://doi.org/10.1007/978-3-030-50991-0_2. [34]

The Climate Reality Project (2019), *Regenerative Agriculture and Municipal Climate Action Plans*, https://www.climaterealityproject.org/blog/regenerative-agriculture-and-municipal-climate-action-plans (accessed on May 2024). [27]

Tittonell, P. (2014), “Ecological intensification of agriculture—sustainable by nature”, *Current Opinion in Environmental Sustainability*, Vol. 8, pp. 53-61, https://doi.org/10.1016/j.cosust.2014.08.006. [14]

USDA (2023), *Productivity and Resource Use in Global Agriculture: An Update and Revision of the ERS International Agricultural TFP Data Product*, US Department of Agriculture, https://www.ers.usda.gov/data-products/international-agricultural-productivity/. [38]

Villoria, N. (2019), “Consequences of agricultural total factor productivity growth for the sustainability of global farming: accounting for direct and indirect land use effects”, *Environmental Research Letters*, Vol. 14/12, p. 125002, https://doi.org/10.1088/1748-9326/ab4f57. [1]

Wezel, A. et al. (2009), “Agroecology as a science, a movement and a practice. A review”, *Agronomy for Sustainable Development*, Vol. 29/4, pp. 503-515, https://doi.org/10.1051/agro/2009004. [23]

Wezel, A. et al. (2013), “Agroecological practices for sustainable agriculture. A review”, *Agronomy for Sustainable Development*, Vol. 34/1, pp. 1-20, https://doi.org/10.1007/s13593-013-0180-7. [43]

WUR (2018), *Circular agriculture: a new perspective for Dutch agriculture*, https://www.wur.nl/en/show/circular-agriculture-a-new-perspective-for-dutch-agriculture-1.htm (accessed on 7 April 2024). [30]

2 CONTRIBUTIONS BY CONFERENCE SPEAKERS

Introduction

2.1. Why is the sustainable productivity of agriculture important and why do we need to measure it?

Johan Swinnen
International Food Policy Research Institute (IFPRI)

Key messages

- To end hunger while reducing the environmental impact of agriculture, productivity gains must be made integrating environmental sustainability.
- Measuring changes in productivity and their associated externalities are key when tracking the sector's performance, as well as to understanding the impact and trade-offs that are associated with innovations and policy choices to achieve Sustainable Productivity Growth (SPG).
- Although developing a robust measure of SPG remains a challenge due to heterogeneity in methodologies and difficulties in placing a value on natural assets and environmental services, significant progress has been made to develop an environmentally sustainable productivity index (ESPI) that can inform policymakers on how to steer policies towards SPG.

Hunger and poverty were significantly reduced between the 1990s and mid-2010s, and yet the world is no longer on track to meeting the SDG goal of zero hunger by 2030. Indeed, predictions by IFPRI and the FAO state that over half a billion people will face hunger by 2030 (FAO et al., 2022[1]). The recent challenges such as geo-political conflicts and the COVID-19 pandemic do not strongly impact this result (Heady and Hirvonen, 2022[2]; Resnick and Swinnen, 2023[3]). Rather, the increasing prevalence of undernourishment comes with a slowdown in productivity growth, particularly in Africa where output growth has been largely driven by area expansion.

Agriculture and food systems have significant environmental impact. Food systems consume more than 30% of energy and 70% of freshwater sources, produce around one-third of greenhouse gas emissions, and are major contributors to biodiversity loss, and to environmental and health hazards (Willett et al., 2019[4]). Productivity gains to be made going forward must integrate environmental sustainability (Bureau and Antón, 2022[5]).

Achieving sustainable productivity growth requires both innovation and policy reform in which measurement plays an important role. Measuring changes in productivity and associated externalities enables a more accurate assessment of the current situation in addition to enabling the comparison of the impact and trade-offs linked to different policies and innovations.

Obtaining a robust measure of sustainable productivity growth, however, remains challenging for several reasons. The heterogeneity of existing methodologies complicates comparisons across countries, commodities, and over time. Accounting for the use of natural resources and environmental performance is hindered by limited reliable data on resource use and difficulties in valuating natural assets and environmental services. Measuring stocks and flows of natural resources typically depends on the use of imperfect proxies. To design an indicator that is useful in the policy world, that indicator must be comprehensible to policymakers. Yet an indicator that is too simplistic will likely be of little technical and political use.

There has been, nevertheless, significant progress towards measuring sustainable agricultural productivity thanks to international efforts to develop agri-environmental indicators at the country level (Deconinck, Jansen and Barisone, 2023[6]) (WEF, OECD and BIAC, 2023[7]), including the OECD Database on Agri-Environmental Indicators (AEI). It is now technically feasible to take the environmentally sustainable productivity index (ESPI) to policymakers.

Although progress in measurement has been made, more progress is needed in the areas of policy reform and innovation. The current slowdown in productivity growth is linked to a global decrease in public investment in agricultural research and development (R&D). In developing countries, and especially in Africa, R&D investment is below targets. In developed economies, mobilising resources for sustainable productivity investment requires an effort to reform public support for agriculture.

At present, more than USD 800 billion in government support is spent on agriculture annually, much of which is invested in practices, policies, and programmes that hinder SPG. Measurement is important to identify ways to efficiently reallocate this public support. Moreover, it is important to take a broader food systems approach in stimulating investment and innovation in SPG. In OECD Member countries, the farm sector receives just 15-20% of the value of consumer spending on food, and in lower- and middle-income countries that number varies from 30 to 50%. Hence it is crucial to bring in other agents and stakeholders in the food system to stimulate innovations, particularly as they represent a majority of the value created in the food system. They are also important in stimulating transformations and innovations at the farm level via vertical relationships, exchange structures, and incentive systems. Indeed, reforms in the up- and downstream segments of value chains can have major implications for agricultural producers and their sustainability impact (Laborde et al., 2022[8]).

Finally, incorporating sustainability into our approach to productivity—from measurement to policy to innovation—means facing more complicated political economy constraints than was previously the case. Measurement is therefore a necessary but not sufficient condition for the significant policy reforms that are required, especially in a polarised world.

Sustainable productivity performance and food prices[1]

The indicator developed by Cobourn et al. (2024[9]) to measure environmentally sustainable productivity and the Environmentally Sustainable Productivity Index (ESPI) visibly follows a trend similar to the FAO Food Price Index (FFPI), which measures changes in world food prices. The FFPI shows that world food prices were relatively stable from 1990 to the mid-2000s, increased sharply in the 2007-2008 period, then fell sharply with the economic recession in 2009, and once again increased in the 2010-2012 period. Likewise, ESPI appeared to be stable up to 2005, rose sharply from 2006 to 2008, and fell sharply around

[1] Based on correspondence with other speakers following the conference.

2009 before recovering a few years later. The correlation between the FFPI and ESPI is quantitatively strong: between 60% and 75%, depending on whether current or lagged indicators are used.

Such a high correlation suggests that the similarity between FFPI and ESPI is not coincidental. Prior IFPRI research shows that global food prices were correlated with energy and fertiliser prices across the 2000-2020 period. It is likely that changes in energy and fertiliser costs induced farmers to adjust their use of these inputs, which could possibly lead to changes in environmental externalities. Specifically, an increase in energy and fertiliser prices (and possibly other input prices) could reduce environmental externalities, pushing up the ESPI and vice versa when these costs fall. It would be useful to analyse alternative hypotheses on the relationship between FFPI and ESPI as a causal relationship between the two indices could have important policy implications.

2.2. Towards the benchmarking of environmentally sustainable agricultural productivity: Comparing TFP and agri-environmental performances across countries

Moriah Bostian
Lewis & Clark College

Key messages

- Traditional Total Factor Productivity (TFP) data across countries can be compared if inputs and outputs are defined consistently to calculate standardised indexes. However, measuring inputs is heterogeneous across agencies, as are the input quality and environmental quality.
- Current agri-environmental indicators enable cross-country benchmarking of agriculture's environmental performance.
- Incorporating environmental variables into traditional TFP measures is central to measuring environmentally sustainable productivity. This requires that positive and negative externalities are included.
- While incorporating negative externalities from agriculture is relatively straightforward, the inclusion of ecosystem services is less obvious due to the influence of underlying ecosystem conditions. Nonetheless, the construction of ecosystem condition indexes based on economic index theory is a possible way forward.

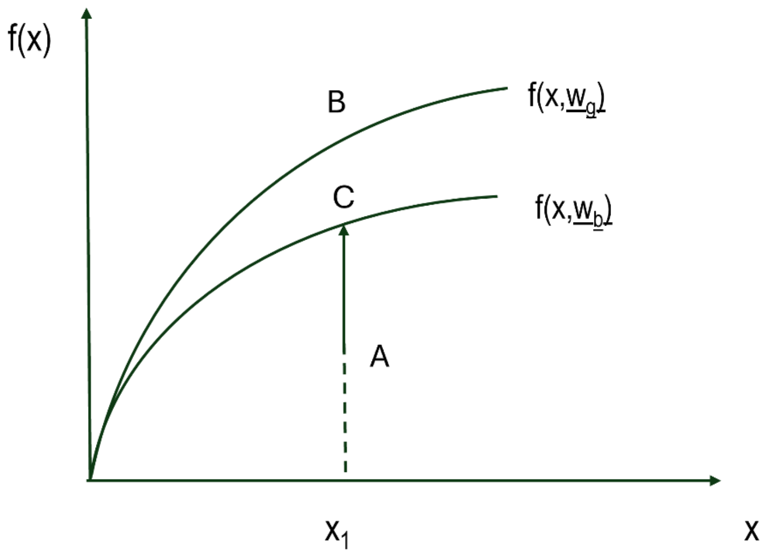
Cross-country comparability of indicators is essential to identify best practices and can help policymakers compare and adopt solutions across borders. This is highly relevant for benchmarking the environmentally sustainable agricultural productivity performance of countries as well, which is based on the measurement of traditional total factor productivity (TFP) and agri-environmental performance. This section addresses two issues, namely whether we can compare across countries traditional TFP performance and, secondly, agri-environmental performance. It also reflects on the incorporation of environmental variables into TFP data, highlighting the importance of including ecosystem services (positive externalities) alongside pollution (negative externalities) and presenting some potential ways forward.

What can be learnt from the discussions that took place at this conference? On the possibility of comparing across countries traditional TFP performance, it is clear that this is possible. Experts at the conference showed that by defining inputs and outputs consistently across countries, standardised indexes of total output, total input, and overall TFP can be computed and that the resulting standardised indexes can then be used for cross-country comparisons of traditional TFP growth rates. It is important to note the need for consistent input measurement across the agencies; current differences in USDA ERS and EC TFP measures derive mainly from differences in measuring the input component to TFP. While USDA ERS adjusts the input component for differences in input quality (e.g. land quality), the EC relies solely on differences in input quantities (e.g. land areas). Although both agencies maintain consistent accounting practices for cross-country comparisons, it is important to be aware of the differences in their approaches when comparing their respective TFP measures. To note that changes in input quality over time also derive partly from technical change.

Concerns were expressed about the heterogeneity of input quality and environmental quality. In addition to the intrinsic differences in standard input quality, changes to the production environment can alter production possibilities over time. Ignoring these extrinsic differences in the production environment when making TFP comparisons across countries can be considered unfair in the sense that it does not fully account for differences in resource constraints. Some speakers emphasised the importance of accounting for both the intrinsic and extrinsic differences for the output component, with a particular focus on externalities such as greenhouse gas (GHG) emissions and biodiversity change.

Figure 2.1 illustrates the concept of fair benchmarking. Point A represents an observed production level of an output, f(X) and a given input use, X1. Point B represents possible production output under good environmental conditions, Wg, while point C represents possible production under bad environmental conditions, Wb. Thus, point C represents the fair benchmark if actual environmental conditions correspond to Wb, while point B can be considered an unfair benchmark for production entity A, given Wb.

Figure 2.1. Fair benchmarking with extrinsic differences



Source: Adapted from Simone Pieralli's presentation material at the conference "Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies".

On the possibility of comparing agri-environmental performance across countries, the answer is *yes*, with some qualifications in practice. Before turning to these practical qualifications, it is important to emphasise that the same theoretical methods which allow for standardised cross-country productivity comparisons can be extended to also include environmental values, in much the same way that values for conventional production inputs and outputs are currently included. We have the methods in place to construct aggregate agri-environmental performance indicators at the country level. However, in practice, we lack similar standardised accounting methods for the various underlying environmental values, due largely to issues of definition and measurement. For instance, incorporating ecosystem services into cross-country TFP comparisons is complex, while incorporating levels of pollution from agriculture, such as GHG emissions or nutrient losses, is relatively straightforward; incorporating ecosystem services needs to take into consideration the quantity and quality of such services that contribute to agricultural production, which in turn depend on the underlying ecosystem conditions.

Current agency databases mainly include quantities of natural assets, while qualitative measures are restricted mainly to management practices. FAO is undertaking environmental monitoring which, despite some success, faces challenges due to differences in biome type and data collection across countries. The OECD is advancing work in the area of agri-environmental indicators (AEI), most notably with the development of the upcoming AEI Dashboard. In its initial form, this dashboard will include indicators for agricultural land in production, GHG and ammonia emissions, nutrient balances, and biodiversity, represented by an index of farmland bird biodiversity. While limited in its current measurement of ecosystem services and conditions, the dashboard presents a framework that could be expanded to include other environmental indicators, such as additional measures for biodiversity, water quality, and habitat.

Related to this, the current guidelines developed by the European Environmental Agency (EEA) – and which contribute to the broader System of Environmental-Economic Accounting for Agriculture, Forestry, and Fisheries (SEEA AFF) led by the United Nations Statistical Division (UNSD) – consider qualitative measures in terms of condition. In this context, ecosystem conditions reflect the overall quality of an ecosystem asset in terms of its underlying characteristics, which in practice are often represented by multiple indicators. At present, standardised methods for aggregation and weighting of multiple indicators for composite index construction exist, many of which derive from economic index theory, and these same methods have been used to construct ecosystem condition indexes. Examples include indexes for soil quality, water quality, wetland condition, and biodiversity. Some of these applications also include shadow price estimation, which could also be used for valuation purposes in the absence of market prices.

There are several good opportunities available for moving forward. First, integrated assessment models (IAMs) can be used to fill some of the current gaps in data for agri-environmental indicators. These IAMs link agricultural practices to surrounding ecosystem conditions by representing the various pathways by which agricultural production affects the environment (e.g. nutrient runoff, erosion, GHG emissions), as well as in some instances the pathways by which the environment affects production possibilities (e.g. soil salinity, climate conditions). These IAMs can be calibrated to a variety of spatial scales. Much of the data and methods for measuring change to input quality are in place. A practical approach moving forward would be to begin with a small number of key indicators for ecosystem conditions that could be consistently monitored across countries. Similarly, a practical approach for measuring outputs would be to begin with a few key environmental outputs, such as GHG emissions and nutrient losses.

Note

This section is builds on a paper published as Bostian, M. and T. Lundgren (2022), “Valuing Ecosystem Services for Agricultural TFP: A Review of Best Practices, Challenges, and Recommendations”, *Sustainability*, Vol. 14/5, p. 3035, https://doi.org/10.3390/su14053035. This paper includes an extended reference list and draws on ongoing work at the OECD Network on Agricultural Total Factor Productivity and the Environment.

2.3. Proposal for an environmentally sustainable productivity index

Kelly Cobourn
Virginia Polytechnic Institute and State University (Virginia Tech)

Key messages

- The proposed environmentally sustainable productivity index (ESPI) integrates agri-environmental indicators and economic productivity metrics into a single measurement that facilitates consistent comparisons in environmentally sustainable productivity performance between countries and over time. It is possible to build a rigorous empirical index using publicly available databases on total factor productivity from USDA-ERS and Agri-Environmental indicators from OECD.
- The index combines good outputs (agricultural commodities), bad outputs (e.g. pollution), and inputs into a measure of productivity growth incorporating a preference parameter which can reflect the weights policymakers and society place on bad environmental externalities versus good outputs.
- To enable the implementation of the proposed index in practice, it is necessary to address the challenges related to data sources and variable definitions, the estimation of the weights to aggregate outputs and inputs, the choice of bad outputs to include in the index, and the choice of the preference parameter for good versus bad outputs.

Tackling the triple challenge of providing food for a growing global population, protecting agricultural sector livelihoods, and improving environmental outcomes requires increases in both agricultural productivity and environmental sustainability. To advance these goals, a systematic approach to measuring progress and to evaluating policy instruments is needed, yet there are currently no internationally accepted methods of measuring environmentally sustainable productivity. It is essential that new methods be developed to account for whether growth in agricultural productivity has come at a cost to biodiversity, soil health, water quality, climate, and other ecosystem services.

A framework for an environmentally sustainable productivity index (ESPI) that integrates environmental externalities and the depletion of natural resources into a measure of total factor productivity (TFP) growth in agriculture was developed by Cobourn et al. (2024[9]). There are existing TFP indexes that are currently used by policymakers to monitor the performance of the agricultural sector. However, these indexes are limited in two key respects: they do not account for environmental dimensions of sustainability (nor social sustainability); and although they support evolution of productivity changes over time, they do not support cross-country comparisons. The ESPI proposed in this work addresses these limitations by integrating agri-environmental indicators and economic productivity into a single measurement that facilitates consistent comparisons in environmentally sustainable productivity performance between countries and over time.

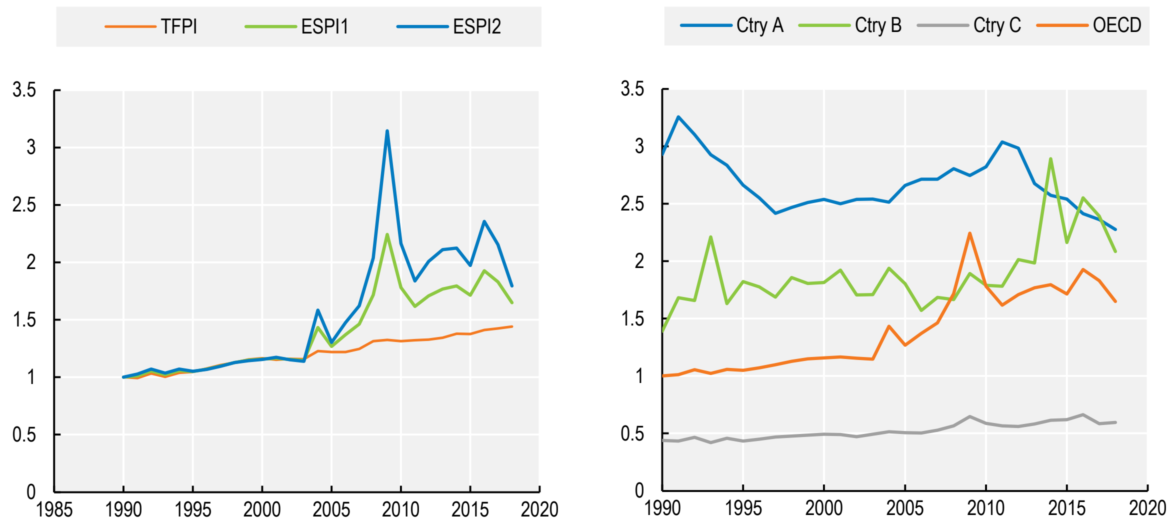
The proposed ESPI builds on index theory to integrate good outputs (agricultural commodities), bad outputs (negative environmental externalities), and inputs (including natural capital) into an index of productivity growth. The structure of the ESPI ensures that the index value increases with a decrease in the production of bad outputs or with a decrease in the depletion of natural capital inputs, all else constant. It incorporates a preference parameter that reflects the relative weights that policy makers and society place on bad outputs versus good outputs. As formulated, the proposed ESPI framework is flexible, as it can accommodate any environmental variables for which data are available; it is practical, as it is straightforward to calculate using existing data resources; and it is informative, as it summarises how output and input mix indicate differences in the environmental sustainability of agricultural production across diverse countries.

Although there is general agreement among policymakers and technical experts that developing an ESPI of this type is desirable, there are unresolved questions about how to implement the index in practice. Implementation requires addressing key challenges related to data sources and variable definitions; estimation of the weights to aggregate outputs and inputs; the choice of bad outputs to include in the index; and the choice of the preference parameter for good versus bad outputs.

This study highlights the importance of these choices using an empirical proof-of-concept in which ESPI values are calculated for 28 countries, including 18 OECD Members, for the years 1990-2018. Publicly available data from the USDA's international agricultural productivity database are combined with the OECD's agri-environmental indicators, which capture the best available data on three environmental externalities that are systematically tracked by countries—greenhouse gas emissions, nitrogen surpluses, and phosphorus surpluses. The analysis reports results for three index types (additive, multiplicative, and benefit-of-the-doubt), with the relative weights for market and nonmarket outputs and inputs estimate using a data envelopment analysis (DEA) approach, and for a range of values in the preference parameter weighting bad versus good outputs.

The left-hand panel of Figure 2.2 reports average values for TFPI and two ESPI index time series for the 18 OECD Member countries in the dataset. The results shown are those using multiplicative indexes to summarise good outputs, bad outputs, and inputs. The two ESPI time series reflect differing values for the preference parameter over good versus bad outputs, with a parameter value of 0.304 used for ESPI1, and 0.5 used for ESPI2. The ESPI numbers lie above the TFPI numbers in this panel, indicating gains in environmentally sustainable productivity over the past three decades for the OECD countries included. However, the gap between the ESPI and TFPI series has changed over time, increasing until 2009 and declining thereafter, indicating slowing progress over the last decade. The values for ESPI2 lie above those of ESPI1, illustrating that increasing the weight placed on bad outputs (i.e. placing a greater reward on environmental performance) increases the divergence between the TFPI and the ESPI.

Figure 2.2. Average ESPI and TFPI series for 18 OECD countries (left panel) and illustrative cross-country comparisons (right panel)



Note: All index values are expressed relative to the average of the 18 OECD countries in 1990 (OECD 1990 = 1). Results for multiplicative indexes are reported. Index values in right panel are for ESPI1.
Source: Cobourn et al. (2024[9]).

The right-hand panel of Figure 2.2 illustrates the ESPI1 index values for three anonymous countries in the dataset and for the 18-country OECD average. Countries A and B have ESPI numbers exceeding the average, indicating that they perform well in terms of environmental sustainability, whereas Country C exhibits relatively low ESPI values compared to the average. Although Country A has high ESPI values, the series has been trending downward in recent years, converging toward the group average. In contrast, Country B saw a long period of decline in its ESPI values, but a rebound in recent years. The short-term changes in the ESPI value for each country are heavily influenced by changes in the production of bad outputs, which contributes to greater volatility in the ESPI series than in the TFPI series.

A question was raised at the conference about the potential correlation between the 18-country OECD series in the left panel of Figure 2.2 and world food prices, which increased sharply from 2006-2008, followed by a rapid fall and recovery. The work presented in this study focuses foremost on defining and consistently measuring productivity, which is a necessary precursor for an analysis that seeks to explain the observed ESPI values. At this stage of inquiry, this study cannot definitively comment on the drivers of changes in the ESPI series. One hypothesis is that changes in crop prices, which increased food prices in 2007-2008, drove a shift in livestock and crop production patterns that altered bad outputs and led to a (lagged) spike in the ESPI. It is also possible that high fertiliser prices in 2008 drove a decrease in nutrient use and an increase in the ESPI, which declined as fertiliser prices and use recovered. These hypotheses and others would need to be tested empirically to be able to draw any conclusions about the relationship between food prices and the ESPI. This is only possible once agreement has been reached on how to measure environmentally sustainable productivity.

The ESPI proposed illustrates that it is empirically possible to offer a first step forward in the monitoring and analysis of sustainable productivity performance by providing a pragmatic and flexible measurement tool. However, further analysis is needed to explore the consequences of technical choices for measurement and policy analysis. Once the foundations for the measurement of environmentally sustainable productivity are established, it will be possible to analyse the factors that drive differences in the ESPI values between countries and over time. The index can then provide a powerful basis for policy analysis by capturing within-country and cross-country variability and a diversity of policy approaches aimed at improving agricultural sustainability.

Note

This section is based on work with Christopher O'Donnell (University of Queensland), Jesús Antón (OECD), and Ben Henderson (World Bank), published as Cobourn, K. et al. (2024), "An Index Theory Based Approach to Measuring the Environmentally Sustainable Productivity Performance of Agriculture", *OECD Food, Agriculture and Fisheries Papers*, No. 213, OECD Publishing, Paris, https://doi.org/10.1787/bf68fb78-en.

2.4. Proposal for a Sustainable Total Factor Productivity metric using societal shadow values

Arne Henningsen
University of Copenhagen

Key messages

- Sustainable total factor productivity (TFP) is defined in here as the ratio between the societal value of the outputs produced and the societal value of the societal costs of the production, indicating the profitability of the production from the society's perspective.
- Sustainable TFP can be applied at various scales, and take into account not only the economic and environmental dimensions of sustainability, but also the social dimension of sustainability.

This section proposes a novel framework to measure sustainable TFP. Most existing approaches for taking into account non-market inputs and outputs in the measurment of TFP take the producer's perspective by using market prices and marginal abatement costs as weights for aggregating inputs and outputs. In contrast, our proposed framework takes the society's perspective by using shadow values of all market and non-market inputs and outputs as weights. This results in sustainable TFP values that evaluate the production from the society's perspective considering social, environmental and economic aspects of production.

Continued global population growth and the replacement of non-renewable resources with renewable raw materials for a bio-based economy require increased agricultural production, yet resources such as land and water are limited. Hence, meeting global demands for food and renewable raw materials requires growth of agricultural productivity, which means that output growth must outpace growth in input use. In previous decades, the main driver of global agricultural production growth has been productivity growth (Fuglie et. al. (2024[10]).

The substantial growth in agricultural production, however, has led to significant environmental damage such as greenhouse gas (GHG) emissions, water pollution, soil depletion, and loss of biodiversity. Awareness of this has led to various initiatives worldwide to make agricultural production more sustainable. The concept of sustainability was introduced in the international policy discourse by the UN-initiated Brundtland Commission and includes three dimensions: economic, environmental, and social, known as the three pillars (Purvis, Mao and Robinson, 2019[11]).

It is generally acknowledged that it must be aimed for both agricultural productivity growth and more sustainable agricultural production, in short sustainable productivity growth (SPG). This is exemplified by the Sustainable Development Goals (SDGs) of the United Nations that seek to "double the agricultural productivity" (SDG 2.3), "ensure sustainable food production systems" (SDG 2.4), and "promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" (SDG 8). One of the initiatives that strives for SPG is the Coalition on Sustainable Productivity Growth for Food Security and Resource Conservation (SPG Coalition), which was launched at the United Nations Food Systems Summit in September 2021 (USDA, 2024[12]).

To evaluate whether a farm, firm, sector, country, region, or the entire planet is achieving SPG, and to gauge the effectiveness of policies and programmes aimed at promoting SPG, reliable measurement methods are essential. Although traditional productivity is clearly defined as the ratio of outputs to inputs, currently neither a clear definition of SPG nor an established method to measure it can be found in the scientific literature.

Various measures of productivity are frequently used by researchers, analysts, and practitioners, with total factor productivity (TFP) being the most comprehensive traditional measure of productivity. TFP is defined as the ratio between a quantity index of all outputs and a quantity index of all inputs (OECD, 2001[13]). As the weights for aggregating different outputs and inputs are usually closely related to the market prices of the outputs and inputs, TFP can roughly be seen as the ratio between revenues and costs, and thus as the profitability from the producer's perspective.

Given that traditional productivity measures such as TFP account only for market inputs and market outputs, while they ignore any non-market inputs and outputs, economists have started to incorporate the environmental effects of production processes into measures of TFP, either by modelling environmental damage as an input (e.g. Abad (2015[14]) or as an undesirable output (e.g. Chung et. al. (1997[15]), Färe et al (2004[16]) Førsund (2018[17]). Given that market prices of non-market goods are generally unavailable, these methods for obtaining so-called environmentally adjusted TFP usually use the marginal abatement costs of undesirable non-market outputs, i.e. the loss of profit that producers would experience by reducing the undesirable output by one unit, as weights of these undesirable outputs. Hence, these new frameworks for measuring TFP that include non-market inputs and outputs are evaluated from the producer's perspective.

We build on these frameworks to introduce a new TFP measure that we call sustainable TFP that measures SPG from the society's (rather than from the producer's) perspective, and that can consider not only the economic and environmental dimensions of sustainability, but also the social dimension, e.g. the working conditions of agricultural labourers. It can be applied at various scales, from individual producers to the entire agricultural sector, as well as to other economic sectors.

As explained above, traditional TFP measures and environmentally adjusted TFP measures use market prices as weights for inputs and outputs, and the latter additionally use marginal abatement costs as weights for non-market outputs. In contrast, our measure of sustainable TFP uses the society's evaluation of all market and non-market inputs and outputs as weights, i.e. the societal shadow prices of all inputs and outputs. Thus, the measure of sustainable TFP that we propose is basically the ratio between the societal value of the outputs produced and the societal value of the societal costs of the production, indicating the profitability of the production from the society's perspective.

Deviations between societal shadow prices of market inputs and market outputs and the market prices of these inputs and outputs can originate from (a) policies that affect the market prices (e.g. import tariffs, export taxes or subsidies, import or export quotas, internal subsidies or taxes) (e.g. Monke and Pearson (1989[18]), Pearson et al. (2004[19])) or (b) market imperfections (e.g. due to market power) (e.g. Kray (2002[20]). Given that price support measures in the agricultural sector have been substantially reduced or even phased out in many countries in the previous three decades (e.g. in the European Union's 1992 MacSharry reform) and that markets for agricultural inputs and outputs are often working reasonably well, the societal evaluations of market inputs and outputs are nowadays similar to the corresponding market prices in most of the countries. Methods for obtaining societal shadow prices of market inputs and market outputs are described, e.g. in Monke and Pearson (1989[18]), Pearson et al. (2004[19]), and Kray (2002[20]).

The scientific literature provides a plethora of methods for the evaluation of non-market goods that can be used to obtain the societal shadow prices of non-market inputs and outputs for calculating the measure of sustainable TFP that we suggested. These methods can be used to estimate the monetary values of benefits or damages that the society incurs from non-market inputs and outputs such as pollination services by insects, beautiful landscapes, GHG emissions, pollution of surface water or ground water, quality of life in rural areas, or working conditions of agricultural labourers. Societal shadow prices of undesirable outputs are usually substantially higher than the corresponding marginal abatement costs. In fact, in the case of no regulation, no financial consequences of causing undesirable outcomes, and no intrinsic motivation of producers to reduce undesirable outputs, marginal abatement costs are expected to be close to zero because producers do not have incentives to adopt even the cheapest abatement measures. Hence, from the society's perspective, environmentally adjusted TFP measures usually apply too low weights to undesirable non-market outputs. However, in the hypothetical case of optimal regulations and policies that maximise social welfare, the market prices of market inputs and outputs and the marginal abatement costs of undesirable non-market outputs are equal to the societal shadow prices of these inputs and outputs and, thus, the environmentally adjusted TFP coincides with sustainable TFP (except for that sustainable TFP' additionally takes into account non-market inputs, desirable non-market outputs, as well as the social dimension of sustainability).

While the scientific literature provides estimates of societal shadow prices of some important non-market inputs and outputs of agricultural production such as GHG emissions, estimates of the societal shadow prices of many non-market inputs and outputs of agricultural production are currently unavailable. Hence, in order to incorporate all non-market inputs and outputs in our measure of sustainable TFP, it is necessary to obtain societal shadow prices of many non-market inputs and outputs with appropriate methods that are available in the scientific literature. However, as a starting point, one can begin with calculating incomplete measures of sustainable TFP that take into account only the most relevant non-market inputs and outputs. Subsequently, one can use appropriate methods to obtain societal shadow prices of additional non-market inputs and outputs, and gradually add further non-market inputs and outputs to the calculation of sustainable TFP.

We illustrate our concept of measuring 'sustainable TFP' with an application to country-level data of global agricultural production from 1993 to 2021. Given data limitations on a global scale, we take into account only one non-market good: GHG emissions. We use data on market inputs and market outputs provided by the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) (Fuglie, Jelliffe and Morgan, 2024[10]), data on GHG emissions from the Food and Agriculture Organisation (FAO), and the societal price of greenhouse gas emissions from the meta-study on the 'social price of carbon' by (Tol, 2023[21]).

Preliminary results indicate that the environmentally adjusted TFP is almost identical to traditional TFP because the marginal abatement costs of GHG emissions are so low that GHG emissions have a very low weight relative to the market inputs. In contrast, we find that 'sustainable TFP' grows faster than traditional TFP in many countries because in these countries the aggregate output grew faster than the combined societal costs of market inputs and GHG emissions, while GHG emissions decreased faster or increased slower compared to market inputs. However, this growth in sustainable TFP should not lead to complacency as it is probably too slow to sufficiently address the worsening climate crisis and because our empirical analysis ignores several highly relevant non-market inputs and outputs.

Obtaining more comprehensive measures of sustainable TFP that consider additional non-market inputs and outputs requires more data and particularly more harmonised and standardised data on non-market inputs and outputs of agricultural (and other) production processes, as well as more studies on the societal evaluation of these non-market goods.

Note

This section is based on work with Frederic Ang (Wageningen University), Moriah Bostian (Lewis & Clark College), Hervé Dakpo (Université Paris-Saclay, INRAE, AgroParisTech, PSAE), and Maria Vrachioli (Technical University of Munich).

2.5. Can we combine productivity and environmental sustainability performance? To what degree is this a technical or a societal and political question?

Bernhard Dalheimer
Purdue University

Key messages

- Experts agree that it is technically feasible to combine productivity and environmental sustainability into a single measurement metric.
- Valuing environmental outcomes requires assigning societal values or weights, a process shaped by societal and cultural considerations, political priorities, and ethical considerations. This highlights that the advancement of SPG measurement is both a technical and societal question, requiring active and inclusive dialogue among stakeholders to align technical frameworks with societal goals.

As agricultural systems face the triple challenge of having to boost productivity while safeguarding the environment and livelihoods, sustainable productivity is a key outcome that requires adequate monitoring indicators. However, combining productivity and environmental sustainability into a single, meaningful measure is notoriously complex, requiring statistical tools and societal judgement. This section asks if this a technical challenge or is it a societal and political one.

Many externalities can be measured and their measurement continues to improve

Over the past few decades, the ability to measure environmental and social outcomes has improved significantly, and continues to do so rapidly (Chen et al., 2022[22]). Advances in data collection and technology have transformed the scope and accuracy of these measurements. Remote sensing in particular has become a cornerstone of environmental monitoring, providing real-time and large-scale data on land use, deforestation, water use, and greenhouse gas emissions. These tools enable precise tracking of resource productivity, such as identifying areas of land degradation or quantifying carbon sequestration in forests, offering unprecedented insights into the environmental trade-offs of agricultural practices

In addition to environmental outcomes, social dimensions—such as rural employment, income distribution, and food security—have been increasingly measurable through integrated surveys and economic modelling. These metrics allow policymakers to assess the broader societal implications of agricultural productivity. By capturing both environmental and social outcomes, these advancements provide the foundation for creating more comprehensive and inclusive sustainable productivity measures.

While capacities to measure environmental and social outcomes are not equal across all these externalities, there are enough reliable agri-environmental indicators available to put productivity growth into perspective. For example, greenhouse gas emissions, forest cover, and increasingly water quality and access are well measured (eg. (FAO, 2022[23]; Karl et al., 2024[24]). Other externalities such as biodiversity degradation continue to be challenging to measure and, in particular, to harmonise across countries, yet have been subject to a nascent literature that integrates agricultural output growth and loss of species (Dalheimer et al., 2024[25]).

There is a rich and innovative toolkit of methodologies available

A rich and longstanding literature has proposed and developed a host of suitable measures that integrate economic outcomes with environmental or social ones (e.g. Chung et al. (1997[15]); Cuesto and Zofío (2005[6]); Färe et. al. (2007[26]); Murty et. al. (2012[27]); Dakpo et. al. (2016[28]). Two recent innovations were made by Henningsen et al. (2024[10]) who presented an approach rooted in extending the concept of Total

Factor Productivity (TFP) to incorporate societal costs and benefits; and another by Cobourn et al. (2024[9]) who propose an index-theory-based framework to integrate environmental externalities into productivity metrics. Both methods illustrate the technical feasibility of combining productivity and sustainability, while underscoring the societal decisions inherent in assigning weights to these dimensions.

Henningsen et al. (2024[29]) argue for broadening traditional productivity metrics to reflect societal values. Traditional TFP focuses on market goods—inputs (e.g. labour) and outputs (e.g. agricultural commodities)—valued through their market prices. By contrast, "sustainable TFP" incorporates both market and non-market impacts, such as greenhouse gas emissions and nitrogen runoff. The societal perspective reframes productivity as the ratio of the societal value of outputs to the societal value of inputs, capturing both economic and environmental dimensions.

This approach depends on assigning societal values to non-market impacts. For example, the cost of nitrogen pollution must reflect its broader societal harm, such as water contamination. The key challenge lies in determining these values, which are often context-specific and influenced by societal priorities, such as food security versus environmental conservation.

Cobourn et al. (2024[9]) propose the Environmentally Sustainable Productivity Index (ESPI), which builds on index theory. The ESPI incorporates "good outputs" (agricultural commodities), "bad outputs" (environmental externalities like greenhouse gas emissions), and resource inputs. This method uses shadow pricing to estimate the societal costs of non-market impacts and aggregates these into a unified measure. The framework supports cross-country comparisons and tracks productivity trends over time.

The ESPI's application, however, hinges on assigning weights to environmental impacts relative to commodity outputs. Decision-makers must determine the relative importance of reducing environmental harms versus increasing agricultural output. Cobourn et al. (2024[9]) emphasise that this weighting cannot be determined agnostically; it requires societal input or consensus.

The societal and political dimensions of sustainable productivity

The key insights from both approaches are twofold. First, it is technically feasible to compile meaningful indicators of sustainable productivity growth in terms of both data and methods. Second, sustainable productivity measurement ultimately depends on societal decisions about priorities. Assigning weights—whether societal values in the Henningsen et al. (2024[29]) approach or shadow prices in the Cobourn et al. (2024[9]) framework—requires an explicit acknowledgment of trade-offs.

For example, how much weight should be given to greenhouse gas emissions compared to crop yields? Should these weights differ between countries with varying economic conditions? These questions are not purely technical, but involve societal, political, and ethical considerations. Moreover, achieving harmonisation across countries is critical for meaningful comparisons and policy benchmarking. As Cobourn et al. (2024[9]) note, a lack of standardisation in sustainable productivity metrics makes it difficult to compare progress across nations or to identify best practices. Yet harmonisation requires international dialogue to reconcile differing priorities and resource constraints.

Sustainable productivity metrics require agreement on societal goals and priorities. Achieving such consensus involves more than scientific modelling: it requires active dialogue among stakeholders, including policymakers, farmers, environmental groups and communities. This dialogue must address fundamental issues such as equity, and where wealthier countries may prioritise environmental conservation while developing nations focus on food security and economic development.

Is it possible to agree on how to balance environmental and economic goals?

The policy implications of sustainable productivity metrics are considerable. Measures that not only reflect current productivity but also allow cross-country comparisons could help countries learn from best practices, assess the impact of policies, and identify areas for improvement. However, given the diverse economic and environmental priorities across countries, a “one-size-fits-all” metric will have to be a compromise that reflects common ground among stakeholders and countries.

Policy decisions also hinge on how we value societal benefits and costs, especially those that extend beyond national borders, such as climate impacts. For instance, should the social cost of carbon—a figure already variable and contentious—be uniform across countries? Or should it account for different socio-economic contexts? These questions emphasise that sustainable productivity measures while useful, must be adaptable and considerate of local contexts to be meaningful and effective.

While such considerations may seem daunting at first, the literature on environmental performance measurement provides plenty of promising evidence of common ground. The calculation of shadow values—while unidimensional because they are from the perspective of the producer— already provide values for externalities. Based on economic theory, the opportunity cost for the individual is lower than that of society. Thus, such values are always lower bounds of the true value of environmental and social goods which can serve as the starting point to agree on valuation preferences of environmental and social goods.

The way forward: Dialogue and harmonisation

While advancements in measurement techniques have made it technically feasible to integrate productivity and environmental sustainability into a single metric, the societal dimension remains critical. Current academic work highlights the need to assign weights—a process shaped by societal values, political priorities, and ethical considerations. The harmonisation of these metrics, while challenging, is essential for global progress. To combine productivity and environmental sustainability effectively, we must view the challenge as both technical and societal. This requires active, inclusive dialogue among stakeholders to align technical frameworks with societal goals. Only through such efforts can we develop sustainable productivity metrics that drive meaningful change in agriculture and beyond.

Moving forward, the development of such metrics should be pursued alongside active, inclusive discussions about societal goals and priorities. Only through a combination of technical expertise and policy dialogue can we create productivity measures that genuinely reflect the environmental and social values of diverse communities and nations. Ultimately, this dual approach—a combination of rigorous technical methodology and consensus-driven policymaking—will be crucial for achieving the goal of sustainable agricultural productivity that benefits both people and the planet.

2.6. Tracking the performance of innovative livestock production systems with step up, a European platform for evidence and policy

David A. Kenny
Agriculture and Food Development Authority (Teagasc), Ireland

Key messages

- The Strategic Technologies for Europe Platform (STEP) aims to investigate the positive and negative impacts of European livestock systems, monetise its externalities, and identify the potential trade-offs across diverse types of farming systems, practices, and environments.
- The monetisation of externalities associated with livestock systems is essential to understand their sustainable productivity performance. Although research in this area is only starting, an increasing number of projects are being undertaken.

The livestock sector makes substantial contributions to food security and has certain positive environmental impacts. Nevertheless, it is also responsible for substantial environmental damages which are not accounted for when the productivity of livestock systems is assessed. This section makes the case for quantifying the externalities associated with livestock systems to facilitate a more comprehensive measurement of their sustainable productivity performance.

The European livestock sector contributes significantly to food security

The livestock sector contributes significantly to the European economy. In 2022, the estimated value of livestock production and livestock products in the EU27 was EUR 207 billion, representing 40% of total agricultural activity (EUROSTAT, 2023[30]). The sector is a net exporter on the world market and the international trade surplus in livestock commodities has steadily increased since 2000. As incomes and population growth increase, it is projected that by 2050 global demand for food products derived from livestock will increase by 60 to 70%, and that by 2033 global meat consumption will increase by 12% compared to the base period average of 2021-2023 (OECD/FAO, 2024[31]). These increases are largely due to income and population growth, which is expected to exacerbate existing tensions that result from the expansion and intensification of animal production.

Sustainable livestock-based food systems contribute to food security, economic and environmental stewardship, and sociocultural needs. They are vital for achieving most of the United Nation's Sustainable Development Goals (Varijakshapanicker et al., 2019[32]). Livestock production contributes in particular by its use of uncultivable land for food production, the conversion of energy and protein sources that cannot be used by humans into highly nutritious animal-sourced food, and the reduction of environmental pollution due to agro-industrial by-products, while generating income and supporting the livelihoods of millions of people globally. Increasing the sustainability, viability and resilience of climate-friendly agricultural production are key objectives of the EU Farm to Fork strategy. This is also consistent with the FAO's "Four Betters" vision which is comprised of better production, better nutrition, a better environment, and a better life which would leave no one behind (FAO, 2021[33]). However, the sector faces several challenges in developing a sustainable pan-European livestock production system (ELPS).

The challenge of attaining environmental sustainability

The global trend for greater demand of livestock-derived food products faces challenges due to: (i) its impact on the environment (e.g. climate impacts, contribution to eutrophication); (ii) ethical issues (increased societal concerns for animal welfare, including the conditions of production, transport and slaughter); and, (iii) human health considerations (high levels of meat consumption have been associated with an increased risk of certain chronic diseases) (OECD/FAO, 2024[31]). For health and environmental reasons, the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) recommend reducing the share of food of animal origin in human diets by rebalancing protein sources between plant and animal to 50-50% (diets in European countries currently contain approximately 65%-70% animal proteins). In Europe, the consumption of animal products, after a continuous increase since the 1970s, is stagnating or shrinking (except for poultry) and the Farm to Fork strategy of the Green Deal aims to increase food consumption to a more plant-based diet and less red and processed meat (European Union, 2020[34]). The present trend towards less consumption of animal products is accompanied in Europe by a growing demand in terms of 'quality', alongside ethical and environmental considerations linked to animal husbandry.

The impact of animal production on the environment is substantial. Notably, regional concentrations of animal production cause diffuse pollution of air and water. More than 80% of the nitrogen of agricultural origin present in all European aquatic environments is linked to livestock farming activities, and livestock farms are the principal emitters of ammonia. Additionally, the role of European livestock on deforestation has provoked contentious debates. Livestock supply chains are estimated to account for 14.5% of total human induced GHG emissions (Tedeschi et al., 2022[35]) and it is estimated that about 80% of the GHG from livestock is derived from ruminants, accounting for in excess of 90% of total methane emissions from livestock Scholtz et. al. (2020[36]). Indeed, 2% to 12% of gross energy consumed is converted to enteric methane during ruminal digestion, contributing to approximately 6% of global anthropogenic GHG emissions (Beauchemin et al., 2020[37]).

The world ruminant population increased by over 66% from 1960 to 2017, whereas the population of non-ruminants increased even more rapidly, by 435% over the same period (FAOSTAT, 2017[38]). While EU livestock numbers continue to fluctuate and are decreasing in several Member states (EUROSTAT, 2023[30]), the global population of both ruminant and non-ruminants are projected to increase in the coming years, thereby exacerbating GHG emissions from animal agriculture. However, these environmental – as well as health and animal welfare – impacts are not accounted for when the productivity of livestock systems is assessed. This is primarily because most of these costs are externalised, i.e. not reflected in the market prices, and are therefore not accounted for in the decision making of actors in food value chains (Hendriks et al. (2021[39]).

There are ongoing initiatives in Europe to measure and tackle externalities

Resolving problems caused by externalities requires that they be measured and made comparable with monetary market values. Monetisation of externalities is needed to estimate the "true" costs of animal-based products. Preliminary research estimates that such external costs at a global scale could be close to double the market value of food (FOLU, 2019[40]) Scholtz et al. (2020[36]). Efforts are underway in Europe to quantify the externalities of European livestock-based production system, such as the FOODCoST project granted Horizon Europe funding in 2022. Moreover, the European Commission recently launched a Thematic Working Group tasked with identifying a suitable animal-based indicator, or set of indicators, to reflect the impact of the CAP on animal welfare in the European Union, building on work carried out in a study on CAP measures and instruments promoting animal welfare and reduction of antimicrobials use (European Commission, 2022[41]). Accurate and holistic evaluation and monetisation of such indicators is critical to their uptake and implementation as a CAP Pillar II strategy to support improved ELPS.

In response to criticisms of livestock production, European actors in this sector are constructing sectoral plans to be more responsive to societal, environmental, and health concerns. The Farm to Fork strategy aims to achieve by 2030 that at least 25% of the European Union's agricultural land will be under organic farming, as well as to reduce antimicrobial and mineral fertilisers by 50 and 20% respectively, and GHG emissions by 55%. The Farm to Fork strategy also proposes to revise legislation to ensure a higher level of animal welfare. Evolving consumer preferences relating to animal welfare-friendly practices, naturalness, healthy products, farmer's income, and environmental impacts may provide incentives to change existing practices towards more innovative husbandry practices. These could include limiting confinement, mutilations, culling of unproductive animals (i.e. males in egg production), drugs and chemicals, and arable land use on the one hand and increasing outdoor rearing and grazing, natural and biodiversity-enhancing practices on the other. Notwithstanding affordability aspects, industrial intensive livestock production is no longer regarded as acceptable by many citizens.

There is also a need to better understand the impact of grazing by domestic livestock, which currently occupies 26% of terrestrial land cover (FAO, 2012[42]). Research has shown that different husbandry systems are associated with a considerable variety of environmental impacts on animal welfare and health and on animal product composition, which in turn can affect consumer satisfaction and health. Although livestock production in general is often cited for its potentially negative impact on ecosystem diversity (Filazzola et al., 2020[43]), traditional grazing is also seen in Europe as having a positive effect on biodiversity in pastures by creating and maintaining sward structural heterogeneity, particularly because of dietary choice, treading, nutrient cycling, and propagule dispersion. Indeed, the adoption and enhancement of more biodiversity-friendly and agroecological-based farming systems are among the objectives of the EU Biodiversity Strategy for 2030.

These emerging trends and strategies, however, lack systematic science-based evidence concerning the sustainability and quality of the resulting products. To express their preferences and make informed choices regarding the selection of animal derived food products, consumers need reliable information on the safety, nutritional value, and environmental impact of products that are obtained from various husbandry systems as indicated by their sustainability and ethical properties (Prache et al., 2022[44]). The current debate on positive or negative impacts, externalities and values of animal production is based on contradictory data and reflects the difficulties in quantifying natural processes linked to agricultural production and land use.

STEP UP project for quantifying externalities and steering policies towards SPG

The Sustainable Livestock Systems Transition and Evidence Platform for Upgrading Policies (STEP UP) project was developed to provide policymakers with a robust evidence base, including the monetised values of livestock farming as part of the food and wider ecosystems (Figure 6.1). This project is primarily funded through the Horizon Europe research funding programme, along with some funding from UK Research and Innovation.

STEP UP will extensively investigate positive and negative impacts, externalities and their monetisation, including identifying, understanding and ranking potential trade-offs, across diverse types of farming systems, practices and environments throughout Europe. It will build on a wide range of scientific information, reports, expert opinions, practitioner knowledge, and other available material such as databases. The STEP UP team have extensive experience in delivering on this type of mapping exercise, with many having leadership roles in the preparation of key reports for the European Commission (EC), as well as in other international bodies such as the Standing Committee on Agricultural Research (SCAR), FAO, Livestock Environmental Assessment and Performance Partnership (LEAP, FAO), and Global Agenda for Sustainable Livestock (GASL).

In order to align the challenges relating to the sustainability of future livestock systems with those imposed by global limitations on further expansion, STEP UP will embrace the concept of Safe and Just Operating

Space (SJOS) and align the concept to the scale of EU livestock systems. The SJOS includes biophysical tipping points, with social science considerations of distributional equity and justice (Raworth, 2012[45]). Originally defined at the level of the Earth system (Humanity), it encompasses both environmental ceilings that must not be transgressed and social foundations that must be respected. The conceptual framework of Planetary Boundaries (PB) and social issues, which has come to be known as a 'Doughnut', has been proposed to provide a compass for the 21st century (Steffen et al., 2015[46]). Nine Earth-system processes and associated thresholds are considered crucial to define PB. According to Rockström et al. (2009[47]), three have already been surpassed: biodiversity loss, climate change, and nitrogen cycle. Land conversion has been added to the list of exceeded boundaries since the initial report was published (Raworth, 2017[48]). Agri-food and livestock systems are contributing to the crossing of these thresholds; they must reform if the SJOS is to be preserved. In the STEP UP project we propose to operationalize a novel SJOS approach for ELPS.

Throughout the STEP UP project, the socio-economic dimension is embedded as a research topic via the inclusion of economic and social lifecycle assessment (SLCA) impacts and externalities, and by conducting the study with clear stakeholder engagement and a multi-actor approach. The goal is not only to reduce the negative impacts of livestock systems, but to improve their environmental sustainability as well as the socio-economic sustainability of the primary stakeholders.

2.7. Towards a comprehensive assessment of agriculture's sustainability performance: Insights from organic farming

Adrian Muller
Research Institute of Organic Agriculture (FiBL)

Key messages

- To comprehensively measure both the economic and environmental sustainability performance of agricultural practices, it is essential to assess output in human edible calories and protein from whole landscapes over extended periods of time, rather than narrow short-term single crop indicators.
- Adopting a broader food systems perspective that extends beyond assessing production processes to consider food loss and waste, as well as dietary patterns, can open new avenues in measuring the economic and environmental sustainability performance of agricultural production.

Sustainable productivity as a framework to measure the performance of production systems offers a good opportunity to consistently address issues related to sustainable agriculture. On a narrower level, traditional total factor productivity (TFP) can address yields, traditionally seen as the main performance metric for agriculture, in conjunction with the use of other inputs and the production of other outputs in agriculture. Expanding the TFP framework would allow for a deeper analysis of positive co-benefits (e.g. improved soil fertility, biodiversity support) and negative impacts (e.g. various emissions, soil degradation, biodiversity loss).

In general, this measurement strategy is thus well suited to assess outputs from a broad range of approaches (e.g. agroecology, regenerative agriculture, organic agriculture) that aim to improve environmental outcomes. These approaches all emphasise the importance of achieving decent yields, while also giving due weight to other beneficial and damaging outputs on the environment. The goal is to provide a bundle of positive outputs per unit of inputs. Crop production is but one factor (albeit a central one) amongst others, and negative outputs and the use of other inputs need to be kept to a minimum.

Organic agriculture provides beneficial environmental performance on the landscape (Seufert and Ramankutty, 2017[49]). However, a central challenge is overcoming its low-yield performance compared to conventional agriculture. At present, organic yields are on average around 20% lower than conventional yields, although some highly performing organic systems building on high diversity in cropping patterns show differences of around 10% (Ponisio et al., 2015[50]). Hence, efforts are undertaken to increase organic yields, to ensure high yields also in this sustainable production system. It is clear nonetheless that organic yields will most likely not attain the yields of conventional intensive industrialised agriculture, which has a primary focus on obtaining high yields generally accompanied by low awareness of reducing its negative impacts and supporting positive side-effects. A current EU-funded project led by the Research Institute of Organic Agriculture (FiBL) is attempting to identify the main determinants of organic yields and how higher yields can be achieved (OYUP, 2024[51]).

Increased diversity in crop rotations and the breeding of organic crop varieties are promising strategies. As such, there is a focus on specific organic breeding strategies to develop varieties that are optimally adapted to organic production contexts with lower nutrient inputs and biological plant protection strategies. Yet organic production continues to depend on conventionally-bred varieties that are not optimally designed for organic contexts.

Organic agriculture also focuses on soil fertility, soil health, and biodiversity. Some argue in view of this that organic yields may not increase to equalise conventional yields in the future but rather sustain current yields by maintaining production means, most importantly in comparison to decreasing yields in conventional agriculture. The argument is that organic production focuses on sustaining the production means, particularly healthy and fertile soils, as opposed to conventional agriculture which often results in a degradation of soils and loss in soil fertility, leading in turn to lower yields. In this context, a shift of the narrative is warranted by stating that "organic agriculture does not have too low yields for ensuring food security, but conventional agriculture has too high yields for ensuring sustainability".

From a food systems perspective, a broader approach to productivity is needed beyond the focus on yields. Ultimately, what counts is the quantity of food ending up on peoples' plates which is actually eaten. Thus, food waste and loss must be taken into account when addressing yields in agricultural production systems. In organic agriculture, in addition to yield improvements, reduction in storage losses are required. What is of greater long-term benefit: efforts to increase yields or efforts to reduce losses? This question applies not only to organic and other agroecological production systems, but to agriculture of any kind; reducing storage losses and food waste is one strategy to increase supply without yield increases. There not only losses due to pests are relevant, but also waste due to regulations and industrial norms (e.g. related to expiry dates), the homogeneity of the product for easy processing or specific requirements regarding composition for industrial processing (e.g. high protein contents in wheat to ensure high "baking quality"), or market and consumer expectations (e.g. aesthetic aspects such as spotless fruit peels or equal size and form of vegetables).

TFP metrics play an important role is assessing the performance of agriculture but it should account for systemic aspects such as food waste. Improved sustainable productivity growth (SPG) indicators would include the output bundle that finally reaches those that use the outputs, rather than just those produced on the field. A focus on a new narrative could be helpful: "What is the most sustainable product? One that is not produced. And which products do we not need to produce? Those that are lost or wasted." Avoiding these lost products directly saves inputs for their production and on related emissions, thereby reducing the zero productivity parts in the equations that stem from such losses.

For a truly systemic approach to productivity, further steps need to be taken both centrally linked to organic production systems and their role and performance in food systems. First, we need to go beyond single crop yields when defining the main output for assessing the productivity of organic agriculture. The focus should be on the quantity of food obtained over several years (e.g. over a whole crop rotation) from a whole landscape, including the products derived from animals fed on feed crops produced in the landscape. This quantity can be measured through a number of indicators, where the classical yields as physical quantity is less relevant than, for example, total calories or proteins for human consumption.

Second, we need to address the use of the crops produced. In many countries, predominantly in industrialised ones, the productivity of croplands for producing human edible calories and protein is determined by the share of croplands used for feed production. Shifting towards more direct food production on these croplands would improve the level of productivity of agricultural production systems, although this works only if consumption patterns change accordingly towards reduced shares of animal-source food. As with avoiding food waste, such a focus on increased plant-based consumption patterns requires that any debate on sustainable agricultural productivity is addressed with a whole food system perspective, including consumption.

Reducing waste and loss, as well as feed production on croplands, reduces the pressure to produce high yields to achieve a certain calorie and protein supply, thus ensuring food security with relatively lower yields from organic and other agroecological production systems that also deliver other beneficial outputs (Muller et al., 2017[52]). This is partly captured by approaches such as TFP, but only if the main output is defined broadly enough; namely, as "quantity of human edible protein produced from a whole landscape over several years", rather than "biomass yield of a single crop".

Conclusion

TFP approaches to measure performance fit well to agroecological production systems such as organic agriculture. Given the yield gap in organic agriculture and the importance of yields in TFP, improving them is an important task in current agroecological research. However, it is important to adopt a truly systemic and comprehensive TFP approach to assess SPG, going beyond single crop yields as the relevant output measure, and focusing on the output in human edible calories and protein from whole landscapes over an extended period of time. As such, the productivity of agricultural systems cannot be addressed without addressing consumption, including food waste and loss, as well as dietary patterns, in particular as shares of animal-source food and cropland-based feed production become central for encompassing TFP assessments. It is important to be aware of these systemic aspects and to correspondingly adopt a whole food system level approach when addressing productivity in sustainable agriculture, as otherwise, a narrow focus on TFP may again overly focus on increasing single crop yields, c.f. the focus emphasized in OECD (2022, p. 30[53]): “The takeaway message is that we can only continue to feed the world and improve people’s well-being if agricultural TFP continues to grow”.

Data requirements for unbiased SPG assessments are high and it is important to adopt a pragmatic approach on what is covered to avoid overly demanding data collection. Overly simplistic proxies for relevant variables also need to be avoided to ensure unbiased and correct assessments. As OECD (2022, p. 17[53]) states: “Typically, there are three types of obstacles to TFP measurement: obtaining appropriate measures of the outputs and the inputs that are used, especially primary inputs; capturing changes in quality of outputs and inputs over time (or differences across regions in cross section comparisons); and finding appropriate weights on inputs and outputs. These three issues are of particular concern in agriculture.”

Finally, TFP is a relative measure relating outputs to inputs, but it does not account for total production and pollution levels. A central drawback is the landscape-related impacts of most environmental pollutants (except greenhouse gas emissions) that have to be assessed within local ecosystem carrying capacities. Agriculture in a certain landscape can be highly productive measured in high TFP values, but may nevertheless damage the environment and degrade production factors, in case the total emissions transgress the local carrying capacities. Awareness of absolute emissions in a context of local ecosystem boundaries needs to complement a relative performance measure such as TFP.

2.8. Assessing the role of technological innovations in achieving sustainable agricultural productivity

Marc Müller
BrightSpace Project, Wageningen Economic Research

Key messages

- Frameworks such as the Sustainable Development Triangle and the Safe and Just Operating Space provide valuable tools for evaluating the performance of achieving SPG including environmental, social and economic dimensions.
- Expanding the scope of measurement criteria enables the better identification of trade-offs and synergies, crucial for guiding efforts on the choice of policies and innovations for boosting sustainable agricultural productivity.
- Productivity gains achieved through technological innovations may result in more efficient resource use, but do not necessarily reduce the overall quantity of natural resources used. Hence, they do not automatically lead to better environmental outcomes.

The international conference "Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies", explored in Session 5 how specific practices, processes, and technologies applied in the field contributed to advancing sustainable productivity growth in agriculture. This session highlighted the diversity of approaches and underscored the importance of careful assessment and measurement, particularly given the large variety of practices and technologies for sustainable agricultural productivity.

This section offers some reflections on technologies for sustainable agricultural productivity. Jiro Ariyama discussed FAO's WaPOR initiative, which uses remote sensing to monitor agricultural water productivity by measuring biomass production relative to water consumption. In Sudan, this revealed high and low-performing areas. However, low water costs were found to often disincentivise efficiency and improved productivity may inadvertently increase irrigation. Tadashi Yoshihashi highlighted work at the Japan International Research Center for Agricultural Sciences (JIRCAS) on biological nitrification inhibition (BNI), where a wild wheat chromosome with BNI traits was introduced into elite wheat, increasing yields and reducing nitrate formation, nitrous oxide emissions, and fertiliser use. Everton Capote Ferreira described efforts at The Sainsbury Laboratory to develop rust-resistant soybeans in Africa, reducing yield losses, fungicide use, and GHG emissions while improving soil health and biodiversity, supported by smart technologies like GPS and AI for weather and disease prediction.

The projects discussed demonstrate that agricultural productivity gains can align with positive environmental outcomes. However, evidence indicates that increased water productivity may lead to the expansion of irrigated areas, potentially leaving total agricultural water use unchanged or even higher. This illustrates that productivity gains, while essential, may not guarantee sustainability. Additionally, low or non-existent water prices often discourage the adoption of water-efficient innovations. A similar economic challenge applies to the introduction of crop varieties with lower nutrient requirements or greater disease resistance; if the costs of these seeds exceed potential savings, their economic appeal diminishes. Furthermore, high investment costs can exclude smaller farms with limited resources, exacerbating existing income inequalities. Beyond these farm-level challenges, factors such as insecure property rights—particularly related to land use—and inconsistent policy support for innovation frequently hinder investment.

These considerations raise three important questions about the role of technological innovation in sustainable agricultural productivity: should assessments account for hypothetical effects on natural resource use resulting from scaling innovations to landscape or sector level? Is it sufficient to focus solely on environmental processes, like those identified as planetary boundaries, e.g. by Rockström et al. (2009[47]); or should social dimensions such as income and gender inequality also be considered? How extensively should the political context and its capacity to foster innovation be factored into evaluations?

Frameworks such as the Sustainable Development Triangle (Munasinghe, 1993[54]), which integrates environmental, economic, and social dimensions, and the Safe and Just Operating Space (Raworth, 2012[55]), which combines the nine planetary boundaries identified by Rockström et al. (2009[47]) with 11 social and economic dimensions of human wellbeing, provide valuable tools for addressing these questions. The latter framework is applied to European agriculture within the BrightSpace project, which identifies a broad range of socio-economic indicators alongside planetary boundary processes linked to agriculture.

Expanding the scope of sustainability assessments to encompass additional dimensions increases the likelihood of identifying trade-offs alongside synergies. While the examples discussed highlight win-win outcomes within the context of specific projects, scaling these innovations could reveal trade-offs when broader sustainability criteria are considered. It is essential to clearly define the processes included in sustainability assessments and to ensure that the metrics used are transparent and measurable.

In conclusion, trade-offs between increased production and improved environmental performance, or between competing dimensions of sustainability, are likely when more comprehensive criteria are applied. Achieving sustainable agricultural production requires motivation, investment, affordability, and knowledge. Context is crucial: policies, social norms, and secure property rights related to land use can either facilitate or hinder investment. Measuring changes in natural capital stocks and ensuring alignment with planetary boundaries will be vital in this process.

2.9. Environmental Indicators for the Sustainable Intensification of Agricultural Production: Trade-offs and the challenge of scales

Allison M. Thomson
Foundation for Food & Agriculture Research

Key messages

- There are multiple dimensions to the consequences agricultural production has on the environment. Current crop and production systems will continue to impact carbon and nutrient cycling, with implications for water, soil and air quality.
- It is key to simultaneously track and assess agri-environmental and productivity outcomes for a better understanding of the existing trade-offs with the objective to minimise them.
- Scientific research can help identify the synergies and trade-offs between multiple environmental and production goals to help producers make decisions, and to enable governments and private actors to aggregate and track progress of policy commitments.

Assessing quantitative measurements and indicators to determine the environmental impacts from agriculture at a national or global level is challenging when considering the diversity across scales of both agricultural systems and environmental conditions. The broad geographic diversity (e.g. soil properties, landscape positions, water resource availability) and social diversity (e.g. land tenure, access to knowledgeable extension or agronomic advisors, access to seeds and other agricultural inputs) require diverse and dynamic criteria that set which indicators are most relevant to assess progress towards sustainable intensification in a given country or region. Individual land owners and managers must adapt their operations to these constraints; they also have their own unique objectives for the use of the land that may not be directly correlated with profit opportunity. This complexity across scales calls for robust scientific research programmes to better understand the implications of changes in agricultural production and the environment so as to assist all actors to identify and adopt best practices for progressing towards sustainable intensification and track progress.

Measuring sustainable intensification across scales

Improving at once agricultural production and environmental outcomes - that is, achieving sustainable intensification (Thomson et al., 2019[56]) – will have the environmental benefit of sparing land from agricultural expansion. This intensification is critical, particularly if we are to achieve the UN's Sustainable Development Goals. However, while it is easy to define sustainable intensification, it is not easy to achieve and requires comprehensive efforts from the field to the national level. Defining how to measure and track it at aggregate national levels should also take into consideration the feasibility of whether the indicators will respond to desired changes in agriculture systems. Thus, it is important that these high-level tracking indicators take into consideration the implementation and local context in order to understand what types of interventions or practical changes such indicators may incentivise throughout the full chain of actors.

For sustainable agricultural indicators designed to reflect changes in practice, it is useful to consider which incentives or motivating factors will influence adoption by farmers across a region or country. As individual practices or suites of practices will not have the same impact on different fields and farms, one approach is to assess sustainability by tracking change over time in specific environmental outcomes of interest. While this provides a more specific indicator of sustainable intensification at a local scale, it is more challenging to measure and can require significant data collection, the use of agri-environmental modelling, and collaboration with the scientific community. A range of tools at the national and international levels have been developed over the past 15 years to address this measurement and tracking challenge across reginal scales. These are primarily used in the private sector as companies work to better understand and address their Scope 3 impacts on climate, water and biodiversity, while supporting farmers in their sourcing regions (Thomson et al., 2017[57]).

Once key environmental indicators and associated changes in practice are identified for a region, achieving improvements will depend on a range of scientific, technical, financial and social factors. Social science research has identified key factors for success. One is access to guidance and advice from agronomic advisors who are knowledgeable about the practices, the environmental outcomes, and the region. These advisors may be employees of a government, university, NGO, or private company, and it is important for them to have access to the necessary education and resources (Prokopy et al., 2019[58]). Studies have also identified access to financial resources and technical resources as challenges when adopting new practices. For government programmes, a significant challenge for producers can be the complexity of rules and requirements to access funding that supports a change in practice.

The temporal scale of sustainability is also critical to consider. Traditional annual metrics tied to the economic production of specific crops are often unable to capture the full productivity or environmental change of a farm. Often, a change in practice can lead to a temporary (or sustained) decline in crop yield (production of a single crop per growing season), a more challenging or complex farm operation, and risks to qualifying for government support programs. Similar to challenges of organic production, considering productivity as a function of an area of land over multiple years, rather than the volume of marketable gain in a given year, is crucial if productivity measures are to be connected to environmental impact. For example, within a given year a grain crop may be produced during the main growing season with a cover crop during the typically dormant, or fallow, season. That cover crop has environmental benefits of reducing sediment erosion and nutrient loss from the field, providing biodiversity habitat, and enhancing soil health and carbon. It can also contribute value to the operation that is not captured through a commodity sale, such as grazing for livestock, harvesting for animal bedding, or other non-food use (Deines et al., 2023[59]) (Gardezi and Arbuckle, 2019[60]). Combined, these attributes create value, but may not be captured in current productivity measures.

High level indicators designed to track sustainable intensification can incorporate lessons and examples from ongoing efforts to improve environmental outcomes in regional and global supply chains (Freidberg, 2023[61]). Public-private partnerships have proven to be effective tools to share the risk of farming transitions among the various parties who benefit from the environmental improvements– producers themselves, their customers, food consumers, and governments.

Scientific research for sustainability

For lasting improvements to be realised for sustainable intensification, practices and their environmental impact need to be verified by science and demonstrated to work at farm scale in the conditions where adoption is recommended. Research is critical to understanding how practices might reduce the environmental impact, while also understanding any impact on crop yields or other trade-offs. Scientific research can also address challenges and uncertainties regarding the feasibility of adoption. For example, a practice that requires expensive new equipment that a farmer is not trained to use will be more challenging to adopt at scale without support or incentives. Research methodologies that incorporate community and stakeholder co-design principles can help ensure feasibility by addressing any limitations, barriers, or concerns in the practice design and implementation (Andrieu et al., 2019[62]).

Research is also critical to better understand the full suite of impacts from interventions in the complex agroecosystem, especially as these relate to the carbon and nutrient cycles through water, air, and soil. While it is tempting to assume that all environmental indicators will improve with conservation practices, there are documented trade-offs that can occur. For example, reducing tillage intensity can improve certain soil properties, while at the same time increase phosphorous loss from the soil. In certain regions of the United States, this dynamic has caused downstream water quality problems, with algal blooms in surface waters directly traced back to no-till adoption by farmers (Kleinman et al., 2022[63]). Thus the definition of what sustainability means for a region must be specific to the environmental concerns of that region, while monitoring other environmental indicators to keep any negative impacts to a minimum is equally important. For example, in some regions where the primary environmental concern might be water resource efficiency and the solution could be improved irrigation technologies, it is important to simultaneously monitor and consider any greenhouse gas emissions implications of changing the energy requirements for irrigation (Grafton et al., 2018[64])

These complexities highlight the importance of robust scientific research programmes from agronomic and soil sciences in collaboration with agricultural producers to explore alternative management options, understand their synergies and trade-offs with production and environmental goals, contextualise how and where they can be best adopted, and inform public and private support programmes of the most effective ways to achieve the desired impact. Scientific research underpins the methods that are deployed to track and attribute environmental impacts through computational models, as do satellite and proximal remote sensing that can complement, inform, and verify traditional survey methods.

Finally, research methods used to track change over time demonstrate that change may not be continuous or linear, and that many environmental indicators may take several years to change or be influenced by factors outside the control of producers. For example, one of the primary drivers of water quality is rainfall amount and intensity; producers may be making every effort to reduce nutrient loss from their fields, but still see increases in nutrients in surface water in wet years, necessitating a more comprehensive, community approach to reduce downstream environmental harm (McLellan et al., 2015[65]). In addition, climate resilience components should be factored into indicators of sustainable intensification as climate patterns shift and agricultural producers need to adapt. Even if aggregate indicators of sustainability cannot capture unique situations, they can reflect the ranges of uncertainty and degree of confidence in any changes over time.

2.10. Assessing the sustainable productivity performance of innovative agricultural practices and technologies at local and macro level

Maria Vrachioli
Technical University of Munich

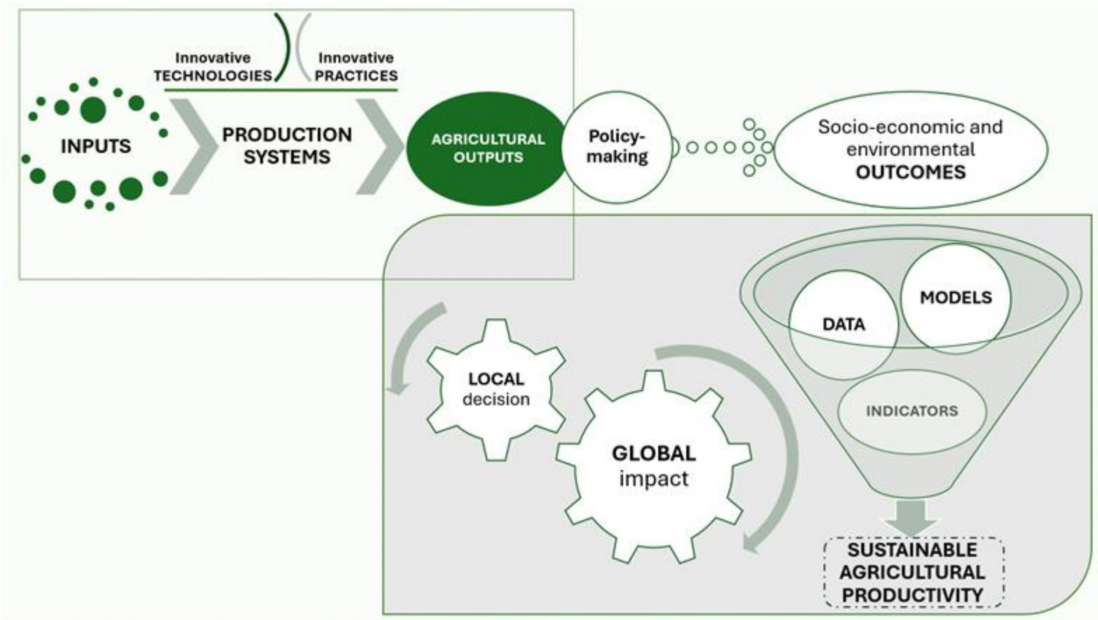
Key messages

- Innovative practices and technologies are essential to improving sustainable productivity growth (SPG) in agriculture. Innovations are often developed at local scales suited to specific agro-ecological and socio-economic conditions, but their impact on boosting SPG hinges on their scalability. Developing flexible metrics that reflect the local context but which can be standardised to align with global sustainability goals is central to assessing whether innovations indeed lead towards SPG.
- The integration of data across scales is key for enabling policymakers to refine SPG policies. This requires robust data-sharing platforms to facilitate the flow of information between local and global stakeholders, and the adoption of standardised reporting protocols to ensure comparability across regions.
- Policymakers need to incentivise innovation through the promotion of research and development for technologies and practices that lead towards SPG, design frameworks that balance flexibility at the local level with contributions to global sustainability objectives, and invest in data infrastructure that enable effective and timely interventions in agricultural systems.

Assessing agricultural sustainable productivity performance is increasingly important as researchers and policymakers seek to balance productivity with environmental sustainability. This has become urgent as global agriculture faces the triple challenge of having to satisfy the nutrition needs of a growing population in an environmentally sustainable way, while providing the livelihoods of those gaining their living along food supply chains (OECD, 2021[66]). Finding innovative practices and technologies in agriculture is therefore increasingly important and requires identifying the methods and metrics needed to assess the effectiveness of agricultural innovations that will improve sustainable agricultural productivity. An emphasis on the interplay between innovation, geographical scale, and policy should be a priority (Figure 2.3).

Sustainable productivity in agriculture requires reconciling increased production with environmental stewardship and economic viability. Coomes et al. (2019[67]) highlight that measuring sustainable total factor productivity (TFP) involves evaluating the output produced relative to inputs, while accounting for environmental and social externalities. This is complex, however, due to the multidimensional nature of sustainability; it requires tools that can offer insights without overwhelming policymakers. Metrics and methodologies to assess sustainable productivity must ensure a balance between comprehensiveness and usability. Indeed, policymakers gain greater insights from metrics that are rigorous and straightforward. A pragmatic approach would involve the use of indicators that capture resource use efficiency, environmental impacts (e.g. greenhouse gas – GHG – emissions, and socio-economic outcomes. Such metrics must remain flexible enough to adapt to diverse local contexts.

Figure 2.3. Conceptualising the measurement of sustainable agricultural productivity



The role of innovation in advancing agricultural sustainability

Innovation is central to achieving sustainable agricultural productivity. It includes advancements in production practices, technologies, and institutional frameworks. Examples include: (i) innovative production practices that target improvements in soil health, organic cropping systems, and livestock management so as to reduce environmental impacts while maintaining productivity; and (ii) innovative production technologies that focusing on technological advancements in water management, nature-based solutions, and tools to minimise GHG emissions. The OECD's 2024 *Agricultural Policy Monitoring and Evaluation* report (OECD, 2024[68]) underscores the importance of these innovations in fostering sustainable productivity growth. For example, precision agriculture and climate-resilient crop varieties demonstrate the potential of technology to reduce resource use while boosting yields. Finally, building on natural capital—such as biodiversity and ecosystem services—should align with broader sustainability goals.

Geographical scale: From a local to a global perspective

Agricultural innovations are often developed and tested at a local scale, where they can be tailored to specific agro-ecological and socio-economic conditions. However, their broader impact will depend on their scalability. Scaling innovations from local to regional and global levels involves identifying and assessing trade-offs and synergies. To achieve this, it is essential to develop metrics that are flexible enough to reflect local contexts, but sufficiently standardised to align with global sustainability goals. It is also important to strengthen the connections between global datasets and local data to ensure consistent monitoring and measurement. The integration of data across scales enhances the ability of policymakers to identify trends, benchmark progress, and refine policies in real time. For example, Burke et al. (2021[69]) explore how integrating satellite data with machine learning can enhance our ability to monitor and improve sustainability metrics, offering a scalable and precise tool to assess environmental and socio-economic factors that are critical to sustainable development goals.

Continuous monitoring and policy integration

Sustainable agricultural productivity requires continuous monitoring to benchmark progress and refine policies, with real-time data playing a crucial role in enabling adaptive policymaking. This iterative process benefits from the establishment of robust data-sharing platforms that facilitate the flow of information between local and global stakeholders, as well as the adoption of standardised reporting protocols that ensure comparability across regions. Policymakers must also consider the dynamic nature of agricultural systems, recognising that continuous innovation and refinement of metrics are necessary to keep pace with emerging challenges such as climate variability and evolving market demands.

Achieving sustainable agricultural productivity hinges on policy reforms that support innovation and encourage sustainable practices. Key policy recommendations include incentivising innovation through the promotion of research and development in sustainable agricultural technologies and practices. In addition, policymakers should design frameworks that balance local flexibility with contributions to global sustainability objectives. Investing in data infrastructure is equally important, as enhanced data collection and analysis are vital for informed decision-making, which in turn enable more effective and timely interventions in agricultural systems.

Conclusion

Sustainable agricultural productivity is critical for global food security and environmental resilience. By integrating innovative practices and technologies, adopting flexible yet standardised metrics, and ensuring continuous monitoring, agriculture can transition toward sustainability. The collaboration between farmers, researchers, policymakers, and practitioners is essential to navigate the complexities of this transition. This requires a commitment to innovation, informed decision-making, and adaptive policy frameworks. Through concentrated efforts, sustainable productivity growth can be achieved, ensuring that agriculture meets the needs of present and future generations.

2.11. The impact of R&D-led productivity growth on GHG emissions and biodiversity

Uris Lantz C. Baldos
Purdue University

Key messages

- R&D-led productivity growth saved about 222 million ha of land from cropland conversion, avoided around 3 Gt CO_2 eq/year of GHG emissions, and saved 9 700 threatened plant and animal species from extinction between 1990 and 2015.
- Continuing to feed the world while reducing the environmental impact of agriculture will require further R&D investments. If R&D spending in developing regions increases by USD 600 billion PPP by 2050, combined with the protection of carbon rich land, 112 million ha could be saved from agricultural expansion, avoiding 1.3 Gt CO_2 eq/year of GHG emissions and protecting 9 900 plants and animals species from extinction.
- Productivity growth associated with the use of high yielding varieties, however, has also led to environmental damages through the overuse of fertilisers, pesticides, and irrigation. Future innovation efforts facilitated by improved monitoring and measurement of environmental and productivity outcomes must be directed to overcome these trade-offs.

Productivity growth, driven mostly by R&D investment, plays a key role in feeding a growing world population while preserving land from agricultural expansion, protecting biodiversity, and avoiding GHG emissions. This section investigates the environmental outcomes of R&D-led productivity growth based on R&D models and global gridded agricultural models. It estimates how greater R&D investments could influence cropland use, biodiversity and GHG emissions, including under scenarios that combine it with environmental protection policies.

Productivity growth is a key driver of the global farm and food system. From 1961 to 2020, global population increased by 160% from 3 to 7.9 billion people, and agricultural output grew even faster by around 270% (FAO, 2023[70]). This remarkable growth in world farm output is mainly due to strong gains in total factor productivity (TFP) (USDA ERS, 2024[71]) and feeding the world sustainably in the coming decades will require further such gains. Although improvements in agricultural TFP growth have been linked to date to one-time market reforms and institutional improvements (Rozelle and Swinnen, 2004[72]), as well as agricultural research and extension (Jin and Huffman, 2016[73]), continuous farm productivity growth will derive primarily from annual investment in agricultural research and development (R&D) (Alston et al., 2010[74]) (Fuglie, 2012[75])

R&D investment generates knowledge capital, which is crucial to the development of new technologies, farm management practices and improved crop varieties that enhance farm productivity. These innovations are spread across countries, especially in regions which share similar farming systems and agro-climatic conditions. Using parameters taken from the literature and publicly available data on R&D expenditures, Fuglie (2017[76]) demonstrated how well R&D-driven productivity growth explained historical TFP growth over the period 1990 to 2011 for key world regions. On average, historical R&D investment has been the basis of more than half of regional TFP growth over this period. In Southeast Asia, The People's Republic of China, and Africa, however, estimates of R&D-led productivity growth are far below historical TFP estimates. These gaps could be attributed to market reforms and institutional improvements which influence the trajectory of agricultural productivity.

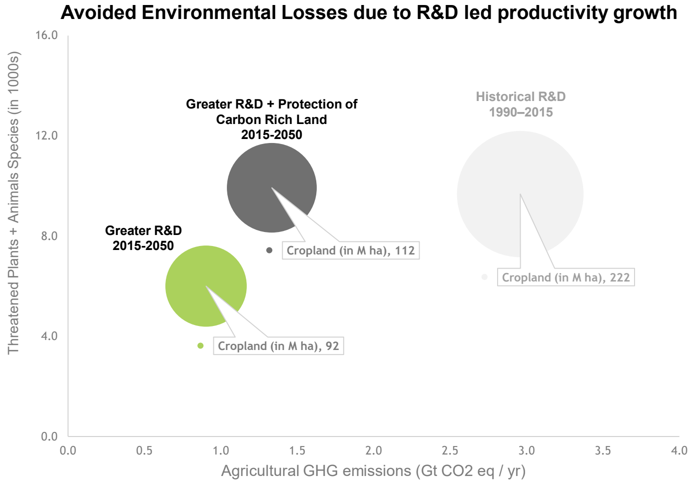
The composition of R&D-driven growth varies worldwide. In developed regions, public and private R&D as well as international R&D spillovers are key sources of agricultural TFP growth. For developing regions, public R&D is the main driver, but investments in international agricultural research also contribute to farm productivity.

Investing in agricultural R&D is a crucial policy tool for achieving sustainability within the global farm and food system. To investigate the environmental benefits from R&D-led productivity growth, investment scenarios from R&D models could be linked to global agricultural models. Aside from incorporating market linkages on production, consumption and prices, these models can also report changes in key environmental indicators such as land use change and greenhouse gas (GHG) emissions. Global agricultural models are also useful for scenario analysis. By comparing the outcomes between two scenarios, for example with and without R&D-led productivity growth, it is possible to isolate the effects of R&D investments on agricultural output and the environment.

Figure 2.4 reports global estimates of avoided cropland expansion, avoided GHG emissions, and threatened plants and animals saved from extinction due to R&D-led productivity growth for three scenarios, namely: “Historical R&D” over the period 1990 to 2015; “Greater R&D” for the future period 2015 to 2050; and “Greater R&D + Protection of Carbon Rich Land”. These estimates are calculated using the R&D model from Fuglie (2017[76]) and a global gridded agricultural model (Haqiqi and Hertel, 2025[77]) which incorporates high-resolution data on where crop production activities occur. Fine scale modelling allows the assessment of gridded environmental metrics such as land use carbon intensity (West et al., 2010[78]) and potential impacts on the number of threatened plants and animals species (Chaudhary and Brooks, 2018[79]). Baseline growth rates common to these scenarios include historical and future growth rates in regional population, per capita incomes (FAO, 2023[70]), historical biofuel growth rates (IEA, 2019[80]), TFP for crops and livestock (USDA ERS, 2024[71]) and TFP for the processed food sector (Griffith, Redding and Reenen, 2004[81]).

The scenario Historical R&D reports the impact of R&D-led productivity growth over the period 1990 to 2015. R&D investments made before 1990 are also included due to the long-term nature of technological innovation. Globally, TFP growth from investments in agricultural research saved around 222 million hectares of natural lands from cropland conversion over 1990 to 2015. This results in around 3 Gt CO_2 eq/year of avoided agricultural GHG emissions, which include emissions from land use change. Furthermore, less cropland expansion results in more natural land being preserved which saves around 9 700 threatened plant and animal species from extinction. These estimates suggest that global TFP growth fuelled by historical R&D investments resulted in less cropland and protected terrestrial carbon and biodiversity.

Figure 2.4. Limiting environmental losses due to R&D-led productivity growth



Note: The size of the circle represents global estimates of avoided cropland expansion.

This framework can also be used to understand how greater R&D investments today will affect future trajectories of cropland use, GHG emissions, and biodiversity. Under the Greater R&D scenario, it is assumed that R&D spending in developing regions increases by USD 600 billion PPP in total over the period 2017 to 2050 (Fuglie et al., 2022[82]). This results in lower global cropland expansion by around 92 million hectares, avoids GHG emissions at around 0.9 Gt CO_2 eq/year, and potentially saves around 6 000 threatened plants and animals species from extinction.

Policies which directly protect the environment can enhance environmental gains from R&D investments as illustrated under the Greater R&D + Protection of Carbon Rich Land' scenario. Protection of carbon rich land consists of identifying areas which have high carbon intensity and preventing future land conversion in these hotspots. Under this scenario, avoided global cropland expansion is estimated at 112 million hectares and avoided GHG emissions at around 1.3 Gt CO_2 eq/year, which is 40% greater than the figure in the previous scenario when only greater R&D policy is considered. Note that hotspots of carbon rich land also overlap with forests which have high biodiversity. Given this, around 9 900 plants and animals species are saved from extinction with the combined policies, which is 65% more than the Greater R&D scenario.

Investment in agricultural R&D is an important policy tool to shape the future, however innovation takes time. In the literature on R&D-driven productivity growth in agriculture, the impact of public R&D investments are typically assumed to last for around 30 to 50 years and it takes around 15 to 25 years for initial investments to significantly affect the path of agricultural TFP growth (Andersen, 2019[83]) (Alston et al., 2023[84]). Econometrics estimates of model parameters also show significant uncertainties on how much knowledge capital affect the path of agricultural productivity (Alston et al., 2010[74]) (Baldos et al., 2019[85]). The lagged productivity effects of R&D as well as uncertainties in technological breakthroughs make it challenging for policymakers to justify sustained increases in agricultural R&D budget especially in today's political environment when there is greater scrutiny in government spending. It is also important to consider all the environmental impacts that may result in greater agricultural productivity from R&D investments. Historically, R&D investments in international agricultural institutes have led to the development and adoption of high-yielding crop varieties (Fuglie and Echeverria, 2024[86]). However, these varieties sometimes led to the overuse of fertilisers, pesticides and irrigation water with negative consequences for natural resources and human health (Pingali, 2012[87]). Going forward, digital agriculture could help limit the negative environmental impacts of farming by increasing farm efficiency through better information via soil and yield maps as well as real-time monitoring of plant water and nutrient needs which will help reduce excess application of water, fertilisers, and pesticides (McFadden, Njuki and Griffin, 2023[88]).

2.12. Enhancing crop productivity, nutritional, and climate resilience impacts through genetic innovation

Yvonne Pinto
International Rice Research Institute (IRRI)

Key messages

- Inducing innovation towards sustainable agricultural productivity requires integrated solutions that address multiple objectives.
- This can encompass integrating advanced technologies such as gene editing, sustainable farming practices, coordinated interventions, and market intelligence that can provide transformative innovations leading towards SPG.

The case study of rice cultivation and genetic innovation in the Mekong River Delta provides an illustration of how innovation and its adoption can lead to sustainable agricultural productivity. Instead of focusing solely on rice, however, a broader question is asked: How do we encourage innovation and ensure its adoption to achieve sustainable agricultural productivity? Using the Mekong Delta as a backdrop, scientists at the International Rice Research Institute (IRRI) have reimagined how challenges can spark transformative solutions.

Transforming agricultural practices: The Mekong River Delta case study

The Mekong River Delta (MRD), which spans over 3.9 million hectares, is Viet Nam's agricultural powerhouse, producing 56% of the nation's rice—a staple crop that feeds 56% of the global population (FAO, 2021[89]). The Mekong River Delta (MRD) contains 12% of the country's natural area and 19% of its population. It produces 50% of the rice, 65% of the aquaculture, and 70% of the fruits grown in Viet Nam. About 95% of rice exported from Viet Nam is grown in the MRD (OpenDevelopment Vietnam, 2022[90]). However, excessive resource use, such as broadcasting seeds at 120 kilograms per hectare, strains the environment (IRRI, 2022[91]). Over-reliance on fertilisers and frequent flooding cycles add to the challenges. Wasteful practices such as straw burning contribute to pollution, and inefficiencies persist in harvesting and logistics (Van Hung et al., 2020[92]).

The MRD provides fertile ground for innovations to address sustainability and productivity. By rethinking traditional practices, the following interventions have been introduced:

- *Alternate Wetting and Drying (AWD):* Using climate-smart maps allows governments to optimise cropping patterns. This reduces salinity exposure and improves water management during droughts (Bouman et al., 2007[93]). A field survey in three provinces (An Giang, Kien Giang, and Soc Trang) found that AWD uses fewer inputs than conventional rice cultivation: nearly 22% less seed, 19% fewer pesticides, and 33% less irrigated water (Tran et al., 2019[94]). Based on a decision of the Vietnamese government in 2016, AWD is regarded as a high-priority option to implement the Nationally Determined Contributions (NDCs) in the MRD region (MARD, 2016[95]).
- *Green Circular Economy:* Innovations have been able to transform rice straw waste into compost and bioplastics (Van Hung et al., 2020[92]). Yield improvements from adopting a low emissions rice model range from 8.8 – 9.5 tons/ha in Can Tho (Vu, 2025[96]) to 6.5 tons/ha in Soc Trang (VNA, 2024[97]).

- *Mechanised Direct Seeded Rice (mDSR):* mDSR has reduced the seed rate by 61–83%, increased nitrogen productivity by 27–32%, and decreased the rice carbon footprint by 19–24% compared to broadcast seeding (Van Hung et al., 2024[98])

Sustainable rice production demands systemic changes, supported by robust measurement, reporting, and verification (MRV) tools. These tools can bridge the gap between scalable practices and climate finance opportunities. IRRI has developed a suite ofMRVtools aimed at supporting greenhouse gas (GHG) mitigation in rice production. These tools facilitate accurate data collection, reporting, and decision-making to promote sustainable agricultural practices.

Revolutionising genetic resource utilization with Artificial Intelligence

Over the 132 000 rice accessions are conserved in the International Rice Genebank hosted at the IRRI Philippines Headquarters. Accelerating the process through which these lines are maximised for global breeding programs is vital for addressing climate change:

- *AI as a game changer*: Funded by Google.org's AI for Social Good program, IRRI integrates AI with phenotyping to identify climate-resilient varieties. This approach has screened 60 000 accessions for drought and flood tolerance in one season, reducing the timeline for full collection evaluation from a decade to two years. The projected economic returns amount to USD 30.79 billion over five years (IRRI, 2023[99]).
- *Gene editing: A complementary solution*: Gene editing is not a standalone fix but a powerful tool within an integrated approach. Applications include improving nitrogen-use efficiency to reduce fertiliser dependence, tackling rice blast and bacterial blight for disease resistance, and enhancing crop adaptability to climate challenges (Zaka et al., 2018[100]). The CGIAR Genome Editing Initiative accelerates breeding efficiency and addresses complex challenges such as climate change and food security.

Innovation adoption hinges on matching solutions to real-world needs. The CGIAR's GloMIP platform provides actionable insights. It tracks market segments across 98 countries, aligns breeding targets with farmer, processor, and consumer requirements, and informs R&D investments with data-driven precision.

Building a new paradigm for agricultural innovation

The approach to rice production requires going beyond simply addressing market needs in the context of climate change and resilience. The use of genetics to enhance both yield and nutritional value creates a more holistic strategy that integrates these elements into a sum-of-the-parts proposition. Moreover, there is a strong recognition of the value in combining genetics, agronomy, and nature-based solutions as alternatives to chemical crop protection and herbicides. This shift toward natural, biodegradable solutions is a crucial step toward minimising residues and health risks, while promoting a more sustainable and environmentally responsible approach to crop production. Rice, with its unparalleled genetic adaptability, holds the key to climate change mitigation and sustainable food systems. Integrating advanced technologies such as gene editing, sustainable farming practices, coordinated interventions, and market intelligence can foster impactful, scalable solutions. The future of agricultural productivity lies not in numbers alone, but in transformative approaches that prioritise people, the planet, and long-term resilience.

2.13. Strengthening institutional frameworks to foster collective action for sustainable agricultural productivity growth

Mikitaro Shobayashi
Research Institute for Humanity and Nature

Key messages

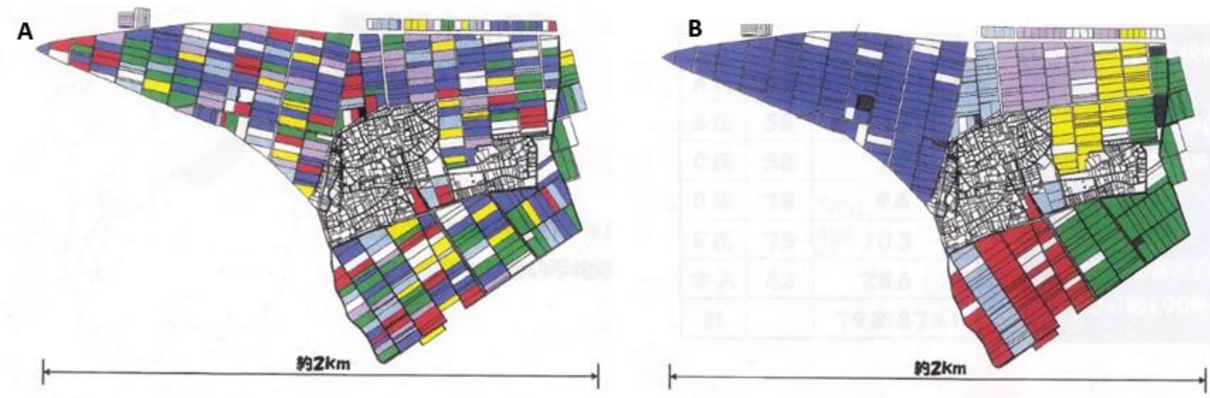
- Sustainable productivity growth (SPG) requires adjusting land use in accordance with economies of scale and scope. This in turn requires flexible institutional and governance mechanisms for its implementation.
- Appropriate and flexible institutions are needed to balance and mitigate trade-offs and synergies that arise when working towards sustainable agricultural productivity. This requires the development of incentives to collectively change agricultural practices that facilitate SPG.

Collective action is vital for facilitating sustainable agricultural productivity growth. This section illustrates how various forms of collective action, including institutional and governance mechanisms, as well as land use adjustments can contribute to boosting sustainable agricultural productivity.

Economies of scale and scope

It is important that institutional mechanisms be able to implement new forms of collective action in a flexible manner. Numerous empirical studies have demonstrated that consolidating widely dispersed cultivated land saves labour and machine hours, and improves total factor productivity (TFP), as shown in Figure 2.5 (Takahashi, Chang and Shobayashi, 2018[101]). Such land-use adjustments will continue to be necessary in regions and countries undergoing structural change.

Figure 2.5. Land consolidation and its impact on the use of resources



Note: A: Before consolidation, B: After consolidation. Each colour refers to a major cultivator.
Source: Shingai Land Improvement Association, Shiga, Japan.

Where economies of scope and scale exist based on the relationship between agriculture's provision of multiple ecosystem services and reduced damage to natural capital, adjusting land use within a given geographic area may improve the relationship with natural capital (OECD, 2013[102]) as evidenced by the following examples. First, to effectively use rice paddies as retention reservoirs, certain areas of the paddy field must be used for rice production and submerged when there is a risk of flooding, which is a classic example of economies of scale. Second, reducing the use of chemical pesticides and installing fish ladders along rice paddies can contribute to fish conservation. Third, the use of linear landscape features to provide shelter for grazing livestock and ecological corridors for wildlife, or for solar sharing that can generate renewable energy and provide shelter for farmers working in the heat. There are nevertheless trade-offs amongst these and measures that should be taken into account.

The appropriate geographical areas and types of activities that require collective action to exploit economies of scale or scope vary depending on the context. For example, using rice paddies as storage ponds requires land use adjustments at the river basin scale, whereas solar sharing can be achieved at a much smaller scale. The incentive measures needed also vary depending on the context.

Establishing governance for such wide-area land use adjustments to improve environmental benefits and agricultural production efficiency is a major challenge, especially in the case of privately-owned agricultural land, where land users are constrained by market principles for agricultural products. Appropriate, flexible institutions are needed to find the right balance between mitigating trade-offs and strengthening synergies, as well as in how to design overall incentive mechanisms to collectively change agricultural practices (Shobayashi, 2023[103]). Creating new types of intermediaries beyond farmland banks could be one option.

Rehabilitation of irrigation infrastructure

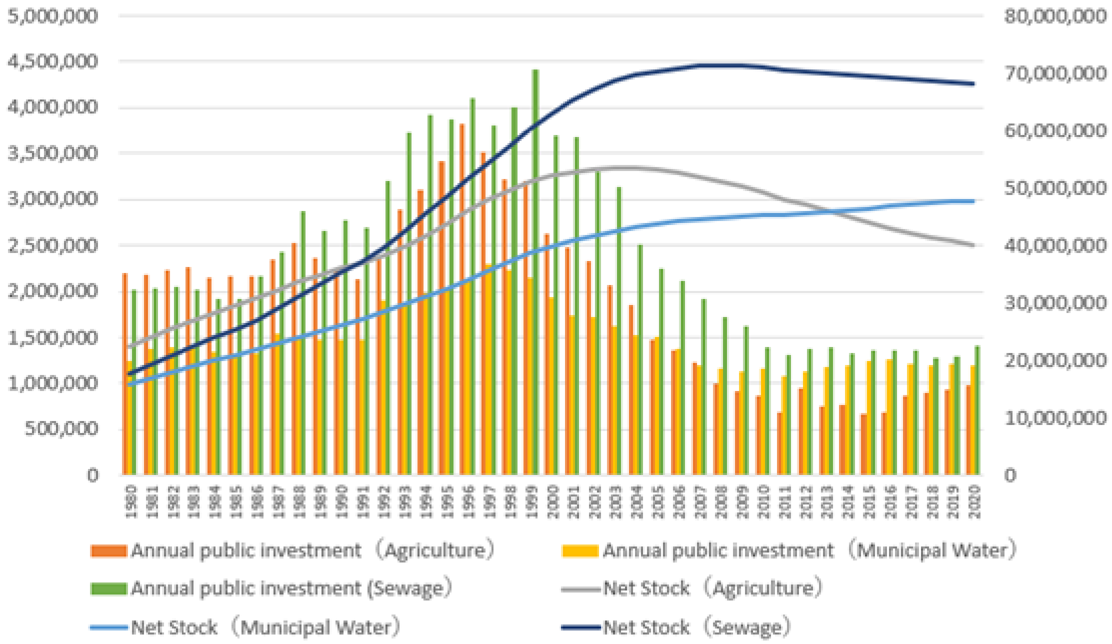
Collective action is required for the rehabilitation of irrigation infrastructure stocks. Considering that 40% of food is produced on irrigated land, which accounts for 20% of total agricultural land at the global level (FAO, 2022[104]), the efficient use and renewal of existing stocks is an important policy issue.

Figure 2.6 shows the decreasing net stock of agricultural infrastructure in Japan. In this case, the question of the roles played by public authorities (e.g. governments) and farmer organisations, (e.g. water users' associations) relates not only to the efficient allocation of water amongst traditional users such as municipal, industrial, agricultural and natural actors through full or partial cost pricing or water markets, but also on envisaging new types of collective action to maximise the value of multiple uses. For example, extending the dry period in rice cultivation can reduce methane emissions, but this requires both collective actions by farmers and collective incentives, such as collective agri-environmental payments or collective contracts in greenhouse gas emissions trading schemes. Redefining the role of water users' associations will enable them to act as intermediaries for this collective action.

As these examples show, it is necessary to emphasise the importance of maintaining and updating the existing institutional infrastructure. In this context, attention needs to be paid to building the social capital and the underlying institutional framework that supports collective action in the context of sustainable productivity.

Figure 2.6. Net stock of major public infrastructure in Japan, 1980-2020

Net stock of major public infrastructure in Japan (JPY million, 2015 prices)



Source: Based on data from Japan's Cabinet Office (2023[105]).

References

Abad, A. (2015), “An environmental generalised Luenberger-Hicks-Moorsteen productivity indicator and an environmental generalised Hicks-Moorsteen productivity index”, *Journal of Environmental Management*, Vol. 161, pp. 325-334, https://doi.org/10.1016/j.jenvman.2015.06.055. [14]

Alston, J. et al. (2010), “Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending.”, Springer, New York, https://link.springer.com/book/10.1007/978-1-4419-0658-8 (accessed on 8 January 2025). [74]

Alston, J. et al. (2023), “Slow Magic: Agricultural Versus Industrial R&D Lag Models”, *Annual Review of Resource Economics*, Vol. 15/1, pp. 471-493, https://doi.org/10.1146/annurev-resource-111820-034312. [84]

Andersen, M. (2019), “Knowledge productivity and the returns to agricultural research: a review”, *Australian Journal of Agricultural and Resource Economics*, Vol. 63/2, pp. 205-220, https://doi.org/10.1111/1467-8489.12296. [83]

Andrieu, N. et al. (2019), “Co-designing Climate-Smart Farming Systems With Local Stakeholders: A Methodological Framework for Achieving Large-Scale Change”, *Frontiers in Sustainable Food Systems*, Vol. 3, https://doi.org/10.3389/fsufs.2019.00037. [62]

Baldos, U. et al. (2019), “R&D Spending, Knowledge Capital, and Agricultural Productivity Growth: A Bayesian Approach”, *American Journal of Agricultural Economics*, Vol. 101/1, pp. 291-310, https://doi.org/10.1093/ajae/aay039. [85]

Beauchemin, K. et al. (2020), “Review: Fifty years of research on rumen methanogenesis: lessons learned and future challenges for mitigation”, *Animal*, Vol. 14, pp. s2-s16, https://doi.org/10.1017/S1751731119003100. [37]

Bouman, B. et al. (2007), “Rice and Water”, *Advances in Agronomy*, Vol. 92, pp. 187-237, https://doi.org/10.1016/S0065-2113(04)92004-4. [93]

Bureau, J. and J. Antón (2022), “Agricultural Total Factor Productivity and the environment: A guide to emerging best practices in measurement”, *OECD Food, Agriculture and Fisheries Papers*, No. 177, OECD Publishing, Paris, https://doi.org/10.1787/6fe2f9e0-en. [5]

Burke, M. et al. (2021), “Using satellite imagery to understand and promote sustainable development”, *Science*, Vol. 371/6535, https://doi.org/10.1126/science.abe8628. [69]

Cabinet Office (2023), *Stock of Infrastructure in Japan 2023*, https://www5.cao.go.jp/keizai2/ioj/index.html (accessed on 8 January 2025). [105]

Chaudhary, A. and T. Brooks (2018), “Land Use Intensity-Specific Global Characterization Factors to Assess Product Biodiversity Footprints”, *Environmental Science & Technology*, Vol. 52/9, pp. 5094-5104, https://doi.org/10.1021/acs.est.7b05570. [79]

Chen, J. et al. (2022), “Chen, J. et al. (2022), “Remote Sensing Big Data for Water Environment Monitoring: Current Status, Challenges, and Future Prospects”, *Earth’s Future*, Vol. 10/2, https://doi.org/10.1029/2021EF002289. [22]

Chung, Y., R. Färe and S. Grosskopf (1997), "Productivity and Undesirable Outputs: A Directional Distance Function Approach", *Journal of Environmental Management*, Vol. 51/3, pp. 229-240, https://doi.org/10.1006/jema.1997.0146. [15]

Cobourn, K. et al. (2024), "An Index Theory Based Approach to Measuring the Environmentally Sustainable Productivity Performance of Agriculture", *OECD Food, Agriculture and Fisheries Papers*, No. 213, OECD Publishing, Paris, https://doi.org/10.1787/bf68fb78-en. [9]

Coomes, O. et al. (2019), "Leveraging total factor productivity growth for sustainable and resilient farming", *Nature Sustainability*, Vol. 2/1, pp. 22-28, https://doi.org/10.1038/s41893-018-0200-3. [67]

Dalheimer, B. et al. (2024), "On the palm oil-biodiversity trade-off: Environmental performance of smallholder producers", *Journal of Environmental Economics and Management*, Vol. 125, https://doi.org/10.1016/j.jeem.2024.102975. [25]

Dapko, K., P. Jeanneaux and L. Latruffe (2016), "Modelling pollution-generating technologies in performance benchmarking: Recent developments, limits and future prospects in the nonparametric framework", *European Journal of Operational Research*, Vol. 250, pp. 347-359, https://doi.org/10.1016/j.ejor.2015.07.024. [28]

Deconinck, K., M. Jansen and C. Barisone (2023), "Fast and furious: the rise of environmental impact reporting in food systems", *European Review of Agricultural Economics*, Vol. 50/4, pp. 1310-1337, https://doi.org/10.1093/erae/jbad018. [6]

Deines, J. et al. (2023), "Recent cover crop adoption is associated with small maize and soybean yield losses in the United States", *Global Change Biology*, Vol. 29/3, pp. 794-807, https://doi.org/10.1111/gcb.16489. [59]

European Commission (2022), *Study on CAP measures and instruments promoting animal welfare and reduction of antimicrobials use: Executive Summary*, https://data.europa.eu/doi/10.2762/297287 (accessed on 20 December 2024). [41]

European Union (2020), *Farm to Fork Strategy*, https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf (accessed on 20 December 2024). [34]

EUROSTAT (2023), "Livestock population in numbers", https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220517-2 (accessed on 20 December 2024). [30]

FAO (2023), *FAOSTAT database*, http://faostat.fao.org/ (accessed on 25 September 2023). [70]

FAO (2022), "Greenhouse gas emissions from agrifood systems Global, regional and country trends", *FAOSTAT Analytical Brief*, Vol. 50, pp. 1-12. [23]

FAO (2022), *The State of the World's Land and Water Resources for Food and Agriculture 2021 – Systems at breaking point*, FAO, https://doi.org/10.4060/cb9910en. [104]

FAO (2021), *Strategic Framework 2022-31*, https://openknowledge.fao.org/server/api/core/bitstreams/29404c26-c71d-4982-a899-77bdb2937eef/content (accessed on 20 December 2024). [33]

FAO (2021), *The State of Food and Agriculture 2021*, FAO, https://doi.org/10.4060/cb4476en. [89]

FAO (2012), "Livestock and landscapes", https://www.fao.org/4/ar591e/ar591e.pdf (accessed on 20 December 2024). [42]

FAO et al. (2022), *The State of Food Security and Nutrition in the World 2022: Repurposing food and agricultural policies to make healthy diets more affordable*, FAO, Rome, https://openknowledge.fao.org/handle/20.500.14283/cc0639en (accessed 26 October 2024). [1]

FAOSTAT (2017), *Food and agriculture data*, https://www.fao.org/faostat/en/#home (accessed on 20 December 2024). [38]

Färe, R., S. Grosskopf and F. Hernandez-Sancho (2004), "Environmental performance: an index number approach", *Resource and Energy Economics*, Vol. 26/4, pp. 343-352, https://doi.org/10.1016/j.reseneeco.2003.10.003. [16]

Färe, R., S. Grosskopf and J. Pasurka (2007), "Environmental production functions and environmental directional distance functions", *Energy*, Vol. 32/7, pp. 1055-1066, https://doi.org/10.1016/j.energy.2006.09.005. [26]

Filazzola, A. et al. (2020), "The effects of livestock grazing on biodiversity are multi-trophic: a meta-analysis", *Ecology Letters*, Vol. 23/8, pp. 1298-1309, https://doi.org/10.1111/ele.13527. [43]

FOLU (2019), *Growing Better: Ten Critical Transitions to Transform Food and Land Use*, https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/FOLU-GrowingBetter-GlobalReport.pdf (accessed on 20 December 2024). [40]

Førsund, F. (2018), "Productivity Measurement and the Environment.", in *The Oxford Handbook of Productivity Analysis*, Oxford University Press, Oxford. [17]

Freidberg, S. (2023), "Metrics and Mētis: work and practical knowledge in Agri-food sustainability governance", *Agriculture and Human Values*, Vol. 40/1, pp. 245-257, https://doi.org/10.1007/s10460-022-10351-0. [61]

Fuglie, K. (2017), "R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture", *Applied Economic Perspectives and Policy*, Vol. 40/3, pp. 421-444, https://doi.org/10.1093/aepp/ppx045. [76]

Fuglie, K. (2012), "Productivity growth and technology capital in the global agricultural economy.", in *Productivity growth in agriculture: an international perspective*, CABI, UK, https://doi.org/10.1079/9781845939212.0335. [75]

Fuglie, K. and R. Echeverria (2024), "The economic impact of CGIAR-related crop technologies on agricultural productivity in developing countries, 1961–2020", *World Development*, Vol. 176, p. 106523, https://doi.org/10.1016/j.worlddev.2023.106523. [86]

Fuglie, K., J. Jelliffe and S. Morgan (2024), "International agricultural productivity data product. Technical report, United States Department of Agriculutre Economic Research Service", https://www.ers.usda.gov/data-products/international-agricultural-productivity (accessed on 13 January 2025). [10]

Fuglie, K. et al. (2022), "The R&D cost of climate mitigation in agriculture", *Applied Economic Perspectives and Policy*, Vol. 44/4, pp. 1955-1974, https://doi.org/10.1002/aepp.13245. [82]

Gardezi, M. and J. Arbuckle (2019), "The Influence of Objective and Perceived Adaptive Capacity on Midwestern Farmers' Use of Cover Crops", *Weather, Climate, and Society*, Vol. 11/3, pp. 665-679, https://doi.org/10.1175/WCAS-D-18-0086.1. [60]

Grafton, R. et al. (2018), "The paradox of irrigation efficiency", *Science*, Vol. 361/6404, pp. 748-750, https://doi.org/10.1126/science.aat9314. [64]

Griffith, R., S. Redding and J. Reenen (2004), "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries", *Review of Economics and Statistics*, Vol. 86/4, pp. 883-895, https://doi.org/10.1162/0034653043125194. [81]

Haqiqi, I. and T. Hertel (eds.) (2025), *SIMPLE-G Gridded Economic Approach to Analysis of Sustainability of the Earth's Land and Water Resources*, Springer Nature Switzerland, Cham, https://doi.org/10.1007/978-3-031-68054-0. [77]

Heady, D. and K. Hirvonen (2022), "A food crisis was brewing even before the Ukraine war – but taking these three steps could help the most vulnerable", *IFPRI* March, https://www.ifpri.org/blog/food-crisis-was-brewing-even-ukraine-war-taking-these-three-steps-could-help-most-vulnerable/ (accessed 26 October 2024). [2]

Hendriks, S. (2021), "The True Cost and True Price of Food", *A paper from the Scientific Group of the UN Food Systems Summit Draft*, https://sc-fss2021.org/wp-content/uploads/2021/06/UNFSS_true_cost_of_food.pdf (accessed on 20 December 2024). [39]

Henningsen et al., A. (2024), *Sustainable Productivity Indicators: Private or Societal Perspective*. [29]

IEA (2019), *World Energy Outlook 2019*, https://www.iea.org/reports/world-energy-outlook-2019 (accessed on 8 January 2025). [80]

IRRI (2023), *Accelerating genetic gains with AI.*, https://www.irri.org/news-and-events/news/irri-receives-google-support-apply-ai-climate-resilient-ricedevelopment (accessed on 10 January 2025). [99]

IRRI (2022), *Sustainable rice practices in the Mekong Delta*, https://news.irri.org/2024/06/mekong-delta-seeks-sustainable-future.html (accessed on 10 January 2025). [91]

Jin, Y. and W. Huffman (2016), "Measuring public agricultural research and extension and estimating their impacts on agricultural productivity: new insights from U.S. evidence", *Agricultural Economics*, Vol. 47/1, pp. 15-31, https://doi.org/10.1111/agec.12206. [73]

Karl, K. et al. (2024), "Harmonizing food systems emissions accounting for more effective climate action", *Environmental Research: Food Systems*, Vol. Alessandro Flammini, Sarah Garland, https://doi.org/10.1088/2976-601X/ad8fb3. [24]

Kleinman, P. et al. (2022), "Addressing conservation practice limitations and trade-offs for reducing phosphorus loss from agricultural fields", *Agricultural & Environmental Letters*, Vol. 7/2, https://doi.org/10.1002/ael2.20084. [63]

Kray, H. (2002), *Agro-Food Policies in Slovakia and Bulgaria: A Quantitative Analysis*, Wissenschaftsverlag Vauk, Kiel. [20]

Laborde, D. et al. (2022), *Repurposing Agricultural Policies and Support: Options to Transform Agriculture and Food Systems to Better Serve the Health of People, Economies, and the Planet*, World Bank, Washington, https://hdl.handle.net/10986/36875 (accessed 26 October 2024). [8]

MARD (2016), *Official document No. 7028/BNN-KHCN on 25 August 2016 on plans for NDC implementation in agriculture up to 2030.*, Ministry of Agriculture and Rural Development (MARD), Hanoi, Vietnam. [95]

McFadden, J., E. Njuki and T. Griffin (2023), *Precision Agriculture in the Digital Era: Recent Adoption on U.S. Farms*, U.S. Department of Agriculture, Economic Research Service, https://doi.org/10.22004/ag.econ.333550. [88]

McLellan, E. et al. (2015), “Reducing Nitrogen Export from the Corn Belt to the Gulf of Mexico: Agricultural Strategies for Remediating Hypoxia”, *JAWRA Journal of the American Water Resources Association*, Vol. 51/1, pp. 263-289, https://doi.org/10.1111/jawr.12246. [65]

Monke, E. and S. Pearson (1989), *The Policy Analysis Matrix for Agricultural Development*, Cornell University Press, Ithaca. [18]

Muller, A. et al. (2017), “Strategies for feeding the world more sustainably with organic agriculture”, *Nature Communications*, Vol. 8/1, p. 1290, https://doi.org/10.1038/s41467-017-01410-w. [52]

Munasinghe, M. (1993), “Environmental economics and sustainable development.”, in *World Bank Environment Paper Number 3. World Bank.*, World Bank, Washington, DC. [54]

Murty, S., R. Robert Russell and S. Levkoff (2012), “On modeling pollution-generating technologies”, *Journal of Environmental Economics and Management*, Vol. 64/1, pp. 117-135, https://doi.org/10.1016/j.jeem.2012.02.005. [27]

OECD (2024), *Agricultural Policy Monitoring and Evaluation 2024: Innovation for Sustainable Productivity Growth*, OECD Publishing, Paris, https://doi.org/10.1787/74da57ed-en. [68]

OECD (2022), “Insights into the Measurement of Agricultural Total Factor Productivity and the Environment”, https://www.oecd.org/agriculture/topics/network-agricultural-productivity-and-environment/. [53]

OECD (2021), *Making Better Policies for Food Systems*, OECD Publishing, Paris, https://doi.org/10.1787/ddfba4de-en. [66]

OECD (2013), *Providing Agri-environmental Public Goods through Collective Action*, OECD Publishing, Paris, https://doi.org/10.1787/9789264197213-en. [102]

OECD (2001), “Measuring Productivity OECD Manual. Measurement of Aggregate and Industry-Level Productivity Growth”. [13]

OECD/FAO (2024), *OECD-FAO Agricultural Outlook 2024-2033*, OECD Publishing, Paris/Food and Agriculture Organization of the United Nations, Rome, https://doi.org/10.1787/4c5d2cfb-en. [31]

OpenDevelopment Vietnam (2022), *The New Normal: Mekong Delta faces droughts and saltwater intrusion*, https://vietnam.opendevelopmentmekong.net/topics/droughts-and-saltwater-intrusion/#:~:text=Considered%20the%20%E2%80%9CRice%20Bowl%E2%80%9D%20of,of%20the%20country's%20seafood%20exports. (accessed on 5 March 2025). [90]

OYUP (2024), *Improving organic cropping systems, project funded by the European Union*, https://www.organicyieldsup.eu/ (accessed on 8 January 2025). [51]

Pearson, S., C. Gotsch and S. Bahri (2004), *Applications of the Policy Analysis Matrix in Indonesian Agriculture*, Yayasan Obor Indonesia, Jakarta. [19]

Pingali, P. (2012), "Green Revolution: Impacts, limits, and the path ahead", *Proceedings of the National Academy of Sciences*, Vol. 109/31, pp. 12302-12308, https://doi.org/10.1073/pnas.0912953109. [87]

Ponisio, L. et al. (2015), "Diversification practices reduce organic to conventional yield gap", *Proceedings of the Royal Society B: Biological Sciences*, Vol. 282/1799, p. 20141396, https://doi.org/10.1098/rspb.2014.1396. [50]

Prache, S. et al. (2022), "Review: Quality of animal-source foods", *Animal*, Vol. 16, p. 100376, https://doi.org/10.1016/j.animal.2021.100376. [44]

Prokopy, L. et al. (2019), "Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature", *Journal of Soil and Water Conservation*, Vol. 74/5, pp. 520-534, https://doi.org/10.2489/jswc.74.5.520. [58]

Purvis, B., Y. Mao and D. Robinson (2019), "Three pillars of sustainability: in search of conceptual origins", *Sustainability Science*, Vol. 14/3, pp. 681-695, https://doi.org/10.1007/s11625-018-0627-5. [11]

Raworth, K. (2017), "A Doughnut for the Anthropocene: humanity's compass in the 21st century", *The Lancet Planetary Health*, Vol. 1/2, pp. e48-e49, https://doi.org/10.1016/S2542-5196(17)30028-1. [48]

Raworth, K. (2012), "A safe and just space for humanity: can we live within the doughnut?", *Oxfam Discussion Papers 461, 26p.*, https://www-cdn.oxfam.org/s3fs-public/file_attachments/dp-a-safe-and-just-space-for-humanity-130212-en_5.pdf. [45]

Raworth, K. (2012), "A safe and just space for humanity: can we live within the doughnut?", *Oxfam Discussion Papers 461, 26p.*, https://www-cdn.oxfam.org/s3fs-public/file_attachments/dp-a-safe-and-just-space-for-humanity-130212-en_5.pdf (accessed on 20 December 2024). [55]

Resnick, D. and J. Swinnen (eds.) (2023), *The Political Economy of Food System Transformation*, Oxford University PressOxford, https://doi.org/10.1093/oso/9780198882121.001.0001. [3]

Rockström, J. et al. (2009), "A safe operating space for humanity", *Nature*, Vol. 461/7263, pp. 472-475, https://doi.org/10.1038/461472a. [47]

Rozelle, S. and J. Swinnen (2004), "Success and Failure of Reform: Insights from the Transition of Agriculture", *Journal of Economic Literature*, Vol. 42/2, pp. 404-456, https://doi.org/10.1257/0022051041409048. [72]

Scholtz, M., F. Neser and M. Makgahlela (2020), “A balanced perspective on the importance of extensive ruminant production for human nutrition and livelihoods and its contribution to greenhouse gas emissions”, *South African Journal of Science*, Vol. 116/9/10, https://doi.org/10.17159/sajs.2020/8192. [36]

Seufert, V. and N. Ramankutty (2017), “Many shades of gray—The context-dependent performance of organic agriculture”, *Science Advances*, Vol. 3/3, https://doi.org/10.1126/sciadv.1602638. [49]

Shobayashi, M. (2023), *Mission Statement for Combining Knowledge for a Fundamental Innovation of Land Use Program*, Research Institute for Humanity and Nature, https://www.chikyu.ac.jp/rihn_e/activities/project/program/02/ (accessed on 8 January 2025). [103]

Steffen, W. et al. (2015), “Planetary boundaries: Guiding human development on a changing planet”, *Science*, Vol. 347/6223, https://doi.org/10.1126/science.1259855. [46]

Takahashi, D., T. Chang and M. Shobayashi (2018), “The role of formal and informal institutions in farmland consolidation: The case of Shiga Prefecture, Japan”, *International Journal of the Commons*, Vol. 12/2, pp. xx-xx, https://doi.org/10.18352/ijc.829. [101]

Tedeschi, L. et al. (2022), “Quantification of methane emitted by ruminants: a review of methods”, *Journal of Animal Science*, Vol. 100/7, https://doi.org/10.1093/jas/skac197. [35]

Thomson, A. et al. (2019), “Sustainable intensification in land systems: trade-offs, scales, and contexts”, *Current Opinion in Environmental Sustainability*, Vol. 38, pp. 37-43, https://doi.org/10.1016/j.cosust.2019.04.011. [56]

Thomson, A. et al. (2017), “Science in the Supply Chain: Collaboration Opportunities for Advancing Sustainable Agriculture in the United States”, *Agricultural & Environmental Letters*, Vol. 2/1, https://doi.org/10.2134/ael2017.05.0015. [57]

Tol, R. (2023), “Social cost of carbon estimates have increased over time”, *Nature Climate Change*, Vol. 13/6, pp. 532-536, https://doi.org/10.1038/s41558-023-01680-x. [21]

Tran, V. et al. (2019), *An investment plan for low-emission rice production in the Mekong River Delta region in support of Vietnam’s Nationally Determined Contribution to the Paris Agreement. CCAFS Working Paper No. 263*, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), https://cgspace.cgiar.org/server/api/core/bitstreams/66bd9d36-de7d-4fa8-b84f-b8cc91b83b64/content (accessed on 10 January 2025). [94]

USDA (2024), *Sustainable Productivity Growth Coalition*, https://www.usda.gov/about-usda/general-information/staff-offices/office-chief-economist/oce-sustainability/sustainable-productivity-growth-coalition (accessed on 13 January 2025). [12]

USDA ERS (2024), *International Agricultural Productivity*, https://www.ers.usda.gov/data-products/international-agricultural-productivity/ (accessed on 8 January 2025). [71]

Van Hung, N. et al. (2020), “Rice Straw Overview: Availability, Properties, and Management Practices”, in *Sustainable Rice Straw Management*, Springer International Publishing, Cham, https://doi.org/10.1007/978-3-030-32373-8_1. [92]

Van Hung, N. et al. (2024), "Mechanized wet direct seeding for increased rice production efficiency and reduced carbon footprint", *Precision Agriculture*, Vol. 25/5, pp. 2226-2244, https://doi.org/10.1007/s11119-024-10163-8. [98]

Varijakshapanicker, P. et al. (2019), "Corrigendum to: Sustainable livestock systems to improve human health, nutrition, and economic status", *Animal Frontiers*, https://doi.org/10.1093/af/vfz043. [32]

VNA (2024), "Soc Trang expands pilot of million hectare low-emission rice project", *Vietnam+*, https://en.vietnamplus.vn/soc-trang-expands-pilot-of-million-hectare-low-emission-rice-project-post297826.vnp (accessed on 5 March 2025). [97]

Vu, L. (2025), "Can Tho achieves VND 30 million/ha profit thanks to low-emissions winter-spring rice", *Nong Ngieg Vietnam*. [96]

WEF, OECD and BIAC (2023), *Emissions measurement in supply chains: Business realities and challenges*, World Economic Forum, Geneva, http://hhttps://www.weforum.org/publications/emissions-measurement-in-supply-chains-business-realities-and-challenges/ (accessed 26 October 2024). [7]

West, P. et al. (2010), "Trading carbon for food: Global comparison of carbon stocks vs. crop yields on agricultural land", *Proceedings of the National Academy of Sciences*, Vol. 107/46, pp. 19645-19648, https://doi.org/10.1073/pnas.1011078107. [78]

Willett, W. et al. (2019), "Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems", *The Lancet*, Vol. 393/10170, pp. 447-492, https://doi.org/10.1016/s0140-6736(18)31788-4. [4]

Zaka, A. et al. (2018), "Natural variations in the promoter of OsSWEET13 and OsSWEET14 expand the range of resistance against Xanthomonas oryzae pv. oryzae", *PLOS ONE*, Vol. 13/9, p. e0203711, https://doi.org/10.1371/journal.pone.0203711. [100]

3 Policy Discussion on Sustainable Productivity Growth

Global Forum on Agriculture 2024: Summary

The 2024 Global Forum on Agriculture (GFA) took place on 29 October at the OECD Headquarters, focusing on the theme "Steering policies towards sustainable agricultural productivity". As part of the "OECD Agricultural Week", the GFA followed the discussions of the international conference "Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies" held at the OECD on the previous day, and preceded the publication of the 2024 Agricultural Policy Monitoring and Evaluation report with a special theme on "Innovation for Sustainable Agricultural Productivity Growth". Chaired by Dr Chavonda Jacobs-Young, Under Secretary for Research, Education, and Economics and USDA's Chief Scientist, the 2024 GFA featured high-level representatives from several countries. There were 151 registered participants in person and 136 online on zoom. The high-level opening panel provided the overall picture on policy makers´ views on achieving sustainable agricultural productivity growth. Three substantive sessions followed, covering i) policy coherence and coordination, ii) agricultural policy approaches and iii) the key role of innovation. Finally, a closing session distilled learnings form the event.

Some key messages repeatedly came up in the GFA discussions

- The world needs sustainable productivity growth (SPG) in agriculture to provide food security, while supporting livelihoods and improving environmental sustainability. This implies that agriculture responds to multiple issues, including environmental pressures (e.g. the sustainable use of natural resources and reducing agriculture's negative environmental impacts), as well as societal considerations (e.g. decreasing and aging farming population in certain countries).
- An integrated food systems perspective is key for achieving SPG, considering the diversity of conditions amongst countries that caution against a one size fits all solution. Different spatial and temporal scales have to be considered to adapt solutions to local realities and practices, some of which may lower output per hectare in the short term but are needed to enhance production's long-term sustainability.
- Achieving SPG requires a change of narrative, making farmers part of the solution, empowering them to be active drivers of the sustainable productivity transformation. Innovation and interactions in a "co-creative" manner are critical to find paths towards SPG.
- Measurement is key for achieving sustainable agricultural productivity. Tracking agriculture's performance is essential for steering policies towards SPG and avoid greenwashing. Furthermore, measurement and data can also be used to incentivise innovation and provide advice to farmers on how to progress towards SPG, leading towards data-driven agriculture.

The following sections report lessons from the three substantive sessions.

Coherence and coordination for sustainable productivity

> *"Policy coherence is crucial for achieving sustainable agricultural productivity growth. This requires that policies are aligned, so that the efforts in one policy area do not undermine, but to the contrary reinforce efforts in others to the extent possible."*[1]

SPG encompasses economic, environmental and social dimensions, hence coherence and coordination were repeatedly recognised as essential prerequisites for its achievement.

This is embodied in the notion of policy coherence which requires the coordination of initiatives and collaboration among all actors. From the perspective of governments, this needs to involve both horizontal coordination across policy areas (e.g. agriculture, environment, environment, trade, social policy, etc), as well as vertical coordination between various levels of government. Different policy areas should not undermine each other, but foster synergies and overcome trade-offs. Agriculture's contribution is needed to progress on environmental objectives, such as net zero greenhouse gas emissions targets, halting species decline and improving water quality. SPG helps achieving these multiple objectives and directing policies to work together.

Facilitating such collaboration for SPG across the value chain needs inclusive decision making to achieve effective and acceptable solutions. Coordinated action should involve the whole value chain, including farmers, consumers, retailers, civil society, governments, financial institutions, researchers and many more. Consumers express their preferences and influence decisions. The private sector, including retailers, have developed a great number of sustainability initiatives and reporting standards. This plethora of initiatives can create difficulties and contradictory signals to farmers and other actors. Governments need to work with the private sector and provide oversight. The question of international standard setting, including the role of the OECD, could also be explored to help with harmonisation.

> *"We have to walk with many, instead of running with a few and dragging the others with us."*

Collaboration between researchers, farmers and the private sector is key to adopt and deliver solutions for overcoming sustainable productivity challenges on the ground. Examples include the Agri-Environmental Partnerships in the EU and living labs implemented in several countries such as the United States, France, Hungary, Ireland and other EU members. These initiatives can help de-risk the trial or adoption of innovations for farmers and facilitate demonstrations from farmer to farmer.

Agricultural policy approaches targeting SPG

Policies, which play a key role in paving the way towards SPG, were another major focus area of the GFA. They are essential for de-risking farming which is recently subject to more frequent extreme weather events and geopolitical tensions. Overly complex policy landscapes and policy uncertainties prevent innovation. The predictability of the policy environment is critical to invest, innovate and overcome the adoption gap that hinders SPG.

Yet, policies also need to be able to respond at times of crises and shocks like the pandemic. In the recent period of high inflation consumers may not be able to pay the price premium for sustainable products and governments have a role in keeping long-term sustainability objectives feasible.

---

[1] To illustrate the nature GFA presentations, direct quotes from GFA participants are highlighted in green and italics.

By setting out the overall visions and target, policies can set commitments to steer action towards SPG. Globally, Sustainable Development Goal 2.4 set by the United Nations in 2015 was a first key stepping stone to guide the world towards SPG. In 2022, OECD Agriculture Ministers2 committed to "take action to achieve sustainable productivity growth consistent with SDG 2.4". Several countries also set out domestic policy objectives to enhance SPG, such as Japan's 2024 Amendment of the Basic Law on Food, Agriculture and Rural Areas. South Africa´s National Policy on Food and Nutrition Security foresee the collaboration of over six national departments to produce food, while monitoring its environmental impacts. Switzerland's vision for Swiss agriculture by 2050 aims to ensure food security while reducing agricultural greenhouse gas emissions, applying an integrated view addressing both food production and consumption.

Policies can encourage investments on environmentally sustainable farming practices, finding innovative ways to renumerate agri-environmental services to keep agriculture profitable and reduce its environmental footprint. Examples from Australia, Brazil and New Zealand were discussed together with EU´s recent eco-schemes. France explained how different ministries (environment and agriculture), other territorial agencies and actors work together to remunerate farmers for ecosystem services, while using indicators to measure impact of their practices. In the United Kingdom, the government is currently repurposing payments for environmental services.

Countries are implementing diverse policy approaches to deliver on their SPG objectives. These include voluntary approaches and incentives, regulations, training and innovation. Each of the tools have advantages and drawbacks. Getting the balance right requires keeping farmers on board and accounting also for their global impact. As examples:

- Several countries have implemented regulatory approaches such as the Water Framework Directive and the Nitrate Directive in the European Union that seek to enhance nutrient management and thus reduce water pollution. In South Africa, the Conservation of Agricultural Resources Act provides control against the overuse of natural resources.
- Market based solutions are also gaining prominence, acknowledging that solutions will not work if markets and consumers do not recognise them. The OECD can play a role in making the business case for environmental sustainability. There are already significant developments on carbon footprint reduction schemes, but other areas such as biodiversity are in their infancy. Some governments are already facilitating market creation through voluntary approaches for agricultural products that strive towards SPG, as done in the United States.

Boosting innovation paths towards sustainable productivity

Funding is key for innovation, with a strong link between spending on research and development (R&D) and total factor productivity (TFP) growth. The reduction of investment in R&D since 2010 is a concern, particularly when only a small fraction of agricultural support is spent on innovation. Repurposing other payments could help boost innovation.

Innovation is essential for achieving SPG as it can help produce more with less and overcome existing trade-offs between policy goals. At the same time, innovation efforts need to be steered towards the right direction to effectively drive productivity gains that are compatible with improved sustainability. Policy makers can contribute to create an innovation ecosystem that rewards success in improving sustainability, not only economic productivity. Targeted policies and research programmes can boost innovation and drive it towards SPG. Examples discussed include as the EU's Horizon Europe and agri-innovation partnerships or the Global Research Alliance on Agricultural Greenhouse Gases. The example of the Netherlands illustrated strong innovation focused on enhancing efficiency that is now increasingly directed towards sustainable productivity.

[2] Declaration on Transformative Solutions for Sustainable Agriculture and Food Systems.

Getting policies right for innovation requires understanding the drivers and barriers of innovation towards SPG. A survey by the European Commission showed that meeting regulatory changes is a main driver of innovation. Meanwhile, costs were reported as the biggest barriers for innovation, alongside the lack of knowledge and skills.

While the right policies can provide an enabling environment for innovation, inappropriate policies and overly restrictive regulations can also hinder innovation. Furthermore, market forces and the private sector are key drivers of innovation, representing a large share of R&D. Market risk management tools such as insurance can help de-risk innovations. Innovation policies also need to consider equity, in particular with respect to small producers, as well as costs and benefits across the value chain. Trade is also a source of innovation to learn from other countries experiences and have incentives to do things better internationally.

Measuring SPG: "What we can't measure, we can't manage"

Measurement was repeatedly mentioned as an essential component for achieving SPG, as tracking agriculture's performance is essential to steer policies towards the desired direction.

> *"We have mainly been using so far total factor productivity, the TFP which is extremely useful, a robust measurement and we aim at continuing to use it. But […] it is not enough. […] We also need to capture environmental and social dimensions."*

There are already methods to measure the total factor productivity (TFP) of agriculture and agri-environmental indicators that track agriculture's environmental performance. Indicators based on what is available now can already inform the discussions and help elevate the discussion to a next level. For example, the EU Agri-Sustainability Compass also presents agriculture's performance in social, economic and environmental dimensions how the EU's agriculture is evolving based on about 20 indicators.

As highlighted at the OECD conference on measuring SPG, GFA participants noted that the integration of these methods is already technically feasible and highly policy relevant. While methods can be perfected over time, they can already provide useful information to policy makers on the direction towards which agriculture is headed and help inform policies.

> *"While we heard it is complex [to measure SPG…], we already have a lot of indicators available. […] We are ready to advance the work on this and to build together […], with the policy makers here at the OECD and the stakeholders […] some metrics that improve the relevance of the discussion when it comes to designing public policies which are helping to build sustainable agricultural productivity."*

The 2022 Declaration of OECD Agriculture Ministers called on the OECD to facilitate the measurement of sustainable agricultural productivity. The OECD has been playing a key role in this through work on the OECD agri-environmental indicators, and through networks of experts, such as the Network on Total Factor Productivity and the Environment and the Farm Level Analysis Network.

> *"The OECD will continue […] facilitating the robust and comparable measurement of sustainable productivity growth, supporting governments with data and analysis as they decide how to move forward and how to steer policies towards more sustainable productivity growth, and facilitating future discussions so that we can all continue to learn from each other along with way."*
>
> *"We should do this now, not in ten years, because in ten years, we already have to deliver."*

Annex A. Agenda of the Conference

28 October 2024, OECD Headquarters, Paris

Session 1. Working breakfast: Measuring the unmeasurable: learning from the cross-country benchmarking and measurement experience of other OECD Directorates

Measuring sustainable agricultural productivity has long proven to be a challenging area. To move forwards, can we learn from the OECD's measurement and benchmarking experience in other domains?

Speakers

- **Marion Jansen** – Director, OECD Trade and Agriculture Directorate
- **Steve MacFeely –** Director, OECD Statistics and Data Directorate

Session 2. Opening: Sustainable agricultural productivity and food systems

The opening session discussed how sustainable agricultural productivity growth can help address the triple challenge food systems face, underlining the importance of its measurement.

Moderator: **Marion Jansen** – Director, OECD Trade and Agriculture Directorate

- How can data and measurement track agriculture's performance towards sustainable productivity and help overcome food systems challenges?
  Spiro Stefanou – Administrator, Economic Research Service, United States Department for Agriculture
- How can the measurement of sustainable agricultural productivity help decision-makers orientate policy towards addressing the triple challenge food systems face?
  Catherine Geslain-Lanéelle – Director of Strategy & Policy Analysis, Directorate-General for Agriculture and Rural Development, European Commission
- How is the academic community advancing the measurement of sustainable productivity growth in agriculture?
  Paloma Melgarejo– Professor of Research, Spanish National Institute for Agricultural and Food Research and Technology, Spanish National Research Council (INIA-CSIC) and Scientific Advisory Board Member, OECD Co-operative Research Programme (CRP)
- Farmers' perspective: How are farmers striving to achieve sustainable agricultural productivity?
  Rūdolfs Pulkstenis – Vice-President, European Council of Young Farmers (CEJA)

Session 3. Keynote speech: Why is the sustainable productivity of agriculture important and why do we need to measure it?

The keynote speech introduced why the sustainable productivity of agriculture matters and why it is important to measure it.

- **Johan Swinnen** – Director General, International Food Policy Research Institute (IFPRI)

Session 4. Towards the cross-country benchmarking of environmentally sustainable agricultural productivity: Where do we stand with indicators?

With the increasing recognition of the need to measure sustainable agricultural productivity, several approaches emerged to align traditional Total Factor Productivity (TFP) measures with social and environmental indicators. Most progress to date has been made on environmentally adjusting TFP measures, incorporating various environmental indicators into agricultural TFP measurement.

The session discussed what the state-of-the-art approaches are towards measuring environmentally sustainable agricultural productivity. Through a panel discussion with leading researchers in the field, it discussed where we stand in terms of the global benchmarking of agricultural productivity, agri-environmental sustainability and, finally, environmentally sustainable agricultural productivity. How indicators to date can be used in policy decisions and what the way forward could entail for developing indicators? Intertwined with indicators and methodological questions, the session highlighted the role of data in efforts to measure sustainable productivity.

Moderator: **Jesús Anton** – Head of Unit, Productivity, Sustainability and Resilience Benchmarking, Agriculture and Resource Policies Division, OECD Trade and Agriculture Directorate

Panel discussion

- *Can* we *compare traditional TFP figures across countries?*
    - **Keith Fuglie** – Economist, Economic Research Service, United States Department of Agriculture
    - **Simone Pieralli**– Joint Research Centre, European Commission
- *Can we compare agri-environmental performance across countries?*
    - **Francesco Tubiello** – Senior Statistician and Team Leader, Environment Statistics, FAO
    - **Guillaume Gruère** – Head of the Agriculture and Resource Policies Division, Trade and Agriculture Directorate
    - **Bruno Alves** – Researcher, Brazilian Agricultural Research Corporation (Embrapa)

Discussants

- **Moriah Bostian**
- **Dr. Robert B. Pamplin Jr**. Professor of Economics, Lewis & Clark College

- *Can we* combine *productivity and environmental sustainability performance? How much is this a technical or a societal/political question?*
    - **Kelly Cobourn** – Associate Professor, Virginia Polytechnic Institute and State University: Environmentally Sustainable Productivity Index
    - **Arne Henningsen** - Associate Professor, University of Copenhagen: Using social shadow prices

Discussant

- **Bernhard Dalheimer** - Assistant Professor, Department of Agricultural Economics, Purdue University

Discussion

Closing remarks by moderator: Where do we stand in measuring sustainable agricultural productivity?

Session 5. "Lessons from the field: How to achieve environmentally sustainable productivity in agriculture? Specific practices, processes and technologies and results"

While the objectives of sustainable productivity growth (SPG) in agriculture, which encompass food and nutrition security, farmer and farmworker wellbeing, and environmental health, are universal, the practices, processes and technologies used to achieve it can vary widely.

Real-life examples of practices, processes and technologies used to advance SPG are hence diverse, illustrating that there is no single best solution for every situation. The diversity of approaches and practices underscores the importance of assessing success in advancing sustainable productivity growth with outcome measures. The session included brief presentations on a number of diverse, real-life examples of practices, processes and technologies that attempt to advance SPG. The presentations focused on the methods and data used to measure outcomes and progress, considering both intended and unintended impacts on social, economic, and environmental outcomes. Through the examples, the discussion explored the indicators that are used to assess whether, in given settings, they are contributing to SPG. The session underlined the importance of consistent measurement and reporting, while emphasising the importance of multiple indicators to capture progress towards the diverse components of sustainable agricultural productivity growth and the measurement of potential trade-offs and synergies.

Moderator: **Spiro Stefanou** – Administrator, Economic Research Service, United States Department for Agriculture

Segment 1. Production practices for sustainable agricultural productivity

- Natural regeneration and agroforestry for sustainable agriculture productivity
  - **Peter Minang** – Director for Africa, Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF)
- Evaluating and analysing the environmental performance of innovative livestock production systems
  - **David Kenny** – Head of the Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Agriculture and Food Development Authority (Teagasc), Ireland
- Improving yields in organic cropping systems
  - **Adrian Muller** – Senior Scientist, Department for Food System Science, Research Institute of Organic Agriculture (FiBL)

Discussant

  - **Allison Thomson** - Scientific Program Director, Foundation for Food & Agriculture Research

Segment 2. Technologies for sustainable agricultural productivity

- WaPOR: Monitoring agricultural water productivity with remote sensing
  - **Jiro Ariyama** – Water Resources Management Expert, FAO
- A Nature-based solution for fertilizer use reduction using biological nitrification inhibition
  - **Tadashi Yoshihashi** – Project Leader, Biological Resources and Post-harvest Division, Japan International Research Center for Agricultural Sciences (JIRCAS)
- Delivering rust-resistant soy for Africa
  - **Everton Capote Ferreira** – Postdoctoral Scientist, The Sainsbury Laboratory, 2Blades

Discussant

  - **Marc Müller –** Project Coordinator, Brightspace Project, Wageningen University & Research

Discussion with the audience

Discussant

  - **Maria Vrachioli –** Senior Research Staff, Technical University of Munich

Session 6. Measuring innovation efforts and their impacts driving sustainable agricultural productivity growth

Through a panel discussion, the session explored the role of innovation in harnessing sustainable agricultural productivity. It started by measuring the investment efforts in innovation and its impacts on improving sustainable productivity, to understanding how to overcome some of the barriers hindering innovation efforts. Are innovation efforts advancing sustainable agricultural productivity growth?

Moderator: **Alessandra Zampieri** – Director of Sustainable Resources, Joint Research Centre, European Commission

- ***Segment 1. Measuring innovation performance***
  - **Uris Baldos** – Research Associate Professor of Agricultural Economics, Purdue University
  - **Nevena Alexandrova-Stefanova** – Policies and Capacities for Innovation Unit Leader, FAO Office of Innovation
  - **Joaquin Arias** – Coordinator, Observatory of Public Policies for Agrifood Systems, Inter-American Institute for Cooperation on Agriculture (IICA)
  - **Matthias Nachtmann** – Digital Farming - Sustainability Business Development Lead, BASF
- ***Segment 2. Going beyond numbers: How can we induce innovation and its adoption in a direction that ensures sustainable agricultural productivity?***
  - *The case of genetic innovation*: **Yvonne Pinto** – Director General, International Rice Research Institute (IRRI)
  - *The case of land use innovation*: **Mikitaro Shobayashi** – Professor, Research Institute for Humanity and Nature

Discussant

- **Jean-Christophe Bureau** – Professor, Agro-Paris Tech

Discussion

Session 7. Roundtable on Policy Implications: How do the lessons learnt at today's conference influence policy agendas?

Summarising the results of the discussions throughout the day, the session discussed how lessons learnt from the different sessions should be integrated into policy agendas, and how they can help policy-makers progress towards overcoming the triple challenge food systems face. Closing the conference, the session provided a bridge to Global Forum on Agriculture which discussed the topic from a policy perspective the next day.

Moderator: **Marion Jansen**, Director, OECD Trade and Agriculture Directorate

Panellists

- **Elise Golan** – Director for Sustainable Development at the United States Department of Agriculture
- **Catherine Geslain-Lanéelle** – Director of Strategy & Policy Analysis, Directorate-General for Agriculture and Rural Development, European Commission
- **David Laborde** – Director of Agrifood Economics and Policy Division, FAO
- **Guillaume Gruère** – Head of the Agriculture and Resource Policies Division, OECD Trade and Agriculture Directorate
- **Johan Swinnen** – Director General, IFPRI

Background

Productivity growth has been behind the substantial increase in agricultural production in the past decades, contributing to feed the growing world population while at the same time reducing pressures on natural resources. Productivity "is commonly defined as a ratio of a volume measure of output to a volume measure of input use" (OECD, 2001, p. 11[1]). Total factor productivity (TFP), which is the most comprehensive measure of productivity, "relates total output quantity to total input quantity" (OECD, 2022, p. 16[2]). Thus, TFP growth assesses improvements in the efficiency of resource use and captures the notion of "producing more with less" (OECD, 2022[2]) (Bureau and Antón, 2022[3]).

TFP growth can, however, have unintended negative impacts on environmental, social, or economic sustainability, such as impacts on water and soil quality, water stress, greenhouse gas emissions, income distribution or farmworker welfare. The concept of sustainable agricultural productivity growth seeks to address these unintended impacts. According to the OECD Productivity, Sustainability and Resilience Framework (OECD, 2020[4]), sustainable agricultural productivity growth refers to productivity growth compatible with the preservation of natural capital in the short and long run. Reconciling total factor productivity with the objectives of social and environmental sustainability is key for overcoming the food systems challenges the world faces. Sustainable agricultural productivity growth can be defined as "agricultural productivity growth that advances social, environmental, and economic development objectives to meet the food and nutrition needs of current and future generations".[1]

In the 2022 the Declaration on Transformative Solutions for Sustainable Agriculture and Food Systems, OECD Agriculture Ministers committed to take action to achieve sustainable productivity growth, and called the OECD to facilitate its measurement. The international conference on "Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies" took place in Paris on 28 October 2024. It focused on measuring sustainable agricultural productivity to inform agricultural policies and practices, discussing how to reconcile agricultural productivity and environmental sustainability. The Global Forum on Agriculture took place the following day, on 29 October 2024, focusing on achieving policy coherence to facilitate progress for sustainable agricultural productivity.

Conference objectives

Food systems are facing a triple challenge of ensuring food security, while supporting livelihoods and improving environmental sustainability. Sustainable productivity growth aims to reconcile these diverse objectives. The conference brought together policy makers and researchers to discuss the concept and measurement of sustainable agricultural productivity. It aimed to bridge the gap between academic and policy communities and translate and orient research efforts to pragmatic and policy relevant ways to measure agricultural performance for achieving sustainable productivity growth to address food systems challenges. The exchange among experts and policy makers focused on the current and evolving state of sustainable agricultural productivity performance and the state of the art on measurement and data, as well as on the main challenges to reconcile productivity and sustainability, focusing particularly on the environmental aspects of sustainability.

[1] As defined by the Coalition on Sustainable Productivity Growth for Food Security and Resource Conservation.

The conference explored the following questions:

- Why do we care about sustainable productivity? What are the trends on sustainable agricultural productivity growth and what are the implications?
- What is the state of the art on measuring sustainable agricultural productivity and what are the main challenges ahead?
- How can innovation and R&D contribute to sustainable agricultural productivity growth? Which practices support sustainable agricultural productivity growth and what are the trade-offs?

Conference organisers

The conference was organised by the OECD's Trade and Agriculture Directorate, in collaboration with the European Commission's Directorate-General on Agriculture and Rural Development and the United States Department of Agriculture and its Economic Research Service. It has been funded by the European Union and the OECD Co-operative Research Programme.

The conference also benefited from the work of OECD Network on Agricultural Total Factor Productivity and the Environment (TFPN), through which the OECD has convened world class experts for more than seven years.

Participants

The conference brought together experts from different backgrounds and policy makers: experts from OECD and other countries, as well as selected members of the TFPN; delegates of the Committee for Agriculture and participants of the Global Forum on Agriculture; representatives of the private sector, including farmers and practitioners/advisory services; and experts from international organisations.

References

Bureau, J. and J. Antón (2022), "Agricultural Total Factor Productivity and the environment: A guide to emerging best practices in measurement", *OECD Food, Agriculture and Fisheries Papers*, No. 177, OECD Publishing, Paris, https://doi.org/10.1787/6fe2f9e0-en. [3]

OECD (2022), "Insights into the Measurement of Agricultural Total Factor Productivity and the Environment", https://www.oecd.org/content/dam/oecd/en/networks/network-on-agricultural-total-factor-productivity-and-the-environment/Insights-Into-The-Measurement-Of-Agricultural-Total-Factor-Productivity-And-The-Environment%20_220511_1617.pdf. [2]

OECD (2020), "OECD Agro-Food Productivity-Sustainability-Resilience Policy Framework: Revised Framework", https://one.oecd.org/document/TAD/CA/APM/WP(2019)25/FINAL/en/pdf (accessed on 28 June 2024). [4]

OECD (2001), *Measuring Productivity - OECD Manual: Measurement of Aggregate and Industry-level Productivity Growth*, OECD Publishing, Paris, https://doi.org/10.1787/9789264194519-en. [1]

Annex B. Agenda of the Global Forum on Agriculture 2024

29 October 2024, OECD Headquarters, Paris

Session 1: High-level opening of the Global Forum on Agriculture 2024

Speakers

- **Chavonda Jacobs-Young**, Under Secretary for Research, Education, and Economics and Chief Scientist of the United States Department of Agriculture, Chair of GFA 2024
- **Ulrik Knudsen,** Deputy Secretary General, OECD

Session 2. High-level panel: Why does sustainable agricultural productivity matter and how to steer policies towards it?

Chair: **Chavonda Jacobs-Young**, Under Secretary for Research, Education, and Economics and Chief Scientist of the United States Department of Agriculture

Speakers

- **Anikó Juhász**, Deputy State Secretary of Agricultural Economy, Ministry of Agriculture, Hungary
- **Marten van den Berg**, Director-General for Agriculture, Ministry of Agriculture, Fisheries, Food Security and Nature, Netherlands
- **Hideki Hagiwara,** Deputy Director General, Ministry of Agriculture, Forestry and Fisheries, Japan
- **Mihail Dumitru**, Deputy Director-General, Directorate-General Agriculture and Rural Development, European Commission
- **Jean-Marc Chappuis**, Deputy Director General, Federal Office for Agriculture, Switzerland

Discussion.

Session 3. Introductory video and presentation: How to achieve policy coherence for sustainable agricultural productivity?

- **Marion Jansen**, Trade and Agriculture Director, OECD

Session 4. Coherence: Co-ordination to advance towards sustainable agricultural productivity

The session explored how to facilitate coherent co-ordination between different actors and domains needed to enhance sustainable agricultural productivity, to capitalise on synergies and overcome trade-offs between different policy areas.

Chair: **Mathilde Mesnard**, Deputy Director, OECD Environment Directorate

Speakers

- **Hamish Marr**, Special Agricultural Trade Envoy, New Zealand
- **Ciaran Devlin**, Deputy Director, Head of Evidence & Analysis, Future Farming and Countryside Programme, Department for Environment, Food and Rural Affairs (Defra), United Kingdom
- **Catherine Conil**, Head of the Sustainable Agriculture and Food Office, Ministry of Ecological Transition, France
- **Melanie Muro**, Head of Programme, CAP and Food, Institute for European Environmental Policy (IEEP)
- **Augusto Luís Billi**, Director of the Department of Non-Tariff Negotiations and Sustainability, Ministry of Agriculture, Livestock and Food Supply, Brazil
- **Emmanuelle Cariou**, Project Officer, Horizon Europe, French National Research Agency (ANR) – agroecology partnership

Session 5. Policies to pave the way towards sustainable agricultural productivity

The session discussed how specific policies, including voluntary approaches, regulation and budgetary expenditures can contribute to ensure sustainable productivity outcomes and guarantee the consistency between measures in different policy areas.

Chair: **Catherine Geslain-Lanéelle**, Director of Strategy and Policy Analysis, Directorate General for Agriculture and Rural Development, European Commission

Speakers

- **Charlotte Denny**, Divisional Manager, Sustainable Trade & Environment, Ministry for Primary Industries, New Zealand
- **Kathryn Zook**, Senior Adviser on Climate to the US Secretary of Agriculture: Partnerships for Climate-Smart Commodities, United States
- **Charlotte Sode**, Deputy Head of Unit, Global Issues, Directorate General for Agriculture and Rural Development, European Commission
- **Jared Greenville**, Executive Director, Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Australia
- **Jemina Moeng,** Chief Director, Food Security Branch, Food Security and Agrarian Reform, Department of Agriculture, Land Reform and Rural Development, South Africa

Session 6. Innovation policies and policies to induce innovation for sustainable agricultural productivity

The session focused on the role of innovation in overcoming trade-offs between policy objectives for sustainable agricultural productivity. It explored how governments can create incentives to innovate for sustainable agricultural productivity growth; how policies can open opportunities to induce the innovation process in the direction of sustainability; how to ensure the complementarity of policies across different areas and avoid putting unnecessary burdens to innovation.

Chair: **Marten van den Berg**, Director-General for Agriculture, Ministry of Agriculture, Fisheries, Food Security and Nature, Netherlands

Speakers

- **Johan Swinnen**, Director General, IFPRI
- **Giampiero Genovese,** Head of Unit, Economics of the Food System, Joint Research Centre, European Commission
- **Kristina Šermukšnytė-Alešiūnienė,** CEO of AgriFood Lithuania DIH
- **Rohit Kaushish,** Chief Economic Advisor, National Farmers Union, United Kingdom
- **Hervé Guyomard**, Research Director, National Research Institute for Agriculture, Food and Environment (INRAE), France

Session 7. Closing session: How to steer policies towards sustainable agricultural productivity?

The session discussed key takeaways from the GFA on how sustainable agricultural productivity can help decision-makers orientate policy towards addressing the triple challenge food systems face. Chairs of the respective GFA sessions shared their thoughts which was followed by closing remarks from the Chair of GFA 2024 and the OECD.

Chair: **Chavonda Jacobs-Young**, Under Secretary for Research, Education, and Economics and Chief Scientist of the United States Department of Agriculture, Chair of GFA 2024

Speakers

- **Mathilde Mesnard**, Deputy Director, OECD Environment Directorate
- **Catherine Geslain-Lanéelle**, Director of Strategy and Policy Analysis, Directorate General for Agriculture and Rural Development, European Commission
- **Marten van den Berg**, Director-General for Agriculture, Ministry of Agriculture, Fisheries, Food Security and Nature, Netherlands

Discussion.

Closing remarks by GFA Chair and OECD

- **Ulrik Knudsen –** Deputy Secretary General, OECD
- **Chavonda Jacobs-Young** – Under Secretary for Research, Education, and Economics and Chief Scientist of the United States Department of Agriculture

Background

Food systems are grappling with a triple challenge. They are expected to provide safe, nutritious and sufficient food to a growing global population, while providing livelihoods to those along food supply chains and contributing to environmental sustainability (OECD, 2019[1]). Sustainable agricultural productivity growth plays an essential role in reconciling these diverse objectives food systems are expected to deliver on.

In November 2022, as part of the Declaration on Transformative Solutions for Sustainable Agriculture and Food Systems, OECD Agriculture Ministers emphasised the importance of sustainable agricultural productivity growth. They committed to "take action to achieve sustainable productivity growth consistent with SDG 2.4"[1] and called on the OECD to support this by "facilitating robust and comparable measurement of sustainable agricultural productivity growth". At COP28, the UAE Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action set out the objective to accelerate and scale up science and evidence-based innovation to increase sustainable agricultural productivity (COP28, 2023[2]).

According to the OECD Productivity, Sustainability and Resilience Framework (OECD, 2020[3]), sustainable agricultural productivity growth refers to productivity growth compatible with the preservation of natural capital in the short and long run. Sustainable agricultural productivity growth can be defined as "agricultural productivity growth that advances social, environmental, and economic development objectives to meet the food and nutrition needs of current and future generations".[2] Agricultural productivity is best measured through estimations of total factor productivity (TFP). However, traditional TFP measurements do not include environmental externalities, implying that TFP growth can have unintended impacts on sustainability (such as water stress, worsening water and soil quality, greenhouse gas emissions, income distribution, farmworker welfare, etc.). The concept of sustainable agricultural productivity aims to take a more holistic view on the measurement of agriculture's performance, ensuring that externalities are incorporated into the calculation of agricultural productivity (OECD, 2022[4]) (Bureau and Antón, 2022[5]).

In the 2022 Declaration, OECD Ministers committed to take action to achieve sustainable productivity growth and called the OECD to facilitate its measurement. Under the theme "Steering policies towards sustainable agricultural productivity", this year's Global Forum on Agriculture on 29 October 2024 focused on the commitment to achieve policy coherence for sustainable agricultural productivity. Policy coherence requires to achieve multiple food systems goals, ensuring that "various policies are aligned so that efforts in one policy area do not undermine efforts in another area, and even reinforce those efforts where possible" (OECD, 2021[6]). The GFA was be preceded by a conference on 28 October 2024 that tackled Ministers' call to facilitate the comparable measurement of sustainable agricultural productivity, entitled "Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies".

[1] Sustainable Development Goal (SDG) 2.4 calls for ensuring sustainable food production and resilient agricultural practices that increase productivity as well as production, while maintaining ecosystems, strengthening adaptive capacity to climate change and extreme events, and improving land and soil quality by 2030.

[2] As defined by the Coalition on Sustainable Productivity Growth for Food Security and Resource Conservation (SPG Coalition, n.d.[7]).

Objectives of the 2024 Global Forum on Agriculture

The GFA sought to raise awareness among policy makers of the need to achieve sustainable agricultural productivity growth to meet the multiple goals food systems are expected to deliver on. By sharing policy experience, the conference discussed the importance of policy coherence to avoid the unintended impacts of agricultural production and the role of innovation to find new solutions that encompass productivity and sustainability achievements, reconciling competing objectives.

The main questions the GFA sought to address included:

- Why do we care about sustainable productivity?
- How to achieve better environmental outcomes of agriculture while keeping or increasing current levels of agricultural productivity and social wellbeing?
- How to identify the synergies and trade-offs between these objectives? How can we better capitalise on these synergies and overcome trade-offs?
- How can governments facilitate the search of solutions and innovation?

Through a sequence of sessions, the GFA discussed different areas of government action, including governance arrangements and policies that can pave the way to sustainable agricultural productivity, in collaboration with the private sector and civil society. In addition, it explored the role of innovation policies and policies to induce innovation to advance sustainable agricultural productivity growth.

Participants

The Forum was chaired by Chavonda Jacobs-Young, Under Secretary for Research, Education, and Economics and Chief Scientist at the United States Department of Agriculture. Several countries committed high level presence. The GFA had high level of participation from OECD Members, accession countries, Committee for Agriculture (COAG) participant countries, and Key Partners, in addition to a select number of other non-member invitations.

References

Bureau, J. and J. Antón (2022), "Agricultural Total Factor Productivity and the environment: A guide to emerging best practices in measurement", *OECD Food, Agriculture and Fisheries Papers*, No. 177, OECD Publishing, Paris, https://doi.org/10.1787/6fe2f9e0-en. [5]

COP28 (2023), "COP28 UAE Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action", https://www.cop28.com/en/food-and-agriculture (accessed on 5 April 2024). [2]

OECD (2022), "Insights into the Measurement of Agricultural Total Factor Productivity and the Environment", https://www.oecd.org/content/dam/oecd/en/networks/network-on-agricultural-total-factor-productivity-and-the-environment/Insights-Into-The-Measurement-Of-Agricultural-Total-Factor-Productivity-And-The-Environment%20_220511_1617.pdf. [4]

OECD (2021), *Making Better Policies for Food Systems*, OECD Publishing, Paris, https://doi.org/10.1787/ddfba4de-en. [6]

OECD (2020), "OECD Agro-Food Productivity-Sustainability-Resilience Policy Framework: Revised Framework", https://one.oecd.org/document/TAD/CA/APM/WP(2019)25/FINAL/en/pdf (accessed on 28 June 2024). [3]

OECD (2019), *Innovation, Productivity and Sustainability in Food and Agriculture: Main Findings from Country Reviews and Policy Lessons*, OECD Food and Agricultural Reviews, OECD Publishing, Paris, https://doi.org/10.1787/c9c4ec1d-en. [1]

SPG Coalition (n.d.), "Sustainable Agricultural Productivity Growth: What, Why and How", https://www.usda.gov/oce/sustainability/about-spgc (accessed on 30 April 2024). [7]