Guidelines for Developing Agricultural Science and Technology Indicators

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Table of Contents

List of boxes

List of tables

List of figures

Acronyms

AR&D: Agricultural research and experimental development

ASTI: Agricultural Science and Technology Indicators

CAADP: Comprehensive Africa Agriculture Development Programme

CGIAR: Consultative Group on International Agricultural Research

DEA: Data Envelopment Analysis

FAO: The Food and Agriculture Organization of the United Nations

FTE: Full Time Equivalent

HC: Headcount

IFPRI: International Food Policy Research Institute

LMICs Low- and Middle-Income Countries

NARI: National Agricultural Research Institution

NARS: National Agricultural Research System

NSO: National Statistical Office

MoA: Ministry of Agriculture

OECD: Organization for Economic Co-operation and Development

PPP: Purchasing power parity

STI: Science, Technology and Innovation

STA: Science and Technology Agencies

UN: United Nations

UNESCO: United Nations Educational, Scientific and Cultural Organization

WIPO: World Intellectual Property Organization

Foreword

(This section will be included in the final version of the document)

Acknowledgements

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Executive summary

These guidelines for developing Agricultural Science and Technology Indicators (ASTI), serve as a comprehensive manual for countries aiming to enhance their agricultural research and development (AR&D) capabilities. This document provides detailed guidance on the planning, collection, analysis, and dissemination of data concerning investments and human capacities in agricultural research and experimental development. The primary goal is to produce harmonized and comparable indicators to better serve the National Agricultural Research Systems (NARS).

The guidelines are designed to provide the necessary framework to generate sound indicators. Supported by the Food and Agriculture Organization (FAO), the new approach to the ASTI initiative emphasizes institutionalizing ASTI both within national statistical systems and the NARS to ensure sustainability and relevance. The guidelines have been informed by past experiences around the production of indicators as well as recent piloting of the new approach, led by FAO. The latter aims to propel ASTI measurements to the level of global data collection and harmonization of the global dataset across United Nations (UN) Member States

Investing in agricultural research is recognized as a highly effective strategy for reducing poverty and hunger while addressing climate change impacts on food systems. Agricultural research stakeholders require data to analyze investment and capacity trends, identify key gaps, set future priorities, promote efficient resource use, and ensure effective coordination and coherence of agricultural research initiatives. Thus, quantitative data is crucial for measuring, monitoring, and benchmarking the inputs, outputs, and performance of AR&D systems and assessing progress toward successful implementation of targets related to science and technology.

The objective of these guidelines is to standardize, harmonize, and improve the ASTI data quality through new institutional arrangements and operational mechanisms for in-country data collection. Efforts in data collection have been rationalized by identifying a core set of variables to be measured annually, while other structural variables that enable more granular measurements and analysis can be measured at longer intervals.

Institutionalization is a key component of the new approach to ASTI data collection, analysis, and dissemination. This involves engaging stakeholder institutions at global, regional, and national levels to share workloads of data collection and analysis, enhance co-creation, and ownership of the results and analysis. Several models for institutional arrangements have emerged from pilot projects. Each model offers a unique approach to coordinating and supervising national agricultural research activities, depending on the country's institutional setup and capabilities.

The guidelines also provide detailed instructions on designing questionnaires to capture the core and structural variables related to human resources, financial resources, and research focus. The questionnaire design ensures that the data collected is relevant, accurate, and comparable. Quality control measures are addressed, including the establishment of a framework for data quality, verification upon receipt, and comparison with data from previous years using validated outlier

detection strategies. Imputation techniques for missing data are also proposed to maintain the integrity and usability of datasets.

The production of indicators is a crucial step in transforming raw data into meaningful insights that can inform policy and decision-making. The guidelines outline the production of human and financial resource indicators based on the data from the questionnaires, and the dissemination of these indicators through technical briefs and visualizations. It emphasizes the importance of making cumulated data series accessible through data portals ready to be used for advocacy and policymaking. The dissemination strategy includes the use of data analyses to support advocacy efforts, ensuring that the information and knowledge derived reaches decision-makers and stakeholders who can drive change.

The adoption of a harmonized ASTI methodology for all countries is aimed at improving the overall quality of the ASTI global dataset. The new approach of ASTI promoted by FAO aims to strengthen NARS through evidence-based policies, ultimately contributing to global agricultural development goals. By institutionalizing ASTI within national statistical systems and fostering collaboration among stakeholders, the process becomes country-owned. The countries can thus ensure the sustainability and relevance of their AR&D efforts, while driving progress towards a more resilient and productive agricultural sector. The guidelines emphasize the need for a global dataset of harmonized indicators, which will better serve in planning and operationalizing AR&D within NARS and their regional and global collaborative structures.

1. Purpose of this document

This document provides countries with guidelines for the planning, collection, analysis and dissemination of data on investments and human capacities in agricultural research and experimental development (AR&D), which is the core data for building Agricultural Science and Technology Indicators (ASTI). These will result in the production of harmonized and comparable indicators to monitor National Agricultural Research Systems (NARS).

The guidelines have been drafted based on past experiences of the ASTI program, formerly managed by International Food Policy Research Institute (IFPRI), in addressing the collection, analysis and publication of ASTI indicators principally from Low and Middle Income Countries (LMICs) and other AR&D data collection initiatives conducted by different organizations at national, regional and international level. In particular, the recent transition of the ASTI data series to FAO, with the objective of rolling out data collection on a global scale and harmonizing AR&D datasets across all United Nations (UN) Member States, triggered the need for a comprehensive methodological guide for this purpose. In this new context, a review of and adjustment to the operational mechanisms is required, such as the distinction between core indicators to be measured regularly and more granular structural indicators to be measured at longer intervals, greater implication of country-based institutions in the process, leading to institutionalization of ASTI within the national statistical systems. The new approach has been tested, ahead of the revision of these guidelines, through a set of country pilots that provided key findings to recommend to countries on how to produce quality and relevant indicators.

Therefore, this document caters for the introduction of ASTI in countries implementing them for the first time, countries that have been implementing them using the ASTI-IFPRI led approach, and countries that already have existing systems that report general R&D data according to international recommendations, such as the OECD's Frascati Manual. The document describes the process of planning, implementation and results publication on a regular basis. It also provides definitions of terms that should be used to enable the harmonization of quality datasets across countries and thus enable the availability of comparable data on AR&D.

The guidelines describe a range of approaches that have been used for implementation in countries, which are adaptable to different country contexts. They also describe the desirable process of institutionalization of ASTI within a country, with close collaboration of the NARS institutions and the National Statistical Offices (NSO), as well as other relevant stakeholders, such as the Science and Technology agencies (STA) and the Ministries of Agriculture (MoA). Therefore, the guidelines can lead to the establishment of a solid foundation for the long-term institutionalization of ASTI through the adoption of fit-for-purpose data collection models and the integration into official mechanisms at country level. The institutionalization process is expected to be achieved over time, depending on the starting point of the country, the relevance of the AR&D, and the need for data to inform policymaking in this regard. In parallel, the regular collection of data to report to international organizations, such as FAO, will lend itself well to a country-owned process and the establishment of monitoring frameworks to strengthen NARS through evidence-based policies.

Finally, the guidelines also present a survey instrument to collect ASTI data, which is also flexible to be used for other data collection purposes that the NARS institutions may consider useful. Therefore, the guidelines will set countries on the path to develop strategies to maximize uptake of AR&D data, all of which can enhance advocacy for further investments in Agricultural Research and Development.

This document has been structured into several chapters to introduce the various aspects of the ASTI production process and to facilitate an understanding of the importance of implementing ASTI measurements using a harmonized approach across countries, regions and agricultural commodity sectors.

Following this introductory section, **chapter 2** provides an overview of the conceptual framework, history and development of the measurement of ASTI, especially the program led by IFPRI to additionally cover the LMICs. It also describes how, based on the case made for such measurements to also be carried out within LMICs, countries globally, are now ready for the scaling of ASTI at a larger scale, and to include data both from the LMICs and high-income countries. The formalized measurements at national level and the harmonization of datasets across UN member states will better serve in planning and operationalizing AR&D within the NARS and their regional and global collaborative structures. This shift has involved an in-depth review of the operational mechanisms to produce the indicators and the proposal of a revised approach, better suited to the new context of officially collecting globally harmonized data at a large scale and in a timely manner. Chapter 2 further elaborates on the revised implementation approaches that align with the revised goal of extending a single harmonized ASTI methodology to all countries and the consolidation of a global dataset. It also suggests the implied process of institutionalization of ASTI within the national agricultural research and national statistical systems for better efficiency of measurement and use of the indicators.

In **chapter 3**, the guidelines provide an overview of the process of engagement of institutions in a country, starting from the initial engagement of key institutions to the enlargement of engagement of other relevant institutions, the joint analysis of institutional set up in the country and existing data sources, finding the suitable mandates and roles of the institutions involved in managing ASTI data collection & analysis. The process also includes a review of the target institutions which should provide data, the choice of instrument to collect the data, capitalizing on the mandates of the institutions collecting the data to ensure a good response from the target institutions, and if desirable, organizing a round of sensitization or even capacity development on the data collection process for representatives from the target institutions. The overview provided in this chapter reminds us that the strategy of implementation includes the engagement of local institutions through to the publication and use of the results of ASTI for advocacy for investments in AR&D in the country.

Chapter 4 outlines the key variables on which data are to be gathered through questionnaires, focusing on both core and structural variables, organized around three dimensions of human resources, financial resources and research focus. Building on the structure of questionnaires that have previously been used for data collection on ASTI, as well as the questionnaire recently used in the pilot countries, it provides details on the interpretations of the data to be collected, responding to the structure of the questions, data collection frequency, which will facilitate the generation of the indicators. The chapter also describes the stages in the preparations for field implementation of ASTI data collection, starting with engagement with the target institutions and considering their capacity development on responding to the questionnaire, as a way of ensuring good quality of responses. A checklist is proposed for the necessary preparations for data collection.

Chapter 5 addresses quality control measures to be applied on the data collected through the questionnaires, which starts with the establishment of a framework for data quality. In addition, in order to deal with gaps in the data, imputation techniques for missing data are addressed, so that the datasets remain usable and relevant.

Chapter 6 addresses key methodological considerations for processing the data collected in the form of data series, in a harmonized structure and the subsequent production of indicators on human and financial resources, as well as the focus of research. The chapter also describes the formats of data series that can be used to produce the indicators, both from the data collected and in conjunction with other external indicators. These data series can constitute the national historical dataset on ASTI.

Chapter 7 addresses the general principles to guide dissemination of indicators, how ASTI indicators data series can be packaged as visualizations and other forms of dissemination products. The chapter comprises suggestions for the use of ASTI data analyses to support advocacy.

Chapter 8 addresses the outcomes of the process of institutional engagement which provides the country with the capacity to generate, process, analyze and own its historical datasets on ASTI. The

result of the use of the published results on ASTI and their dissemination can facilitate to advocacy towards decision-makers, as a way for ensuring continued investments in AR&D. Such country-ownership of the process enables policymakers to abide by their national commitments in regional and global agreements, recognizing the efforts of the data-contributing institutions and reinforcing their continued commitments of the production of ASTI. In turn, countries can carry out targeted advocacy at regional and global levels, with the help of regional organizations of the Member States in the context of global efforts on ASTI.

2. The framework for ASTI measurement

2.1 Importance of ASTI in the development agenda

There is considerable evidence that investing in agricultural research is a highly effective pathway both for reducing poverty and hunger and for addressing the climate change impacts on food systems. Regardless of the mode of investments, timeframe, and specific targets for adaptation chosen, studies have consistently shown that spending on agricultural research has had a greater impact on agricultural productivity than other types of public expenditures (Stads et al, 2022). In LMICs, AR&D often represents one of the most significant areas for public investment in Science, Technology and Innovation (STI) and thus has considerable prominence in national STI policies. It has also been demonstrated to yield beneficial impacts on the environment and natural resources management. The imperative nature of investments in AR&D becomes evident when considering the formidable challenges that small-scale producers across the globe are currently grappling with and are poised to encounter in the foreseeable future. Consequently, strategic and sustained investments in AR&D are indispensable for empowering these producers to surmount the considerable obstacles they face.

Quantitative data are essential to any informed decision-making process. Agricultural research stakeholders require such data to analyze investment and capacity trends, identify key gaps, set future priorities, promote efficient resource use, and ensure effective coordination and coherence of agricultural research initiatives. Thus, quantitative data are essential to measuring, monitoring, and benchmarking the inputs, outputs, and performance of AR&D systems and to assess progress toward the successful implementation of targets related to science and technology.

From a global perspective, a range of institutions already generate or curate different types of data on Agrifood systems R&D inputs. The publicly accessible data sources range from UN agencies such as The Food and Agriculture Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO) and World Intellectual Property Organization (WIPO), to other multilateral organizations like Organization for Economic Co-operation and Development (OECD) or the World Bank, to international research organizations like Consultative Group on International Agricultural Research (CGIAR) and International Food Policy Research Institute (IFPRI), to private foundations and multistakeholder platforms. But major gaps exist in the R&D inputs data series that are publicly available, especially in Low- and Middle-Income Countries (LMICs).

R&D indicators are also vital in assessing the contribution of agricultural research to broader development goals, such as agricultural and economic growth, food security, poverty reduction, and climate change mitigation: they are an indispensable tool when assessing the contribution of agricultural STI to agricultural growth and, more generally, to economic growth.

The collection of AR&D data is not straightforward because agricultural R&D is carried out by many diverse institutions (including government, higher education, non-profit, and private for-profit agencies) and funded through multiple sources (government budgets, donor grants, private sector, producer levies, product sales). While national statistical agencies in high-income countries have generally developed the means for acquiring and reporting R&D information, the challenge has been acute especially in Low- and Middle-Income Countries (LMICs). The ASTI program, formerly managed by the IFPRI, has attempted to fill this gap over the past two decades through collaborative alliances with national research agencies, regional coordinating bodies, and international institutions, with donor funding support. This effort has succeeded in compiling, analyzing, and publishing agricultural research data relating to institutional developments, investments, human resource capacity, and research outputs in more than 90 LMICs.

The ASTI program, while at IFPRI, faced several challenges, especially in terms of sustainability, frequency and country ownership of the data, and it was discontinue**d. FAO aims to resume the main data series and extend coverage to all UN m**embers. This transition involves both challenges, mainly involving improved operational mechanisms at the national level, and opportunities, namely the potential for methodological harmonization at the global level to expand ASTI into a single dataset that incorporates data from all UN member states. Thus, one overarching goal of the transition process is to standardize, harmonize and improve the overall quality, timeliness and completeness of the ASTI dataset while making it more sustainable and country owned.

2.2 Historical background and uses of ASTI

In LMICS, findings and outputs of the ASTI program at IFPRI have had important policy relevance at the national, regional, and international levels(Beintema et al. 2020). At the country level, these indicators are an important input into medium- to long-term agricultural sector plans or development strategies in numerous countries. Research managers and policymakers use this data to formulate policy and inform decisions related to strategic planning, priority setting, monitoring, and evaluation. It is also used extensively by in-country stakeholders to advocate for increased AR&D funding, to highlight capacity gaps, and to mobilize resources for neglected research areas. ASTI has also served to provide information to governments and others involved in the public debate on the state of AR&D at national, regional, and global levels (Figure 1).

Figure 1. Categories of users of ASTI

Many international organizations, donor organizations, as well as regional- and national-level decision makers around the world, have extensively used ASTI data and analyses to assess the performance and impact of agricultural research in LMICs, and to influence policy for increased agricultural growth and productivity (Table 1).

Table 1. Use cases of ASTI by a range of sectoral, national, regional and international stakeholders

KEY STAKEHOLDERS / POTENTIAL ASTI USE CASES	National Governments	National research & innovation systems	Donor agencies/ Multilateral agencies	Regional/ Subregional organizations	Scientific/ Academia	International NGOs	Private businesses
ASTI data used for modeling long-term impacts of R&D investment	✓	✓		✓	✓	✓	
ASTI data used for prioritizing and mobilizing resources	✓	✓	✓				
ASTI data used to identify gaps, and set future investment priorities, including funding opportunities to seed innovation	✓	✓	✓	✓		✓	
ASTI data used to set regional and global investment targets in Ag R&D	✓		✓	✓			
ASTI data used to identify entry points for strengthening NARS and local research capacities	✓	✓	✓	✓	✓	✓	
ASTI data used for better coordinating agricultural R&D nationally and across regions	✓	✓	✓	✓	✓	✓	✓

2.3 ASTI Transition and revised framework for measurement

The transition of management of ASTI datasets to FAO aims to reinvigorate, expand and make ASTI data collection and analysis sustainable. This will be carried out mainly through a process of institutionalization in the countries and gradual transition into a commonly used network approach employed by FAO, which primarily relies on the international organizations constitutive mandate to collect from member counties data related to its mission. The transition is also an opportunity to standardize, harmonize, and improve data quality through new institutional arrangements, operational mechanisms, and fostering collaboration within the UN system. This purpose has been considered and incorporated in the design of the new approach to ASTI implementation, with some of the key characteristics described below.

2.3.1 A global dataset of harmonized indicators

The review of the existent ASTI data available pointed to the need for a harmonized dataset across all countries for the purposes of comparison and for planning. However, the efforts required in data collection should be rationalized by identifying a core set of variables to be measured on an annual basis, while other structural variable that enable more granular measurements and analysis, and those that have a slower rate of change, can be measured at longer intervals. This will lighten the regular load of work involved in ASTI measurements and still provide continuity of the datasets.

2.3.1.1 Core variables for annual data collection

In order to have complete, timely and frequent data relevant for policy making, the burden on respondents should be minimized. Thus, the regular data collection process should focus on a reduced number of core variables on agricultural R&D investments and human resource capacity (referred to as Tier I) to be collected through a specifically designed questionnaire and efforts should be made to ensure that the lists of in-country R&D actors are updated and reflect any changes with each new data collection cycle.

2.3.1.2 Structural variables for granular data collection at longer intervals

A second set of variables comprise of those that address structural dimensions related to the institutional setup of AR&D, research capacity, investment, funding sources, commodity and thematic focus, research outputs, which do not need annual data collection. Therefore, these Structural variables (referred to as Tier II indicators) and other specific demands can be collected less frequently, (e.g. every 3-5 years) according to national needs and resources availability. The periodic incorporation of data on structural variables will provide countries with a more detailed understanding of the structure and dynamics of their agricultural science and technology systems.

2.3.2 Integration of ASTI into the National Official Statistical mechanisms

To enhance national validation as well as country ownership of ASTI data, it is important to recognize the crucial role of the National AR&D stakeholders while also involving the NSO in the validation and the integration of ASTI into National Statistical System mechanisms. Broader institutionalization of ASTI in countries along with the participation of both NSS and NSOs is crucial in establishing a well-defined mandate for data collection, guaranteeing compliance with quality standards, and capitalizing on their expertise in making the data available in a timely manner.

2.3.3 Data collection from the private sector

Data from private sectors used to be scarce, and their collection was challenging under the former IFPRI-led ASTI program. But AR&D investments from the private sector are increasingly relevant to understanding the role of R&D in productivity and economic growth in LMICs. The collection of private sector data can be improved either by linking it to the compulsory response statistical operations usually carried out by the national statistical offices or using the lists of companies captured from censuses and surveys. Private sector response is usually only possible if there is a clear mandate for the data collection agency to request this data. In addition, building trust within private sector stakeholders is essential. This can be achieved through confidentiality agreements, the enforcement of statistical confidentiality laws, and the assurance that sensitive information will be properly anonymized.

2.3.4. Harmonization of ASTI dataset across all UN Member States

As has been stated, the transition of ASTI to FAO offers a unique opportunity to broaden the coverage of ASTI across all FAO countries, which implies going beyond the LMICs that was the focus of the ASTI program under IFPRI. Similarly, other systems exist in high-income countries, whereby there are existing datasets. One of the challenges of the development of these guidelines is to work towards harmonization of the data available across all these systems.

2.4 Institutionalization as a foundation for sustainability

As mentioned above, the new approach to ASTI data collection, analysis and dissemination of results is reliant on a process of institutionalization by organizations at different levels, appropriately motivated to collect the data, analyze and produce results that can be used by stakeholder institutions at various levels. The engagement of stakeholder institutions at global, regional and national levels enables shared workloads of data collection and analysis, enhanced co-creation and ownership of the results of analyses at the respective levels or organization (Table 2).

Institutionalization of ASTI occurs at country level with the new implementation approach consisting of a collaborative and shared responsibility for ASTI measurements amongst stakeholder institutions in the country. Thus, several institutions related to Science, Technology and Innovation Indicator measurement in the country are consulted to determine the most appropriate model to implement around the ASTI process, with the NARI and the NSO remaining as key operational institutions in the

process. Several models have been identified through a pilot implementation phase of ASTI, which will be described in the sections below.

Table 2. The process of institutionalization of ASTI at global, regional and country level

Institutionalization process level	UN-facilitated	Country-facilitated and region-facilitated
At global level	• Institutionalization through UN system mechanisms • Integration within FAO statutory bodies and FAOSTAT	• Region-wide compilation and cross – regional comparison of results on ASTI • Coordination and backstopping of ASTI interventions in regions
At regional level	• Availability of an online platform for the Community of Practice • Engagement of Sub-Regional Organizations in ASTI rolling out in sub-regions	• Regional platform for engagement of ASTI National and Institutional focal points • Regional coordination and backstopping of national ASTI interventions
At country level	• Regular data collection through official mechanisms • Capacity-building and promotion of country uptake	• Inter-institutional collaboration between NSO and NARS around ASTI • Integration of the NARI into the NSS & joint publication of results • Working towards an information-system based reporting system

BOX 1: Testing of the ASTI new data collection approach by FAO[1]

The UN FAO carried out a field-test of the approach leading to the institutionalization of ASTI within the global and national systems, amongst 9 pilot countries in four different regions, using different questionnaire designs, available in several formats, addressing specifically Tier I, Tier II and allowing for the flexibility of a country to add additional questions of national interest, the entire process underwent field-testing.

This testing phase has been essential for assessing the effectiveness of the forms in collecting the required data, identifying factors contributing to successful (or unsuccessful) data collection, and obtaining valuable feedback from country focal points and National Statistical Offices on the process. Insights gained from these pilots are helping to build a solid foundation for the long-term institutionalization of ASTI through the adoption of fit-for-purpose data collection models and the integration into official mechanisms at country level.

Feedback from the pilot countries field testing has been useful for enhancing the process design in preparation for a first global roll-out and has largely contributed to the elaboration of the guidelines.

[1] Documentation from the pilot countries field testing is available as follows:

- ASTI Country Pilots Testing Framework (link to Testing Framework document to be inserted)
- Lessons learnt reports of the field testing of each of the 9 pilot countries (link to folder containing Individual country reports to be inserted)
- Synthesis Report: Insights and lessons learnt from the pilot-country measurements of Agricultural Science and Technology Indicators (ASTI) (link to Synthesis Report on Insights and Lessons to be inserted)

3. Planning in-country ASTI process

The transition in the methodology for ASTI measurements will require greater involvement of the NARS institutions, the NSOs and STI agencies amongst others, and the need to steer countries towards fit-for-purpose models to make data collection feasible and sustainable. Therefore, the importance of having more engagement by country institutions, their involvement in the process and their ownership of the results for their own use, cannot be over-emphasized. However, the best strategy for implementation is good planning. Table 3 presents an overview of the different phases in the institutionalization of ASTI, each phase comprising several steps.

Table 3. An overview of different steps in the institutionalization of ASTI

Phases of ASTI	Steps within each phase
Initial sensitization on ASTI & establishing institutional arrangements for ASTI	• Institutional engagement on ASTI at country level • Situation analysis of the institutional set-up • Identification of key partners of ASTI • Inter-institutional collaborative planning on ASTI & review of existing data sources • Defining and formalizing institutional roles and agreements amongst local institutions along the entire ASTI process • Identifying the most suitable ASTI data collection model for a country
Pre-implementation planning of field activities	• Developing a data collection strategy • Identification of the target population for ASTI data collection • Choosing the design of ASTI questionnaire • Sensitization of target audience and capacity development on ASTI/Local stakeholders' engagement workshop • Address common areas of challenges with data collection, referring to definitions and processes *(e.g. observing definitions of R&D, FTE researcher & agricultural focus)*
Implementation of ASTI data collection, analysis and publication	• Use of Statistical standards and tools to enhance the data collection process *(e.g. NSS letter, follow-up protocols, confidentiality, official calendar)* • Use existing administrative data and existing surveys through data sharing mechanisms to improve targeted data collection and quality check • Make contingency allowances for unexpected implementation challenges, and plan for the follow up with respondents on data collection • Identify data series gaps and follow statistical procedures for imputation of values • Where required, use appropriate secondary sources and proxies for reconstruction of trends to maintain integrity of the dataset • Analysis and publication of the results of ASTI Data
Reinforcing the process of institutionalization of ASTI	• Advocate for regular publication as a strong foundation for streamlined national systems *(both NSS and NARS): (continuous publication of aggregated ASTI data are preferable to granular but intermittent availability)* • Develop and promote ASTI use cases (e.g. TFP estimation, grant designing and investment targets) • Monitor increases in user demand accompanying more frequent and country-owned data • Organize high-level awareness raising at regional and national levels as part of institutionalization and resource mobilization for the countries

This chapter introduces the process of planning ASTI implementation as well as and others that follow present the overall stages in the process of engagement, capacity strengthening and development and

initiation of the data collection methodology. Later chapters will cover, in more details, the data collection process, use of data collected to produce the indicators, which will finally be used for advocating for continued investment in AR&D.

3.1 Initial sensitization on ASTI

The usual entry points on ASTI in LMICs have been through the National Agricultural Research Institution (NARI), which is usually the leading agency of the National Agricultural Research System (NARS). The NARI has traditionally not been part of the NSS as, in general, data collection is not part of its mission. Therefore, the process of implementing ASTI lays much emphasis on strengthening the capacity and joint involvement of the NARI and the NSO of the countries in the identification of other partner organizations as well as key data providers, and to get them involved early in the implementation and planning processes.

The initial sensitization and exposure to ASTI data collection approach has proven to be a successful strategy during pilot country field testing by FAO. The general outcome is that such initial exposure and explanations enable a smoother process of planning and collaboration around the implementation of the ASTI data collection process. Therefore, it is strongly recommended as the starting point to the process of engagement, irrespective of whether local institutions or institutional focal points have previously been exposed to ASTI.

A harmonization of terminology, definitions and complementary data collection can improve the efficiency of data collection on ASTI using the existing mechanism, which makes it more appropriate to also involve other institutions. In many cases, there is a need to establish a working relationship between the different organizations, which can be informal or formal.

Nevertheless, the approach always starts with a situation analysis of the context of Agricultural Research in the country, mapping the institutions that could be involved in the implementation of the ASTI methodology, seeking the appropriate institutional arrangements for implementation and going through the implementation process together. There is often a need for an initial meeting or workshop within the country to initiate the implementation process.

Based on the pilot countries experience conducted by FAO, seven types of institutions have been identified, which may be engaged in the implementation or monitoring of agricultural research in the country, and which may wish to be further involved in the implementation of the ASTI data collection, analysis and reporting, as follows:

1. Ministry of Agriculture (MoA)
2. The National Agricultural Research Institute (NARI)
3. The National Agricultural Research System (NARS) institutions other than the NARI (e.g. Commodity value chain research and development, Universities, Private Sector Research Institutions)
4. The Research or Agricultural Research Council, usually also promoting Agricultural Research and Innovation
5. The Ministry of Science and Technology / The Ministry of Science, Technology and Innovation or combination of Ministerial institutions that oversee overall R&D in the country
6. The National Statistics Office
7. An institution grouping a consortium of the above institutions for a specific STI purpose related to Agriculture.

As a guide, the specific objectives of this initial engagement can be formulated as follows:

- To present the ASTI program and its operational mechanisms.
- To initiate dialogues between NARI, NARS institutions and the national statistical office to reach a common understanding of their roles and responsibilities within the new approach.
- To initiate a Situation Analysis of the institutional set-up and the process of identification of

key partners in implementation of ASTI.

- To advocate for and discuss strategies for improving the long-term institutionalization of ASTI and maximizing the assimilation of ASTI results at the national level.
- Optionally, to sensitize country focal points on the ASTI methodology, data management portal, and survey processing supervision.

3.2. Defining institutional roles & agreements among local institutions

3.2.1 Principles to identify the national lead institutions

As the implementing institutions are identified and brought together, there is a need to analyze their potential roles and contributions to the ASTI methodology. The considerations that have been identified from the experience of the pilot countries refer to the competencies of institutions as follows:

A. ***Resource mobilization****:* Which institutions have staff time and financial resources to operationalize the pilot (or ASTI data collection)
B. ***Mandate:*** Which institutions have the appropriate mandates to implement?
C. ***Proximity:*** Which institutions are closest to the source of data?
D. ***Engagement:*** Which institutions are well placed to interpret, use and advocate for ASTI amongst the sectoral actors?
E. ***Advocacy & Use:*** Which institutions are best positioned to appropriately use and are motivated to advocate for ASTI to decision-makers and policymakers?

Through such an exercise, the institutions will be able to identify the champions of ASTI locally and the collaboration agreements that are needed to facilitate smooth implementation and including the process of institutionalization of the ASTI methodology in the country.

3.2.2 Potential roles and responsibilities of institutions engaged with ASTI

Through the discussions on the roles of the institutions, and based on their comparative advantage, a set of potential leadership roles and responsibilities that should be considered are:

1. Overall coordination of ASTI process & being answerable for the country process
2. Coordination of the data collection process
3. Operational management of the data collection process (with human resources to deal with queries, follow ups with potential respondents)
4. Coordination of compilation of data (using the Data Management Portal) and quality control
5. Coordination of data analysis and reporting process at national level
6. Coordination of reporting ASTI data & results of analysis
7. Coordination of advocacy and policy engagement base on ASTI
8. Coordination of the institutionalization of ASTI within the country

These roles can be implemented collaboratively but require leadership of each process to be shared. In general, through such an exercise, the institutions should be able to achieve a clearer definition, understanding and recognition of their roles in the process, agree on their complementary roles and assign each institution to lead at least one of the processes.

3.3 Considering the scope and key concepts of ASTI for data collection

For ASTI indicators, the most relevant procedures and definitions are those developed by the Organization for Economic Co-operation and Development (OECD) and the United Nations Educational, Science, and Cultural Organization (UNESCO). These are described in the Frascati Manual (OECD, 2015), which defines the scope of “research and experimental development”, the relevant principal categories to be measured and the appropriate methodology.

Narrowing down from the sector-agnostic Research and Development scope defined in the Frascati manual, the scope of the ASTI is Agricultural Research and Development (AR&D), and more precisely AR&D performed in National Agricultural Research Systems (NARS). Although data for international research is also monitored in ASTI, it is not collected through the questionnaire.

Box 2: Boundaries of ASTI datasets

ASTI, as described in these guidelines, may limit itself to AR&D rather than expanding to include indicators on the multiple dimensions of the agricultural innovation process. The ASTI program, as implemented by IFPRI, traditionally focused on measuring inputs into agricultural R&D, rather than outputs or outcomes. However, innovation dimensions may be useful at a national level and for different policy purposes. Nevertheless, appropriate national-level measures for agricultural innovation remain difficult to develop, although efforts are now being addressed separately through guidance of the Oslo Manual. The Oslo Manual, "Guidelines for Collecting, Reporting and Using Data on Innovation, was first published in 1992 by OECD. It provides guidelines for collecting and interpreting data on innovation. R&D outputs are complex to measure at the national level and over time, in addition to being hard to compare internationally. However, there is recognition that R&D outputs and outcomes are key supplementary indicators for assessing agricultural R&D performance.

The case of Ecuador serves as an example in this context. During its 2024 pilot test, the country introduced an innovation module as a complementary component to the modules focused on core and structural variables (see Box 7).

Key concepts that are used in the ASTI methodology have also been adopted from the Frascati Manual and additional interpretation have been provided to ensure that there is a clear understanding of what needs to be measured and recorded to enable the creation and maintenance of harmonized ASTI datasets across all countries over time. Some of these key concepts are described below.

3.3.1 Agriculture

These guidelines adopt the definition of agriculture, that includes crops, livestock, forestry, fisheries, natural resources, and the socioeconomic aspects of primary agricultural production as referred to in ISIC, rev.4, Section A, Agriculture, Forestry and Fishing (United Nations, 2008). It also includes farm storage and processing of agricultural products. However, it excludes postharvest or food processing research off farm. Besides, it is recommended that R&D in the agrochemical industry, agricultural machinery, and the food processing industry off farm should not be included in ASTI as these are better reported under those industries. Also not included are the more discipline-oriented basic research activities undertaken by departments such as microbiology and zoology, except when this work has a clear focus on agriculture.

3.3.2 National

The scope of ASTI is national AR&D. Following the definition of the scope developed under the IFPRI-led ASTI program, the concept of "national" refers to domestically targeted research activities that are funded or executed by research agencies within a particular country. Therefore, research activities undertaken by international and bilateral research agencies are excluded unless they are executed by national institutes. Also excluded are research activities undertaken by short-term development projects.

3.3.3 Research and Development (R&D)

These guidelines use the definition for "research and experimental development" as in the Frascati manual, which comprises *creative and systematic work undertaken to increase the stock of knowledge […] and to devise new applications of available knowledge*. Research is considered the *creative work and the original investigation undertaken on a systematic basis to gain knowledge* and development is *the application of research findings or other scientific knowledge for the creation of new or*

significantly improved products, applications, or processes. Overall, R&D is always aimed at new findings, based on original concepts (and their interpretation) or hypotheses. It is largely uncertain about its final outcome (or at least about the quantity of time and resources needed to achieve it), it is planned for and budgeted (even when carried out by individuals), and it is aimed at producing results that could be either freely transferred or traded in a marketplace." Thus, for an activity to be an R&D activity, it must satisfy five core criteria: it must be **novel, creative, uncertain, systematic, transferable, and/or reproducible**.

The term R&D covers three types of activity: basic research, applied research, and experimental development. The ASTI methodology, as described in these guidelines, will not seek to distinguish between these types of research but defining them is useful because put together they define the full scope of AR&D. As defined in the Frascati manual, **Basic research** is *experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.* **Applied research** is *an original investigation undertaken to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective.* **Experimental development** is *systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.*

Among the categories that do not fall under R&D, the most important ones in relation to AR&D are the following four:

- Education, extension and training. However, research conducted by PhD students at universities is included, if possible, as well as agricultural extension and training only when it is done by an agency that is focused entirely on R&D.
- Science and technology information services. Specialized activities to collect, code, record, classify, disseminate, translate, analyze, and evaluate data are considered R&D only when they are conducted primarily for the purpose of R&D support.
- General purpose data collection. In relation to the agricultural sector, this means that topographical mapping and geological, oceanographic, and meteorological surveying are not defined as R&D, though such activities are often conducted within fisheries, forestry, and natural resource management agencies.
- Administration and other support activities. Activities related to the financing of R&D and indirect support are not included. However, administration and clerical activities that are exclusively for R&D are included. For example, administration of an agricultural research institute is considered to be part of R&D.

3.3.4 Research 'performers', institutional units, institutional sectors

The ASTI methodology measures the human and financial resources invested by **"performers" of agricultural R&D, following the performer-based approach recommended by the Frascati manual**. The "performer" is the entity that carries out the research, not the founder of the research.

The **institutional units** involved in the performing of R&D activity are defined as "*an economic entity that is capable, in its own right, of owning assets, incurring liabilities, and engaging in economic activities and transactions with other entities*" (EC, IMF, OECD, UN and the World Bank, 2009. System of National Accounts, United Nations, New York). In the R&D case, institutional units have to be capable of decision making in respect of the conduct of R&D, from the allocation of financial resources for internal or external use, to the management of R&D projects.

The **reporting unit** on the other hand is the entity from which the required statistics are collected. It may itself consist of multiple reporting sub-units within the institution where survey questionnaires are completed.

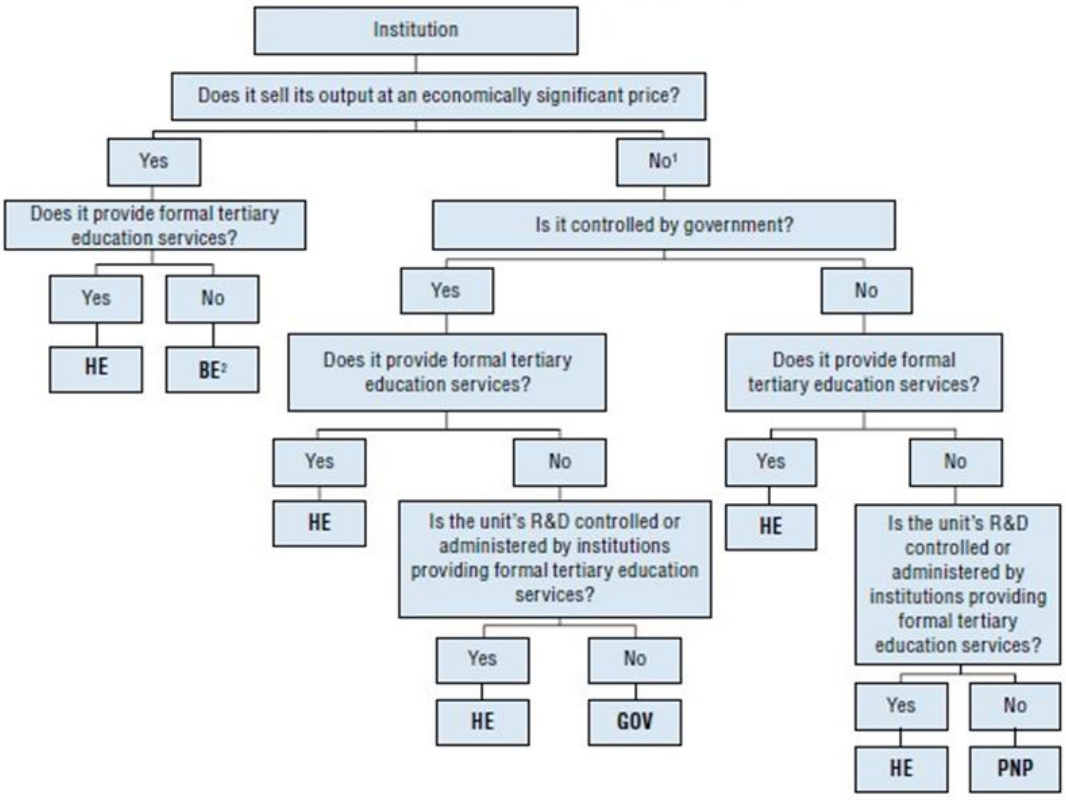
Research performers that are expected to contribute ASTI data belong to different **institutional sectors**, and the data collected changes slightly for each sector. The Frascati manual draws upon the approach of the System of National Accounts (SNA) to identify four mutually exclusive institutional sectors to characterize and classify R&D performing institutions: (i) Government (ii) Higher Education (iii) Business Enterprise, and (iv) Private non-profit (Table 4). While four of the sectors can be related to those of the SNA, the Higher education sector, because of its policy relevance, is unique to the Frascati manual and is made up of institutions that can be in any of the SNA sectors.

Table 4. Sector and institutional classifications used in the Frascati Manual

Sector and institutional classifications for measuring resources invested in AR&D		
1. Government		Research organizations directly administered by the national government, typically as a department or arm of a ministry
2. Higher education		Academic agencies that combine university-level education with research; they include agricultural faculties, as well as specialized R&D institutes administered by universities
3. Nonprofit		Agencies not directly controlled by the national government and without an explicit profit-making objective; in the agricultural sector these agencies are often linked to producer organizations or commodity boards
4. Private for-profit	4a. Business	Entities with the primary aim of producing goods and services for profit; some of these companies have a R&D unit dedicated to agricultural research, though R&D is generally not their main activity
	4b. Public enterprises	Enterprises that are owned by government units; their primary activity is typically the marketing and sale for profit of goods and services, which are often produced by private enterprises

Furthermore, the Frascati Manual provides a decision tree to assist in assigning the proper institutional classification (Figure 2), with some additional insights through a few examples (Box 3).

Figure 2. Decision tree for assigning institutional units to the sectors



Key:

BE	Business enterprise sector
HE	Higher education sector
GOV	Government sector
PNP	Private non-profit sector

1. NPIs primarily serving businesses (e.g. trade associations, etc.) are classified in the Business enterprise sector, following the SNA convention of classifying those into the SNA Corporations sector.
2. This sector can be further subdivided into public and private Business enterprises, depending on whether the institution is controlled by government or not. This is analogous to the SNA treatment of public and private corporations.

Source: Frascati Manual (2015)

Box 3: Examples from the country pilots

Several government research agencies have a semi-public or a semi-autonomous status. Their administrative control is nongovernmental, but they continue to depend on government for funding. Examples include the Colombian Corporation for Agricultural Research (AGROSAVIA) and the National Institute for Agricultural Research (INIA) in Uruguay. The Frascati Manual classifies these institutions as government agencies. The National Agricultural Research Center (CNRA) in Côte d'Ivoire, on the other hand, is largely funded by the private sector. Although ostensibly a private company, CNRA still falls under the supervision of the Ministry of Higher Education and Scientific Research, from which it derives the public share of its funding and is mandated to undertake research for the public. Following the Frascati Manual, CNRA is classified as a government agency.

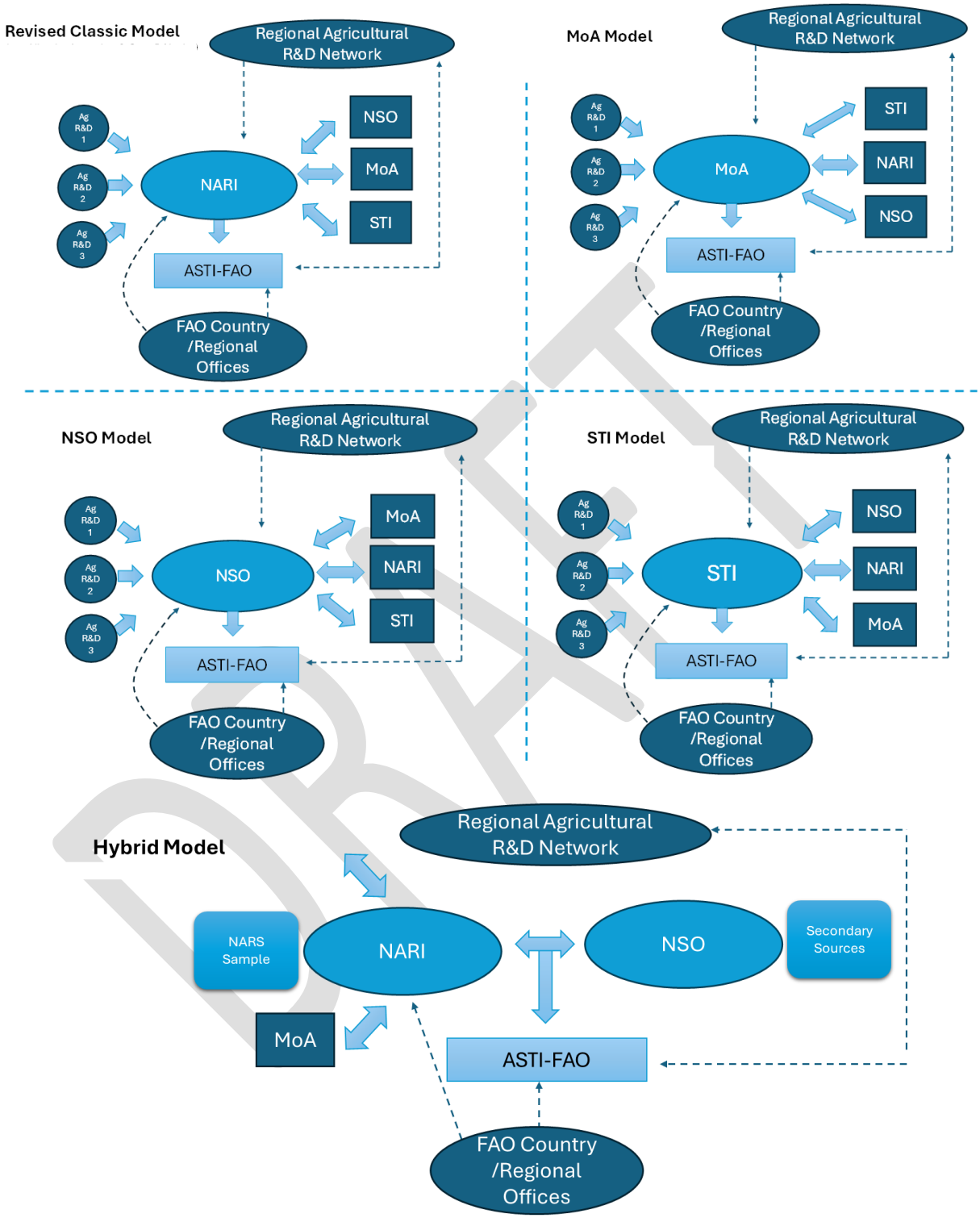
The above sets of considerations, together with the roles of the institutions involved in implementing ASTI will facilitate the identification of a fit-for-purpose data collection model for each country.

3.4 Identifying the most suitable ASTI data collection model for a country

The situation on the ground in terms of institutional set-up differs from country to country. However, through the combination of designs of approaches used across the pilot countries, six models have

emerged for institutional arrangements for the implementation of ASTI data collection, analysis and reporting and are described in Figure 3.

Figure 3. Institutional models for ASTI implementation



1. **“Classic” or NARI revised model:** The NARI is coordinating and supervising national agricultural research activities in the country, it has a clear mandate to collect data on NARS and utilize the data for strategic planning and other purposes. The term “Classic” refers to the previous model adopted by IFPRI for ASTI data collection. The “revised" component of this approach is that the NARI, in collaboration with the NSO, integrates ASTI into the National Statistical System mechanisms and the response to the questionnaire becomes mandatory according to the country's statistical legislation.

2. **Ministry of Agriculture (MoA) model:** The lead agency R&D responsibility is assigned to the MoA because, as key user of ASTI data, it is interested in ASTI data collection. The MoA may oversee the process while delegating the data collection to other organizations or even conduct the data collection. This model has an advantage regarding resource mobilization as the Ministry is usually more able than the NARI to allocate human resources and logistics to support the ASTI implementation. This may also enhance ASTI country ownership.

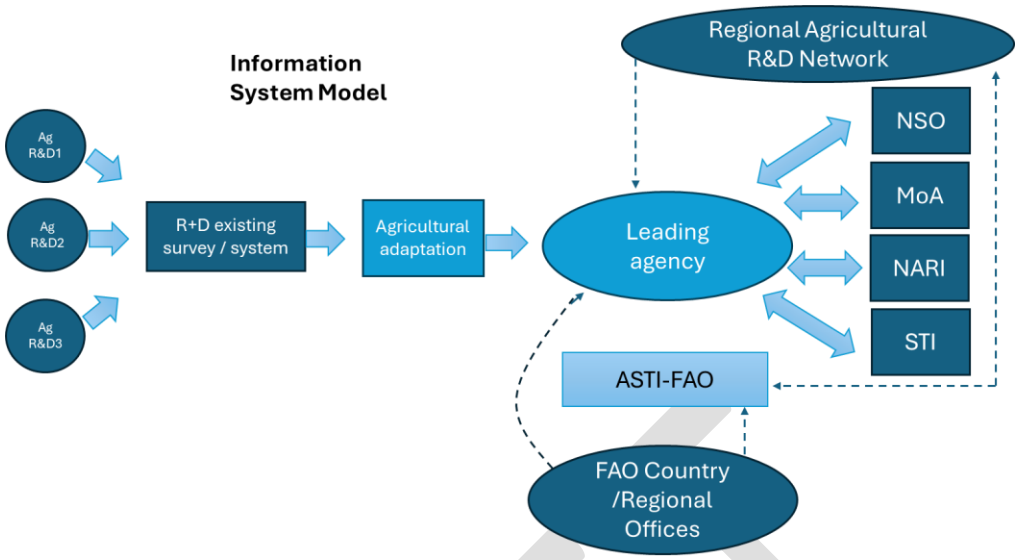
3. **NSO Model:** Data collection falls to the NSO, either because no other institution has the capacity or mandate to lead the effort, or because this has been established in national or regional statistical plans. The latter is the case for countries with a well-established R&D data collection mechanism that already report to regional or global organizations.

4. **Science, Technology and Innovation (STI) Agency Model:** The ASTI data collection mandate, interest or capacities are at a national STI Agency, an organization overseeing the overall R&D activities across all sectors. This may be the case in countries where the agricultural R&D sector is relatively small, or the NARS are not well structured and/or coordinated by the NARI. In addition, the STI model can also be applied in cases where the STI agency has resources and capabilities for data collection (e.g., the ASTI questionnaire could be integrated as a special module of existing R&D data collection mechanisms).

5. **Hybrid Model:** This model has emerged from pilot projects following collaborative efforts involving several organizations at the national level. It is characterized by a mixed approach between NARI, NSO or any other key stakeholder, employing a combined mechanism that integrates primary and secondary data sources.

6. **Information System Model:** This model represents the long-term systematic vision of the ASTI data collection, with a clear mandate and regular products (Figure 4). Examples of Information System models would currently likely be present in high-income countries, but it was also observed in a pilot country for ASTI, Colombia (Box 4). An information system-based approach is most appropriate in situations where institutions that have collaborated in the roll-out of ASTI also jointly established a common information system that can feed the data collection process on an annual basis.

Figure 4. Information System Model



Box 4: The ASTI information system of the NARI (AGROSAVIA) in Colombia

Until 2013, IFPRI collected ASTI in Colombia. At the same time, OCYT was conducting a national survey on science, technology, and innovation across all economic sectors. This overlap, led to a collaborative agreement between IFPRI-ASTI, AGROSAVIA, and OCYT.

Under this agreement, AGROSAVIA and OCYT joined efforts to work collaboratively, incorporating specific questions related to the agricultural sector. This partnership ensured that ASTI was conducted at the national level since 2014.

Significant improvements were made during this period in structuring Colombia's agricultural science and technology system. In 2017, a digital survey was introduced using a tool developed nationally (Box 8). That same year, AGROSAVIA began publishing an annual bulletin that presented indicators of science, technology and innovation activities. In 2024, the National Statistics Institute of Colombia (DANE) started to participate in the system and strengthened the legal framework of the survey by implementing the Statistical Law, which mandates the collection and provision of data. The Colombian experience serves as an exemplary model for developing a system to regularly collect, analyze, and publish agricultural science and technology indicators. This system not only supports international reporting but also provides a robust data dissemination insights for local stakeholders.

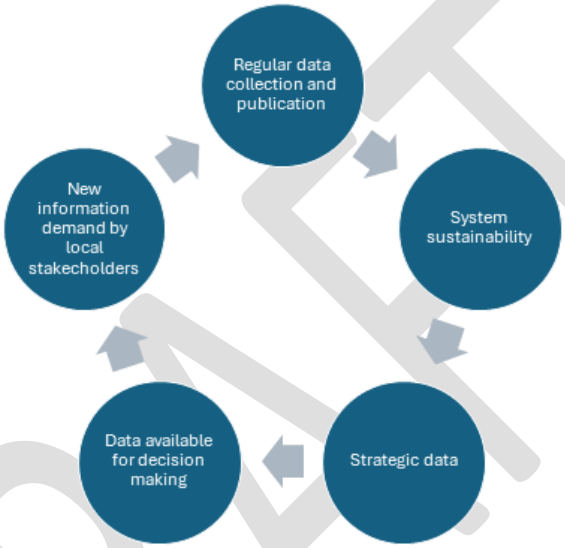
The successful implementation of any of the above models, but more specifically on the information system-based model, relies on addressing four key perspectives: ownership, governance sustainability, and integration of the system, which ensure a comprehensive approach aligned with the sector's needs, as follows:

i. **Ownership:** Promote local ownership of mechanisms for data collection, publication, and use to support national decision-making.
ii. **Governance:** Establish an inter-agency governance model that strengthens system-related actions through agreements and cooperation.
iii. **Sustainability:** Develop an agricultural science and technology indicator system with a medium—and long-term strategy that includes multiple data collection levels, defined publication schedules, and an implementation timeline.
iv. **Integration:** Develop strategies for data collection using secondary sources, administrative

records, and existing surveys. A system requires not only collaboration between organizations but also the creation of an integrated network to optimize information collection.

Additionally, regularity in data collection and publication strengthens the sustainability and local ownership of the framework. This, in turn, fosters a dynamic interrelationship between the information system, data generation, and the information demands of local stakeholders. Therefore, the information-system model is likely to be used across many countries eventually, irrespective of which model a country currently uses, and take a few years to emerge as the stable model, especially as reporting on ASTI becomes an annual process (Figure 5).

Figure 5. Mutually reinforcing relationship between an information system and sustainability of reporting on ASTI



3.5 Formalization of institutional arrangements

Having agreed on the key institutions involved in ASTI implementation and reporting, it might be beneficial to formalize the institutional arrangements through a Memorandum of Understanding, or similar instrument, to reflect the roles and responsibilities of each institution and to recognize their contributions. The formalization of such arrangements amongst institutions also provides an opportunity for raising awareness to policy makers to facilitate resource availability and empowerment of the data collection team.

3.6 Development of a strategy for ASTI data collection

The implementation of ASTI data collection can begin with practical preparations shortly after the initial planning meetings among the implementing institutions, setting the foundations for an overall strategy for ASTI implementation. This should cover the targeting of appropriate institutions, adjusting the questionnaire for the selected set of indicators, reviewing the set of instructions for filling in the questionnaire, scheduling sensitization sessions for the focal points in target institutions on responding to the questionnaire, planning for follow-up on data collection, developing a plan for quality control of data received, cross-checking techniques with complementary sources of data, making provisions for completing gaps in the data collected. Finally, the strategy should also address planning of data analysis, publication and utilization of the published results.

One of the outcomes of the collaborative process and institutionalization of the planning process for ASTI is the joint identification of the target population of institutions investing in Agricultural R&D. The experience from the pilot countries has shown that there are many institutions that are potentially investing in AR&D, including from the private sector. However, an initial wide casting round of data collection has shown that many of the institutions end up reporting that they do not invest in AR&D as defined in the Frascati manual. Thus, there is a process of rationalization of the target institutions for ASTI data collection, which can already be informed by the stakeholder institutions organizing the implementation of ASTI. Over time, and with repeated collections, the set of targeted institutions will be refined.

4. Designing a questionnaire to measure ASTI during field implementation

This chapter outlines the methodology for designing a questionnaire that allows for the measurement of ASTI variables that will enable the production of the indicators. It describes the principal categories of indicators to be monitored for AR&D, the related recommended questions to be asked in data collection, and the measured variables to be derived from the questionnaire response data. This step of the process follows the initial institutional engagement described above, with continuous engagement of the same institutions into the data collection, analysis and use of the indicators later in the process of implementation. The questions used for data collection to measure/calculate the indicators are based on previously developed questionnaires used during the IFPRI-led program and the subsequently modified ones used during the pilot country testing. A sample of the proposed questionnaire has been provided in the Annex. However, it may still be subjected to local adaptation and developed further, based on the local context of a country and projected use of the data. Finally, the chapter provides a checklist to help plan for the field implementation of data collection.

4.1 Principal categories of ASTI

The principal categories of indicators to be measured to assess the AR&D situation in a country pertain to three key areas: human resources, financial resources, and research focus.

1. **Human Resources**: This category encompasses:
   - Researchers' time dedicated to agricultural research.
   - Distribution of researchers by academic degree, gender, and age group.
   - Support staff (technicians, administrators, etc.).
2. **Financial Resources**: This includes analyzing R&D expenditures and funding sources:
   - Expenditures by cost category: salaries, operational and program expenses, and capital investments.
   - Funding sources: government funding, donations, bank loans, commodity levies, sales of goods and services, among others.
3. **Research Focus**: This identifies researchers' focus on terms of commodities, thematic areas, and critical cross-cutting issues.

The first two categories on human resources and financial resources are essential, and the related indicators are recommended as core indicators for annual reporting. The third category, on Research Focus, requires more in-depth assessment, but would not vary in the short term. Thus, the indicators related to the latter are categorized as structural indicators for which data collection does not have to be carried out at an annual frequency. As a result, the construction of variables and indicators is organized into two levels:

- **Core Indicators (Tier 1 indicators)**: Collected annually due to their variability. They are gathered using predefined strategies to ensure temporal and cross-country comparability. In terms of international comparison, the core Tier 1 ASTI indicators are:
  1. Total agricultural research expenditure at constant prices.
  2. Agricultural research expenditure as a proportion of the value added in agriculture, forestry, and fisheries.
  3. Total agricultural researchers in full-time equivalents (FTE).
  4. Agricultural researchers (FTE) per 100,000 farmers.

These indicators are calculated using responses to Tier 1 survey questions incorporating, in some cases, exogenous variables from secondary sources (e.g., World Bank).

- **Structural Indicators (Tier 2 indicators)**: Collected less frequently (every 3 to 5 years) through comprehensive surveys. These variables are more structural and enable deeper analysis, such as researchers' age, focus on commodities, and research outcomes. The calculations of these indicators are covered in more details in Chapter 6.

4.2 Measurement of indicators around human resources

Questions in this section relate to the number of researchers and technicians employed, levels of academic qualifications, the proportion of time that various staff spend on research, the age distribution of research staff, the number of women researchers, and support staff by various categories.

4.2.1 The concept of full-time equivalents (FTE)

ASTI indicators are not just aggregations of individual survey data: some key indicators are the results of calculations that make them more meaningful and comparable. More details on the transformation of collected data into indicators can be found in chapter 7 on dissemination. However, to understand the key questions on HR in the questionnaire, it is essential to introduce the concept of **Full-time equivalent (FTE).** The Frascati Manual describes the **Full-time equivalent (FTE)** of R&D personnel as:

> *"The ratio of working hours actually spent on R&D during a specific reference period (usually a calendar year) divided by the total number of hours conventionally worked in the same period by an individual or by a group. In order to be included in the R&D personnel totals, an individual should make an appreciable contribution to the R&D performed. Therefore, for both internal personnel and external personnel, it is recommended to express FTEs in decimals and to check for the significance of the contribution to a unit's R&D performance by individuals spending less than 0.1 FTE on R&D on an annual basis (i.e. 10 per cent of the total working time, which is about 20 working days per year).*
>
> *Total R&D personnel in FTE terms includes the R&D performance, on an annual basis, by all individuals – internal R&D personnel and external R&D personnel, including volunteers – who contributed to the intramural R&D of a statistical unit, an institutional sector or a country".*

It is to be noted that the survey form itself should not directly ask for the FTEs. Instead, the questionnaire should ask two questions whose answers will be combined to calculate the FTE: the percentage of time spent by Research Performers on AR&D, and the headcount of researchers and support staff with various disaggregation. Thereafter, the values of FTE are calculated combining the data collected as "headcount" and the data collected as percentage of time spent on activities. Details of the actual formulas used are presented in chapter 6.

4.2.2 Time spent on research versus other activities

The method of calculation of the FTEs uses the percentage of time spent on actual AR&D versus other activities (such as teaching, administration, and student supervision), which should be excluded from ASTI calculations of human resources invested in agricultural R&D. An example from the Frascati manual is that four faculty members estimated to spend 25 percent of their time on research would individually represent 0.25 FTE and collectively be counted as 1.0 FTE.

4.2.3 Headcount in human resources

In the questionnaire, questions about human resources should ask values in absolute numbers, or headcount: the expected values are full numbers, including the researchers working partially on agricultural research. Human resources can be classified and characterized into categories defined as follows:

4.2.3.1 Professional research staff

The Frascati manual defines Research staff as "*professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods.*" The number includes staff employed in a formal research position within an organization and holding at least a BSc degree or equivalent. Only staff on-post should be reported.

4.2.3.2 Technical and other support staff

Three levels of support staff are identified:

1. **Technical support staff:** Those who directly support the design and conduct of agricultural research activities but do not hold a formal research position are classified as technical support staff. These employees have at least a secondary education level (i.e., high school or middle school) plus additional technical training. Some technical support positions may require a university degree. Examples of these are laboratory and field technicians and station managers.
2. **Administrative support staff:** Personnel who carry out secretarial and administrative tasks and have at least a secondary education plus additional professional training are classified as administrative support staff. Examples are accountants, computer personnel, personnel managers, and secretaries.
3. **Other support staff.** Remaining staff positions not classified in any of the above categories. Examples include drivers, laborers, and guards.

4.2.4 Assessing headcount and time-use data

Responding agencies do not need to calculate the FTEs themselves, but they need to provide the percentage of time spent on agricultural research, which will be used to calculate the FTE. Therefore, the recommendations for the collection/estimation of FTE data can be adapted to the collection/ estimation of headcount (HC) data. The preferred approach for measuring headcount data for R&D personnel should be as of a given date. Preferably, the point in time should be the same for all reporting units within all sectors of the reporting country.

The general recommendations for these data are:

- ❖ Direct collection of R&D personnel data is the recommended methodology to be used to produce both FTE and HC data series.
- ❖ When no direct data collection is possible, an estimation process can be undertaken to derive FTE and HC indicators from administrative data.
- ❖ Either ex-ante or ex-post, R&D personnel data must be consistent with R&D expenditure data, principally with the categories of "labour costs" and "other current costs-external R&D personnel".

4.2.4.1 Estimation of time-use data

Responses to questions on time-use by researchers are very important in ASTI surveys: the main time-use question is the percentage of time devoted to agricultural research, which is the key question to calculate FTEs; then there are the tier-2 questions on research focus. Therefore, devising and recommending a good data collection/estimation method for this time-use data is essential. The most recommended method is time-use surveys; if they are not feasible, administrative and budget data assigning percentages of researchers' time (e.g. person/month) to specific programs/projects can help to estimate the percentages. It is also recommended that respondents provide more information/illustrate the method used to estimate this data.

4.2.5 Qualifications of human resources

It is recommended to collect time-series data on university qualifications of professional research and technical support staff. A standard degree classification like the anglo-saxon one (PhD, MSc, and BSc) can be used (box 5), but indications should be provided on degree-level equivalents, for instance:

- Research doctoral degrees (e.g., PhD, DSc). Equivalent to more than six years of full-time university education, including a doctoral thesis.
- Master's degrees (e.g, MSc, MEcon, MPhil). Equivalent to five to six years of full-time university education.
- Bachelor's degrees (e.g., BSc, BVM, BPhil). Equivalent to at least three (but usually four) years of full-time university education. This category also includes staff with honors degrees.

Box 5: Degree levels in non-Anglophone countries

ASTI collects data on the number of researchers with PhD, MSc, and BSc degrees. However, universities in many countries offer a much larger variety of academic degrees. Classifying these degrees into the simple PhD-MSc-BSc system is not always easy. Although France has harmonized its academic degree system with those of other European countries, the university systems in many former French colonies in Africa are still based on the old French system. Some small differences remain across francophone African countries, but as a general rule, degrees from francophone universities correspond to the following PhD-MSc-BSc equivalents:

PhD = Doctorat
MSc = Doctorat de médicine vétérinaire, DESS, DEA, master, maîtrise, ingénieur
BSc = Licence

4.3 Measurement of indicators on financial resources

Data on national AR&D spending and funding sources are key. It is recommended that they be collected in local currency units, for ease of data collection. However, values in local currency are not the most meaningful and are not comparable, so the most important financial indicators will be converted to a comparable value at the time of dissemination.

4.3.1 The concept of "purchasing power parity"

To allow for regional and international comparisons, country financial data should be converted into a common currency at the time of dissemination. Although this is not part of the questionnaire design phase, it is useful to be aware of the concept of conversion to a common currency at constant prices. To make financial data comparable internationally and chronologically, it is recommended to first deflating research expenditures in current local currency units and then converting these amounts into a common currency unit using the "Purchasing Power Parity" (PPP) metric PPP conversion factors are published by the World Bank, which defines them as follows: "*PPPs convert different currencies to a common currency and, in the process of conversion, equalize their purchasing power by controlling differences in price levels between countries*". The ASTI methodology emphasizes the "constant prices" factor by using the same reference year for all PPP calculations. See chapter 6 for more details on this calculation and other derived financial indicators that embed external indicators.

4.3.2 Spending

In line with the recommendations from the Frascati manual, survey questions should ask for actual expenditure figures, not budgeted or projected expenditures.

If the financial year does not match the calendar year, expenditures should be reported in the calendar year that covers most of the financial year. For example, if the 2024/25 financial year starts April 1, all costs incurred in 2024 are to be reported under 2024. If the 2024/25 financial year starts July 1, all costs incurred in 2024 are to be reported under 2025.

4.3.2.1 Cost categories

Spending data should be collected against three cost categories:

- **Labour costs of R&D personnel**. All employed R&D personnel (called "internal R&D personnel" in the Frascati manual) remuneration expenditures are reported here including, pension plan contributions, insurance premiums, child education and housing allowances. It is important to include only labour costs for employed persons when they make a direct contribution to intramural R&D, especially if such persons do not work full-time on R&D activities. This category also includes the labor cost of temporary staff like day laborers and long-term consultants, which is often mistakenly included under operating expenditures.
- **Other current R&D costs**. These costs comprise non-capital purchases of materials, supplies, equipment and services to support R&D performed by the statistical unit in the reference year. Items such as gasoline, electricity, stationery, books, agricultural inputs, staff training, travel, and per diem expenses are included here. Royalties or licences for the use of patents and other intellectual property rights, the lease of capital goods, and running costs and maintenance of buildings, cars and equipment are reported here as well. The costs associated with engaging persons who are not employed in the research unit but provide direct services that are integrated into the unit's R&D activities should be included in other current costs (defined as "external R&D personnel" in the Frascati manual, including on-site consultants and researchers from external organisations, research institutes, enterprises, etc., and the self-employed).
- **Capital R&D expenditures**. All expenditures related to the purchase or rental of items that last longer than a year are reported in this category. Examples are research equipment, furniture, computers, cars and vehicles, land and buildings. Depreciation costs (and interest charges) for past capital investments are also included here.

4.3.2.2 Funding sources

It is recommended to collect data on funding received, against different types of funding sources. All funds received within a (fiscal) year should be reported, not budgeted or projected funds. Sources of funding are indicated for total expenditures. Funding source can be grouped in the following categories:

- **Government core allocations**. This category is made up of direct institutional funding derived from a central budget, such as funds provided by a supervisory ministry for day-to-day operations and salaries.
- **Other government allocations**. This category is for reporting government funding that complements annual appropriations from national budgets, for example, in the form of competitive funds and science and technology funds.
- **Loans from multilateral donors**. Loans, for example, from the World Bank, are reported here.
- **Grants from multilateral and bilateral donors and private foundations**. This category is for reporting grants from multilateral donors, such as the World Bank (excluding its loans), the African Development Bank, FAO, and the European Union, and from bilateral donors, such as USAID, JICA, GTZ, and the Government of France. Grant providers may also be regional or international organizations and entities, such as CGIAR centers, FARA, ASARECA, CORAF/WECARD, and SADC. Grants may be awarded by private foundations such as the Bill & Melinda Gates Foundation.
- **Commodity levies and producer organizations**. Funding provided through commodity taxes

levied on agricultural production and exports are reported here.

- **Sale of goods and services**. Income to be reported in this category includes earnings from contract research for public and private enterprises.
- **Other**. Funds from sources other than the above categories should be reported here.

4.4 Measurement of indicators on research focus

Additional data that can enrich the indicators is data on research focus. This can be collected through time-use questions like percentages of researchers' time spent respectively on specific commodities, specific thematic areas, and a few selected cross-cutting themes. Attention should be paid to make sure that the total value of the focus percentages is always 100%.

As for other time-use data, at the time of indicator calculation, the percentage will be adjusted against the overall proportion of time dedicated to agricultural research, to obtain indicators in FTEs. Details about the indicators' calculations are provided in Chapter 6.

4.4.1 Commodity and thematic focus

Through the questionnaire, granular data on researchers' time use on specific commodities and thematic areas can be gathered.

Commodities in ASTI questionnaires administered by IFPRI used to be grouped in a way that is not aligned with the UN reference classification (the Central Product Classification): the same groupings can be used for comparability with legacy ASTI data, but ideally behind the scenes the commodities should be named and grouped in alignment with the CPC groups. In this way, comparisons with other systems that use the CPC will be possible.

Thematic areas should be ideally roughly aligned to the OECD Fields of Research and Development (FORD) classification referred to in the 2015 Frascati manual and in turn aligned with UNESCO's "Recommendation Concerning the International Standardization of Statistics on Science and Technology". Both those classifications are however too broad, while for ASTI indicators, thematic areas related to AR&D should be much more detailed (See Annex 11.1).

4.5 Options for additional indicators

In general, the methodology for measurement of ASTI and the corresponding instruments developed during previous implementation approaches and piloting in countries, have been designed to be flexible and accommodating. This flexibility enables implementing institutions to engage in the process, especially if they can also benefit from the data being collected or have additional questions added to the collection process. This facilitates pooling of institutional resources and overall efficiency in data collection). Additionally, it encourages country ownership of the process and enhanced its value for local stakeholders.

These different combinations of approaches have been field tested, and the templates for core and structural indicators are available for use, to enable the production of harmonized datasets. As mentioned above, the core ASTI variables proposed in these guidelines have been designed to gather the minimum set of data (also referred to as Tier 1) on AR&D investments and human resource capacity, on an annual basis, to generate the core standard variables, which can then be used for comparisons across countries and regions.

Countries should collect data on ASTI based on their needs and interests as they lead the process, but they should also be aware that the data contributes to a global harmonized dataset. Thus, countries (and NARS) can decide to gather more data for an extensive examination of investments in AR&D, for which an additional set of structural variables, which are more nuanced and related to the institutional

setup of AR&D, research capacity, investment, funding sources, commodity and thematic focus, and other specific demands from stakeholders. Structural variables are also referred to as Tier 2 variables.

The flexibility in measurement of the structural variables is that they do not vary as rapidly as the core variables and therefore can be addressed at longer than annual intervals and reported retrospectively for the previous years. Nevertheless, it is recommended to address the Tier 2 variables through the questionnaire at least once every five years in order to maintain continuity of existing global historical records on ASTI. Thus, a country can add Tier 2 questions to the Tier 1 questions in some of the years during the data collection process.

The flexibility of the data collection approach through questionnaires means that a country can also administer slightly different questionnaires to different types of targets responding agencies (e.g. questions related to core and structural variables to research institutions devoted to agricultural research, shorter questionnaires to small companies, or additional specific questions for higher education institutions).

Furthermore, countries (and NARS) can customize the presentation of the instrument (e.g. adding their logos to the questionnaire to reflect the collaboration on the initiative amongst different authorities) can also add questions to address any additional dimensions of AR&D. A good example of such additional indicators is the inclusion of indicators related to innovation, as happened in Ecuador during the ASTI pilot test in 2024 (*see box 6*). Other potential areas to explore include research outcomes as peer-reviewed publications (through secondary repository sources) or the registration of patents.

Box 6: Ecuador extra module on innovation

Ecuador expressed a strong interest in collecting data on innovation at the national level. Consequently, when selected as one of the pilot countries in 2024, it chose to include ASTI's core and structural variables while introducing a dedicated module on innovation aligned with the priorities of local stakeholders.

The process for registering agricultural sector innovations focused on assessing the technological maturity of innovations developed by agencies. This was achieved through a structured questionnaire that identified six levels of maturity—from initial development to market expansion—and nine evaluation criteria. Agencies responded to different questions to determine whether the criteria for each maturity level were met. This approach resulted in a matrix, with innovations represented in columns and maturity criteria in rows. The primary objective was to provide an initial nationwide assessment of the maturity status of agricultural innovations. Ecuador also incorporated additional questions beyond the structural Tier 2 variables to generate data relevant for national decision-making. As an example, a question to capture the ethnic self-identification of researchers was added as a complement.

This approach enabled the collection of core and structural data through a globally standardized methodology, fostering international comparability. At the same time, it facilitated the integration of locally relevant modules and questions, ensuring that the survey addressed the specific needs of local stakeholders while maintaining international methodological consistency for the core variables.

4.6 Sensitization of target audience and training

Once the set of target institutions has been identified, it is often advisable to engage with the potential respondent institutions, ahead of the deployment of data collection through the questionnaire. Therefore, the recommended approach is to identify a focal point within each target institution, who will be responsible for responding to the questionnaire.

The targeting of different categories of target institutions can be carried out by different partners organizing the ASTI data collection, the basis being that each approaches the target it is more familiar with. In large systems, the initial identification of a target institutional focal point to respond to ASTI

may be as a follow up to some form of sensitization of the institutional management. In geographically smaller countries or countries with fewer target institutions, the organization of a national workshop should enable both sensitization on ASTI as well as the identification of the ASTI Focal Point for the target institution.

Additionally, training workshops for the identified focal points will improve response rates and enhance the accuracy of the data collected. The specific objectives of these workshops are usually to:

- Introduce the new data collection mechanism integrated into the National Statistical System, including the mandatory response legal enforcement, when applicable
- To train data providers on the ASTI definitions and questionnaire completion
- To set up a timeline and discuss commitments

Such a collective approach ensures bonding around the collection and use of the data by local NARS institutions. Such workshops also enable any doubt with the methodology to be resolved and to establish linkages between ASTI data collector and respondent from target institutions. Such relationships will serve to facilitate the follow-up during implementation and finalization of data collection.

4.6.1 Engagement with private sector organizations for data collection

There are more difficulties for a NARI to obtain AR&D investment data for private for-profit enterprises as many private companies are reluctant to share information on their agricultural R&D resources and investments due to confidentiality concerns. In addition, private research activities in low-income and middle-income countries tend to be small in scale and ad hoc, making it difficult for surveyors to capture full information, according to the IFPRI-led ASTI past experience. This is particularly the case where the collaboration with the NSO becomes critical as private sector institutions are used to reporting such data to the NSO, and therefore, the request for such information from private sector operators can be handled by the NSO, with aggregated data being passed on for reporting.

4.7 Checklist for the data collection process

It is essential to set clear deadlines for submitting the questionnaire and provide a dedicated institutional email address for inquiries. Before beginning the field implementation phase, a realistic work plan should be developed, including timelines for distribution, potential extensions, and periods allocated for quality control and data processing.

As a summary, the main aspects to consider for the field implementation include:

1) **Analyze the list of agencies**

   Ensure the list of agencies involved in data collection is complete and representative of all sectors (public, private, higher education, nonprofit) conducting agricultural R&D.

2) **Design the questionnaire**

   Create questionnaires tailored to the country necessities, specifying core and structural variables. Establish a clear data collection frequency: core variables annually, structural variables every three to four years and add specific indicators for national purposes.

3) **Choose a data collection system**

   Decide whether to use an existing system (e.g., Excel-based provided by FAO) or develop a custom system for data collection. Consider using statistical software for data aggregation and web forms for data collection for more advanced data processing.

4) **Engage the National Statistics Office (NSO)**

Establish a near collaborative involvement of the NSO and integrate the survey into the national statistical system to improve participation rates. Reference national laws and data protection regulations to enhance credibility.

5) **Include participating agencies' logos**

   Add the logos of all relevant agencies (NSO, NARI, MoA) on the questionnaire to boost credibility and engagement.

6) **Appoint a focal point at agency level**

   Send formal letters to agency authorities, liaise with each agency to designate contact person or focal point to ensure smooth communication, and conduct regular follow-ups and reminders.

7) **Set deadlines and provide support**

   Establish clear deadlines for questionnaire submission and provide a dedicated email for inquiries. Ensure a structured work plan is in place for distribution, extensions, and quality control.

8) **Develop a work plan for data collection**

   Before starting the field implementation phase, create a realistic work plan with timelines distribution, potential extensions, and time allocated for quality control and data processing.

4.8 Field implementation of the data collection process

Field implementation is a critical phase in the data collection process. The methods used vary widely depending on the National Agricultural Research System (NARS) size, the institutions involved, and the concentration of researchers within the system. However, certain general principles, informed by experiences from pilot cases, can be considered.

A key starting point is the design and preparation of the questionnaires, the list of agencies to be included and the data collection strategy. To begin with, it is crucial to analyse the list of agencies involved in data collection. The completeness of this list will be essential in ensuring the data accurately represents the universe of agencies conducting R&D activities in the agricultural sector, whether in the public, private, higher education, or nonprofit domains.

The next step involves designing the questionnaire for each agency type, considering the variables to be included and the frequency of data collection. Core variables may be collected annually, while structural variables could be updated every three to five years. It is therefore vital to establish a clear frequency to support a comprehensive strategy for data collection.

In the past, the ASTI-IFPRI data collection approach used a system based on Excel forms uploaded to a platform to generate national aggregates. An alternative approach is for countries to use their own data processing systems. This could involve processing Excel-based questionnaires using a statistical software or developing a dedicated system to manage data collection via web forms and internal processing. This approach is particularly recommended for countries aiming to establish an agricultural R&D data collection system. Colombia, for example, has developed its own system, which has proven highly effective over the years for monitoring surveys, ensuring data consistency and quality control, and generating post-survey aggregates (*see box 7*).

Box 7: Colombia´s Barrus System

Since 2017, Colombia has been collecting agricultural science and technology data through a national data collection system named BARRUS, developed locally to meet the country's specific needs and requirements. BARRUS is an online platform that users access remotely with a username and password, enabling web-based data entry by topic modules. The system simplifies the process for respondents by offering an online tool that allows partial data submissions and saves. It also enhances data collection and processing by integrating basic online consistency checks, improving data traceability, and boosting the quality and speed of the data collection process. The platform's generic modules were developed by Colombia's science agency (OCYT), while its NARI

(AGROSAVIA) contributed to the design and implementation of the specialized modules tailored for agricultural agencies. This strategy improved both data collection and the speed of implementation. For agencies, having access to an integrated online system allowed them to complete a single survey digitally, enhancing their user experience.

Regardless of the tool employed, several good practices have consistently proven effective, while FAO was testing different data collection approaches for ASTI. Engaging the national statistics office (NSO) and integrating the survey into the national statistical system (NSS) have been successful strategies for boosting participation rates. Additionally, referencing national statistical laws and data protection regulations can encourage faster and higher response rates. Including the logos of all participating agencies—such as the NSO, NARI, and MoA—on the questionnaire has also been shown to enhance credibility and engagement (*see box 8*).

A crucial element in improving response rates is establishing a clear point of contact within each agency receiving the questionnaire. This involves preparatory steps, such as sending a formal letter to the institution's authorities, appointing a liaison, conducting regular follow-ups, and issuing reminders.

Box 8: Argentina´s communication strategy

In Argentina during the 2024 pilot test for the core R&D data collection process was spearheaded by a team from INTA (Argentina's NARI), which managed the distribution of questionnaires, with the support of the National Statistics Office, the Agriculture Ministery and the Science and Technology Agency. As part of the approach, agencies were first contacted directly, and questionnaires were sent only after a designated representative of the agency was contacted.

A crucial component of the ASTI initiative during the pilot data collection involved developing communication materials that prominently displayed the logos of participating institutions, including the National Statistics Institute (INDEC). The letter references to the national statistics law, data protection regulations and include the main objective of the survey. This approach effectively enhanced awareness and engagement among the participating agencies.

Instituto Nacional de Tecnología Agropecuaria — Ministerio de Economía República Argentina — Secretaría de Agricultura, Ganadería y Pesca — indec Instituto Nacional de Estadística y Censos República Argentina

Relevamiento de Indicadores de Ciencia y Tecnología Agropecuaria (ASTI)

Estimados/as:

Nos ponemos en contacto para informarles que en el mes de agosto 2024 comienza el **relevamiento de indicadores de Ciencia y Tecnología Agropecuaria (ASTI)**.

En esta primera etapa, se involucra a distintas instituciones gubernamentales especializadas en investigación agropecuaria, organismos públicos no especializados en dicha materia e instituciones de educación superior.

Los datos recabados permitirán ilustrar las tendencias y las brechas del sistema de investigación en el país, generar información para la toma de decisiones y ayudar a establecer prioridades de investigación.

En la web de ASTI, **www.asti.cgiar.org/es**, se puede apreciar el valor de estos datos en tanto fuente confiable y de libre acceso sobre los sistemas de investigación agropecuaria a nivel global.

Desde **ASTI (FAO), INDEC, INTA** y la **Secretaría de Agricultura, Ganadería y Pesca de la Nación** agradecemos su colaboración para recopilar los datos esenciales sobre su institución.

Este relevamiento se enmarca en la Ley Nacional Estadística 17.622 y la Ley 25.326 de Protección de datos.

La participación de su organismo en esta encuesta es fundamental, ya que:

- **crea una imagen más precisa del sistema de investigación agropecuario en Argentina**
- **pone de relieve las brechas de investigación y su capacidad**
- **ayuda a jerarquizar temas de investigación**
- **mejora la visibilidad de la investigación en su organismo**

En el mes de agosto nos volveremos a contactar para brindarle el formulario correspondiente.

Gracias por su participación.

5. Quality assessment and value imputation

5.1 Quality assessment

Any data collection process must be accompanied by a comprehensive data cleaning and harmonization procedure for the data received and stored. This includes verification upon receipt and comparison with data from previous years using validated outlier detection strategies.

5.1.1 National statistical and data quality assurance framework

The first step in implementing a quality control system is to establish a framework for data quality. The aim of a national statistical and data quality assurance framework is to support the national statistical system in generating reliable and high-quality statistics for informed decision-making. It outlines principles related to the institutional environment, statistical processes, and outputs, which must be followed to uphold the integrity of the statistical system. It also defines the quality of statistics through various dimensions, fostering a shared understanding of the standards to be achieved. In general, countries have a quality framework in place to produce official statistics and, therefore, the integration of ASTI into the NSS mechanisms may also involve key processes to enhance its quality.

The most important quality characteristics depend on user perspectives, needs and priorities. For this reason, a major challenge is to achieve a compromise amongst the needs of the various possible users, the ability to produce and disseminate statistical outputs, that satisfy the most important needs, given the constraints of available resources. Based on work by several international organizations (e.g. FAO, Eurostat, ECB, IMF and OECD) in this area, quality in statistics is defined as the degree to which statistical outputs fulfill requirements and the following quality dimensions:

- **Relevance**: the attribute of a data product that measures to what extent the compiled statistics meet the demands of data users, analysts and policymakers. In that context, relevance depends on the coverage of the required topics and the use of appropriate concepts.
- **Accuracy**: in the context of the quality assurance framework, accuracy is the description of the extent to which the compiled statistics measure the desired or true value (or bias, in statistical terminology). Measures of accuracy include estimates of under or over coverage. There is no definitive or single measure that adequately describes the accuracy of a data product.

  For example, for variables measured in terms of time allocation percentage, data is often an estimation, and it is important to assess the methods used and whether there could be an under- or over-estimation before analyzing and disseminating the data.
- **Precision:** precision measures indicate the degree of confidence placed in the estimates. Measuring the uncertainty surrounding the estimation of the true or desired value is an essential component in quality assessments. Several sources of uncertainty, of a probabilistic or deterministic nature, can affect the estimates of certain variables. Those sources of errors are associated with the data collection, processing and compilation stages.
- **Timeliness**: within the context of the quality assurance framework, for a data product to be useful, it must be timely. Timeliness can be measured as the distance in time units that the data are released following the reference period. With all other things being equal, the shorter the time distance, the higher the quality.
- **Completeness**: as seen previously, both for the current data collection and for the whole data series, data gaps should be filled with estimates. Data series gaps should be identified and statistical procedures for imputation of values should be followed.

5.1.2 Quality control of the questionnaires received from the AR&D agencies

The objective of a questionnaire data control is to ensure the quality and consistency of data collected from agency-submitted questionnaires. To achieve this, a comprehensive review must be conducted before integrating the data into national aggregates, following a defined series of stages in the quality control procedure.

Stage 1: Initial data verification

This consists of verifying the completeness and quality of the data upon receipt on two facets: internal consistency across the questionnaire responses and consistency with the agency´s historical data series.

- **Verify internal consistency across questionnaire responses**

  This involves verifying the coherence within the answers. For example, if a total of 10 researchers is reported, the breakdown of researchers by gender and age should add up to the same total. In addition, some logical relationships between questions may be less direct. For instance, there should be consistency between the number of FTE (full-time equivalent) researchers dedicated to AR&D and the total salary expenditures reported by the agency.

- **Verify consistency with the agency's historical data series**

  This process includes consistency analyses through comparisons with the agency's reported results from previous years. Rather than conducting an internal consistency analysis within the current questionnaire, this stage will focus on a comparative assessment of values reported by the same agency in the past. This approach allows for evaluating whether the observed trends are consistent and whether the relationships between variables align with the agency's historical patterns.

Stage 2: Reviewing data from new or inactive agencies

For agencies without historical data or with outdated records:

- Review the internal logic of the current year's data (e.g. check if the ratio of researchers to research expenditures aligns with national averages).
- Use a comparable agency (e.g., similar size or focus) as a benchmark for validation and control.

Stage 3: Handling outliers

If outliers are identified:

- Contact the agency to confirm if errors occurred during data entry or in the units of measurement (e.g., reporting using a different currency or unit of measurement).
- If the outlier is confirmed to be an error, correct them in the questionnaire before data aggregation. If the outlier is verified as accurate and logically explained, approve the data.

Stage 4: Classification of questionnaires

Each questionnaire must be assigned one of the following statuses:

- **Approved**: Data are logical and consistent after review. The questionnaire is validated and included in the national aggregates.
- **Under Review**: Data contain potential inconsistencies, requiring further clarification from the agency.

- **Rejected**: Data are inconsistent, and the agency cannot provide a reasonable justification. Rejection can be:
    - Total: None of the questionnaire data are consistent.
    - Partial: Specific questions are invalidated while others are approved. Partial information will be used to generate results.

Upon completing the analysis of questionnaires by agency and uploading the approved ones, the next step involves generating aggregated indicators. This can be done automatically if a system is configured for aggregating data from the agencies or through a statistical package if the survey is conducted exclusively in Excel format and needs a manual aggregation.

The aggregated results will form a set of consolidated variables at the national level. Initially tied to the specific questions in the questionnaires, these variables will be refined into indicators through incorporating data from secondary sources, as it will be analysed (detailed in chapter 6).

Analysing the aggregated data will enable the calculation of national totals for key metrics, including researchers, Full-Time Equivalent (FTE) researchers, and AR&D expenditures. This process helps evaluate whether the aggregated results align with the evolutionary trends observed in previous years and identify any significant deviations from expected averages.

A crucial step in this process is analysing the completeness of the dataset, which may require imputing missing data. This imputation can involve filling gaps at the agency level (total data) or within specific questions in an agency (partial data). All imputations must be completed before performing the final aggregated consistency check.

5.1.3 Commonly detected inconsistencies

Noticeable inconsistencies occur when reporting figures for researchers or expenditures deviates significantly from previous submissions by the same agency or comparable institutions. These discrepancies are primarily linked to the following factors summarized on Table 5:

1. **Use of a different unit of measurement**

Agencies may inadvertently use units different from those specified, leading to errors in reporting. For instance, (a) Expenditures reported in **U.S. dollars** instead of the required **local currency**, or (b) Figures expressed in **million**s or **thousands**. Such errors are often identified promptly upon data submission. To ensure accuracy, the following steps are recommended (a) contact the reporting agency: promptly reach out to the agency to verify and rectify any errors before processing, (b) If corrections cannot be made within the required timeframe, discrepancies should be flagged as outliers and subjected to appropriate imputation techniques.

2. **Misinterpretation of definitions**

A common issue is the incorrect interpretation of **agricultural R&D definitions** as outlined in these Guidelines. Institutions may include researchers or expenditures outside the scope of agricultural and/or R&D definitions, e.g. reporting 35 researchers, when only 10 are involved in agricultural activities. Another example of misinterpretation would be the inclusion of extension or training personnel as researchers. The solution to this problem is to follow-up with the agency. Secondary sources, such as institutional websites listing researchers and their areas of expertise, may also be utilized to verify data.

3. **Faulty estimation of the FTE ratios reported**

Inconsistent Full-Time Equivalent (FTE) ratios often point to data inaccuracies. Since FTE values typically remain stable, abrupt changes between years should be closely examined. For example, if a higher education institution reports an FTE ratio of 100%, this value should be carefully assessed. University research staff typically have also teaching responsibilities, which are often explicitly outlined in their job descriptions. Similarly, if a NARI reports an FTE ratio of 30%, this figure may

initially appear underestimated, as NARI researchers are typically dedicated entirely to research activities. The proposed solution is benchmarking to the institutional cluster (e.g., higher education, big or small government agencies, private sector, etc.) which can significantly contribute to the validation of values submitted.

4. **Identification of outliers**

There are certain analytical strategies that can help to identify outliers. For example, analyzing expenditure per researcher ratios can help detect anomalies between years, agencies and institutional cluster. Similarly, trends in key indicators for an agency can also be compared with the institutional cluster averages to identify potential abnormal changes. However, an outlier doesn't necessarily indicate an error but signals the need for further assessment as part of quality control.

5. **Validation of Agency list**

It is essential to maintain an up-to-date agency list, as missing institutions actively engaged in AR&D can lead to underestimated national indicators. In addition, agencies that no longer conduct AR&D could lead to imputation errors and overestimation of aggregates.

Table 5. Frequent consistency issues and possible solutions

Detected problem	Possible cause	Possible solution
Number of FTE researchers	Researchers who do not conduct agricultural R&D were included.	• Contact the agency for review. • Check secondary information sources (e.g., staff registries on the agency's website, alternative data sources). • Apply controls based on historical data and trends of agencies with similar characteristics. • Impute the data if the inconsistency cannot be justified.
	The number of hours dedicated to research (FTE) was overestimated, counting as research time activities such as extension, teaching, etc.	
Research R&D expenditures FTE	Expenditures unrelated to agricultural R&D were included.	
	The number of hours dedicated to research (FTE) was overestimated, which impacted the calculation of FTE-adjusted expenditures.	
	Expenditures reported in a unit or currency are different from that requested	

5.2 Imputation of missing values

Imputation is the process of replacing missing values with plausible, coherent values to facilitate subsequent analysis and data aggregations. Imputation procedures are designed also to replace observed values identified as invalid or inconsistent by the data editing and validation process. In principle, imputation procedures should be applied when the fraction of units to be imputed is much smaller than the fraction of the observed values (in general a 50% threshold is used).

5.2.1 Imputation methods

While it is always preferable to obtain data directly from the reporting agencies, when all approaches for direct data collection have been exhausted, imputation becomes a necessary step. Various tools and strategies can be used to complete historical datasets, enabling the generation of consistent and comprehensive statistics suitable for publication. While this document does not delve into specific imputation methods, the following general guidelines provide an overview.

One approach to impute missing values for a particular agency in a year is to apply the general variation observed in the national aggregate for the sector of the missing value agency. For example, if a higher education institution (i) has missing data for year (t), imputation could involve using the institution's values from year (t-1) and applying the overall variation in the higher education sector within the country during that period (A).

The formula for imputing missing values based on the variation of the immediately higher aggregate is as follows:

$$X_{it} = X_{i(t-1)} \times A_t / A_{t-1}$$

Considering that,

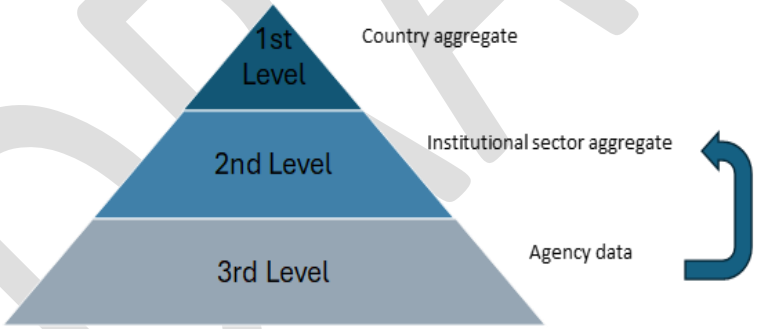
X_{it} represents the imputed value for the missing data of agency i in period t

$X_{i(t-1)}$ represents the last available value for agency i from period t-1

A_t represents the value of the higher-level aggregate (e.g., higher education total or government total) in period t

$A_{(t-1)}$ represents the value of the higher-level aggregate in period t-1

Figure 6. Levels of data aggregation



In some cases, an agency may lack data for certain intermediate periods but still have information for periods preceding and following the gaps. In such situations, a constant growth rate can be applied to the missing periods to maintain a consistent growth trend across the missing years.

For instance, if data is available for period t (Vt) and period t-n (Vt-n), the constant growth rate (r) can be calculated using the following formula:

$$r = (Vt/Vt\text{-}n)^{1/n-1}$$

Considering that,

R represents the growth rate

V_t represents the value at the final period (t)

V_{t-n} represents the value at the initial period (t-n)

n is the number of missing periods

In cases where an agency provides partial information —e.g. only the number of researchers—this information can serve as a valuable input for extrapolating other agency's variables –e.g. expenditure-. Partial data should be carefully evaluated and incorporated, where appropriate, into imputation procedures to enhance the completeness and accuracy of the final estimates.

5.2.2 Using secondary data

For more extensive data gaps where primary agency data is missing, secondary sources may provide useful proxies. These might include using the trends reflected in general R&D surveys in the sector/field or administrative data. The feasibility of this approach will depend on the specific circumstances of each case and the secondary data available.

Historical data from R&D surveys or economic censuses data could be useful to validate or reconstruct time series. Comparative exercises conducted during the FAO pilot projects demonstrated consistency between the "socioeconomic objective" reporting category for agriculture in the general R&D survey and the ASTI data.

6. Production of indicators based on collected data

Data is only good if it is put into use. After data has been collected and its quality has been ensured, if it remains only as raw data, it can be used only by data specialists who understand raw data and can work with it. In order for this data to be useful, meaningful indicators have to be extracted from the raw data, through calculations, including in some cases, external indicators that provide context. Furthermore, data or derived indicators that remain with an organization cannot be used by decision makers and interested stakeholders, if they are not shared or disseminated.

Interpretation entails considering the methodology used in data collection, the definitions used in the questionnaire, as well as calculations necessary to make data comparable or relative to other variables that affect it, for example, calculations to harmonize the data according to different units of measure.

The sections below describe policy-relevant indicators deemed useful during the previous IFPRI-led ASTI data collection and the method to produce them in a comparable way for compatibility with historical data series. The codes and acronyms for the indicators in the tables below are those used in the legacy IFPRI data series, recommended to be continued at the country level to collect data in a compatible way.

6.1 Human Resource Indicators

For assessing human resources capacities, some indicators can be extracted directly from the aggregation of responses to the questionnaire while others are generated in combination with derived indicators whose calculation requires external indicators. The data required to produce these indicators are as follows:

- Data from human resources section of the ASTI questionnaire (see Chapter 4)
- External indicators
  - Population, farmers: "Total economically active population in Agriculture"
  - Population, total: "Total Population" [2]
- One variable that is not normally included in the dissemination products but is a key variable to calculate core indicators is the percentage of time spent by researchers on agricultural research (**RES.PERCENT**). This variable is used in several calculations in the table below to convert from HC to FTE.

[2] These indicators can be downloaded from the FAOSTAT service: search the relevant indicator here: https://www.fao.org/faostat/en/#data

Table 6. Human resources indicators to be included in data series & dissemination products

Indicator acronym[3]	Name	Description and calculations
TIER-1		
RES.HC	Total researchers (headcount)	Sum of all responses to the " Researchers by highest education level and by gender" survey question
RES.FTE	Total researchers (Full-Time Equivalent)	RES.HC * RES.PERCENT **
RES.[gender].HC	Female and male researchers (headcount)	Sum of gender-disaggregated responses to the "Researchers by highest education level and by gender " survey question
RES.[gender].FTE	Female and male researchers (FTE)	As above, but in FTE: RES.[gender].HC * RES.PERCENT
RES.[gender]. [degree].HC	Female and male researchers by level of education (headcount) e.g. RES.FEMALE.PHD.HC, RES.FEMALE.MSC.HC...	Sum of degree- and gender-disaggregated responses to the "Researchers by highest education level and by gender" survey question
RES.[gender]. [degree].FTE	Female and male researchers by level of education (FTE)	As above, but in FTE: RES.[gender].[degree].HC * RES.PERCENT
RES.[inst].FTE	Researchers by institution type e.g. RES.GOV.FTE	Sum of researchers from surveys from the same type of agency. It is recommended to embed the type of agency in the questionnaire, otherwise it is necessary to look up the directory of responding agencies
RES. [gender].[inst].FTE	Researchers by institution type and gender e.g. RES.FEMALE.GOV.FTE	Sum of gender-disaggregated responses to the "Researchers by highest education level and by gender" from surveys from the same type of agency. As above.
RES. [degree].[inst].FTE	Researchers by institution type and level of education e.g. RES.PHD.GOV.FTE	Sum of degree-disaggregated responses to the "Researchers by highest education level and by gender" from surveys from the same type of agency. As above.
***.SHRE**	All disaggregated data should also be presented as shares of the total e.g. RES.FEMALE.BSC.SHRE	[slice] / [total] * 100 e.g. RES.FEMALE.BSC.SHRE = RES.FEMALE.BSC.HC / (RES.FEMALE.BSC.HC + RES.MALE.BSC.HC) * 100
TIER-1 DERIVED INDICATORS		
RES.TOT.ARI.FARMERS	Agricultural researchers (FTE) per 100,000 farmers.	RES.FTE / population, farmers /100
RES.TOT.ARI.POPULATION	FTEs per million population	RES.FTE / population, total /100

[3] Acronyms are from the IFPRI ASTI legacy files: they can be changed or not used, but if a country wants to build on legacy ASTI Country Data Files to maintain the data series or share data in a compatible way, using these acronyms can be useful

Indicator acronym	Name	Description and calculations
TIER-2		
There are many combined tier-2 indicators: here are only some examples. Each institution can choose which tier-2 indicators to publish and in which combinations		
RES.[gender].[agegroup].HC **RES.[gender].[agegroup].FTE**	Researchers by age group and gender e.g. RES.FEMALE.41_50.FTE	HC: The sum of age-disaggregated responses to the "Age distribution of researchers by gender" question. FTE: RES.[gender].[agegroup].HC * RES.PERCENT
RES.COM.[comm].HC **RES.COM. [comm].FTE** **RES.COM. [comm].SHRE**	Headcount / FTE / share of researchers focusing on a commodity or commodity group e.g. RES.COM.LIVEST.SHRE: "Researchers (FTEs), livestock (% of total)"	The .SHRE value is the response to survey question "Commodity focus in percentages" and it can be used to calculate the others: e.g. for livestock: RES.COM.LIVEST.HC = RES.COM.LIVEST.SHRE' * RES.HC RES.COM.LIVEST.FTE = RES.COM.LIVEST.SHRE' * RES.FTE

** RES.PERCENT: Percentage of time spent by researchers on agricultural research – core Tier 1 variable

Some of the key aspects for consideration when developing human resources indicators are listed below.

6.1.1 Distinguishing between headcount and Full-Time Equivalent (FTE) measures

Data collected in the questionnaires is normally in headcount (HC). HC numbers (**RES.HC** indicator acronym) are important data to disseminate, but it is essential to disseminate also the same data in Full-Time Equivalent (**RES.FTE**), as this gives a more accurate picture of the actual human effort devoted to agricultural research.
As illustrated in Chapter 4, the key variable needed to calculate the FTE is the overall percentage of time devoted by all staff to agricultural research (**RES.PERCENT** indicator acronym), expressed in decimals. The formula to calculate the FTE is:

*RES.HC * RES.PERCENT*

RES.HC and **RES.FTE** should be present in all dissemination products. RES.FTE is normally calculated during data preparation and interpretation.

6.1.2 Documentation of time allocation methodologies

The ASTI questions that ask for percentage of time allocation (% allocated to agricultural research, % allocated to focus areas) are among the most difficult for agencies to answer, and answers may differ depending on the methods used for calculating or estimating time allocation.
Ideally, questionnaire instructions will have recommended good practices for calculating time allocation and/or have recommended providing a note documenting the method used for calculating / estimating time allocation (see section on questionnaire design). Given that not all responding agencies have the opportunity to follow best practices like those recommended in the Frascati manual (e.g. individual surveys to the R&D staff), it is important to consider the methodologies used to

understand if there may have been an under- or over-estimation (in which case data may need to be revised: see Data revision below), or simply to add a note in the dissemination products documenting the methodologies.

6.1.3 Explanation of qualification classifications

As mentioned in the methodology section, qualification classifications may differ in different countries. ASTI (following the Frascati manual) provides definitions of the various qualifications that try to cater for different situations: it is important to interpret this data correctly, and to include the definitions in the dissemination products.

6.1.4 Gender disaggregation

Gender analysis is being given increasing importance in all types of statistics. Besides the tier-1 indicator on HC disaggregated by degree and gender, it is recommended to always include secondary breakdowns by gender in as many indicators as possible (if the collected data allow): for instance, researchers by position and gender, support staff by type and gender.

6.1.5 Derived indicators

Some ASTI indicators are more meaningful when combined with other external indicators that provide context. An example is a derived indicator used in the IFPRI-led ASTI program: Agricultural researchers (FTE) per 100,000 farmers. This indicator is a simple ratio: Agricultural researchers (FTE) / Total economically active population in Agr) (a FAOSTAT indicator). Other derived indicators can be defined by countries based on their needs and priorities.

6.2 Financial Indicators

Financial indicators can be extracted both directly from the aggregation of questionnaire responses, and as derived indicators whose calculation requires external indicators. The data necessary to produce these indicators are as follows:

- Data from the financial resources section of the ASTI questionnaire
- External indicators from the World Bank[4] Table 6 shows how these external indicators are used in the calculation of derived ASTI indicators)
    - **NY.GDP.DEFL.ZS**: "GDP deflator (base year varies by country)": the ratio of GDP in current local currency to GDP in constant local currency. In all formulas below, the base year for rebasing the deflator is indicated as Y*.; the deflator variable is calculated as follows: deflator = NY.GDP.DEFL.ZS[country, year] / NY.GDP.DEFL.ZS[country, Y*] *100
    - **PA.NUS.PPP**: "PPP conversion factor, GDP (LCU per international $)"
    - **NV.AGR.TOTL.CN**: "Agriculture, value added (current LCU)" (agricultural GDP)
    - **AGGDP.CURNTLCU** (million): NV.AGR.TOTL.CN / 1,000,000
    - **AGGDP.CONSTLCU** (million): AGGDP.CURNTLCU / *deflator*
    - **AGGDP.PPP** (million): AGGDP.CONSTLCU / PA.NUS.PPP [Y*]
- The percentage of time spent by researchers on agricultural research (**RES.PERCENT**)

[4] These indicators can be downloaded from the World Bank data bank service: select the countries and the series here: https://databank.worldbank.org/source/world-development-indicators/Series/

Table 7. (a) Financial indicators to be included in data series & dissemination products

Indicator acronym	Name	Description and calculations
(a) TIER 1		
EXP.CURNTLCU.HC **EXP.CURNTLCU.FTE**	Spending, total (million current LCU) Spending (FTEs), total (million current LCU)	Sum of totals of responses to the "Total expenditures by cost category (in thousands of current, local currency units) " survey question. .HC: absolute amount in local currency. .FTE: the same, but only expenses related to the % of time devoted to ag research: EXP.CURNTLCU.HC * RES.PERCENT
EXP.CONSTLCU.HC **EXP.CONSTLCU.FTE**	Spending, total (million constant Y* LCU) Spending (FTEs), total (million constant Y* LCU)	As above but in "constant" local currency (stripped of inflation fluctuations thanks to the GDP deflator): EXP.CURNTLCU.HC / deflator .FTE: the same, but only expenses related to the % of time devoted to ag research: EXP.CONSTLCU.HC * RES.PERCENT
EXP.PPP.HC **EXP.PPP.FTE**	Spending, total (million constant Y* PPP$) Spending (FTEs), total (million constant Y* PPP$)	As above but at constant prices (harmonized applying the PPP): EXP.CURNTLCU.HC / deflator / PA.NUS.PPP [country, 2011**] .FTE: the same, but only expenses related to the % of time devoted to ag research: EXP.PPP.HC * RES.PERCENT
EXP.[cat].CURNTLCU.HC/FTE/SHRE **EXP[cat].CONSTLCU.HC/FTE/SHRE** **EXP[cat].PPP.HC/FTE/SHRE**	Spending in currency conversions as above, disaggregated by spending categories, plus .SHRE for the % out of the total e.g. EXP.SALARIES.PPP.FTE	Sum of category-disaggregated responses to the "Total expenditures by cost category (in thousands of current, local currency units) " survey question.
TIER-1 DERIVED INDICATORS		
EXP.TOT.ARI.AGGDP	Spending as a share of agricultural gross domestic product (AgGDP) (%) This is also called agricultural research spending intensity.	Agricultural research expenditure as a proportion of the value added in agriculture, forestry, and fisheries. EXP.PPP.FTE / NV.AGR.TOTL.CN[country,year]/1000000)/ deflator / PA.NUS.PPP [country, Y*] * 100
EXP.TOT.ARI.FARMERS	Million constant Y* PPP dollars per 10 000 farmers	EXP.PPP.FTE / 3010.601[country, year] /100

* Y* is the base year for re-basing the deflator. 2011 was the base year for PPP until 2017 in ASTI; the most recent one as of 2025 is 2021.

Table 7. (b) Financial indicators to be included in data series & dissemination products

Indicator acronym	Name	Description and calculations
(b) TIER 2		
FUND.CURNTLCU.HC **FUND.CURNTLCU.FTE**	Funding, total (million current LCU) Funding (FTEs), total (million current LCU)	Sum of totals of responses to the "Total funding by source (in thousands of current, local currency units) " survey question. .HC: absolute amount in local currency. .FTE: the same, but only funding related to the % of time devoted to ag research: FUND.CURNTLCU.HC * RES.PERCENT
FUND.CONSTLCU.HC **FUND.CONSTLCU.FTE**	Funding, total (million constant Y* LCU) Funing (FTEs), total (million constant Y* LCU)	As above but in "constant" local currency (stripped of inflation fluctuations thanks to the GDP deflator): EXP.CURNTLCU.HC / deflator .FTE: the same, but only funding related to the % of time devoted to ag research: FUND.CONSTLCU.HC * RES.PERCENT
FUND.PPP.HC **FUND.PPP.FTE**	Spending, total (million constant Y* PPP$) Spending (FTEs), total (million constant Y* PPP$)	As above but at constant prices (harmonized applying the PPP): FUND.CURNTLCU.HC / deflator / PA.NUS.PPP [country, Y*] .FTE: the same, but only expenses related to the % of time devoted to ag research: FUND.PPP.HC * RES.PERCENT
FUND.[src].CURNTLCU.HC/FTE/SHRE **FUND[src].CONSTLCU.HC/FTE/SHRE** **FUND[src].PPP.HC/FTE/SHRE**	Funding in currency conversions as above, disaggregated by funding sources, plus .SHRE for the % out of the total e.g. FUND.GOVCORE.PPP.FTE	Sum of category-disaggregated responses to the "Total funding by source (in thousands of current, local currency units) " survey question.

* Y* is the base year for re-basing the deflator.

Some of the key aspects for consideration when developing financial indicators are listed below.

6.2.1 Standardized currency conversion and financial data comparability

For regional and international comparisons, financial data should be converted into a common currency for the analysis and dissemination stages. To do this, the recommended methodology, already used in legacy IFPRI datasets, first deflates research expenditures in current local currency units and then converts these amounts into a common currency unit using the "PPP index" or "Purchasing Power Parity index".

The formula used is total spending in local currency divided by the deflator coefficient for that country for that year multiplied by 100 and then divided by the PPP index for that country in the selected base

year (2011 was the reference year until 2017; after that, 2017 is the new recommended reference year):

EXP.CURNTLCU.HC / deflator / PA.NUS.PPP [country, Y]*

6.2.2 Derived indicators and the ASTI Intensity Index

As indicated in Tables 6 & 7, ASTI data series has always included, and it is recommended to always include derived indicators that combine ASTI data with external contextual indicators to build more meaningful indicators. The two financial derived indicators illustrated in the Table 7 are:

- **Spending as a share of agricultural gross domestic product** (AgGDP) (%) (agricultural research spending intensity): this calculates the share after applying to the ag GDP absolute value the same deflator and PPP calculation used for total spending PPP:
  EXP.PPP.FTE / NV.AGR.TOTL.CN[country,year]/1000000)/ deflator / PA.NUS.PPP [country, Y] * 100*
- **Million constant Y* PPP dollars per 10 farmers**: a simple ratio:
  EXP.PPP.FTE / 3010.601[country, year] /100
  (The PPP conversion of financial data is also in a way a derived indicator, but it is more of a conversion than an actual combination of two indicators.)

An advanced indicator traditionally produced by the former IFPRI-led ASTI program is the **ASTI Intensity Index (AII)**. The index is obtained using the Data Envelopment Analysis (DEA) and is used to calculate feasible levels of investment and investment gaps for individual countries (Terzi & Pierini, 2015).

The calculations involved are explained in the documentation as "The **AII** calculates the R&D investment intensity of a country relative to the main structural factors affecting intensity, using a combination of external indicators: the size of the agricultural sector (proxied by AgGDP), the size of the economy (proxied by GDP), income (proxied by GDP per capita), and potential spill-ins (proxied for a country i as the sum of R&D investment of all other countries weighted by a measure of the similarity of country i's output composition with output composition of each other country). These four variables are proxies for structural variables that constraint policymakers' decisions on R&D. For example, R&D investment in a low income country with a small economy would probably invest proportionally less in R&D than a high income country with a large economy because of a small market for innovation and constrained supply of researchers due to a less developed education system, quality of research institutions and budget constraints among several other factors.

In generic form, this measure can be represented as:

AIIi = ƒ [(R&Di / GDPi) , (R&Di / AgGDPi) , (R&Di / yi) , (R&Di / SPi)]

Considering that,

AII_i represents the AII of country i

R&D represents the expenditure in agricultural R&D

y represents the income per capita

SP represents the measures potential spill-ins

F {} represents a function aggregating the four partial intensity measures into a single number that measures the R&D investment intensity of country i

The DEA method looks for endogenous weights to aggregate the partial indices into the overall AII. This approach has been extended more recently to build indices that comply with characteristics required by index theory. The approach used by Whittaker and colleagues (2015) is adapted here to build a multifactored measure of R&D intensity."

6.2.3 Coherent interpretation of different cost categories

As mentioned in the methodology section, agencies' financial reporting systems do not always match the classifications used by ASTI. This can make it difficult to extract data according to the definitions outlined above. If necessary, follow-up queries should be submitted to clarify the details underlying the financial data provided. Footnotes can be used in dissemination products if the definition of a data category differs from ASTI's usual practice.

6.2.4 Treatment of multi-year projects

"Expenses incurred and funding received may not match in a given year, as funding for multi-year projects may reach institutions at the start of a project and budgeted costs may not yet be realized at year's end" (ASTI Practitioner guide). This should be clarified in notes.

6.3 Research focus

Ideally commodities and thematic areas should be aligned with international standards. While there is no agreed standard on thematic areas in agriculture, it may be worthwhile to consider an alignment with the OECD Field of Science (FoS) classification referred to in the 2002 Frascati manual, then evolved into the Fields of Research and Development (FORD) classification and in turn aligned with UNESCO's "Recommendation Concerning the International Standardization of Statistics on Science and Technology". The ASTI questionnaire provided in the ANNEX contains the classifications used in the past by the IFPRI-led ASTI program. Countries can decide to use their own categories or add categories to the existing ones.

6.4 Variables and recommended breakdowns

The tables above give an idea of possible breakdowns to include in the dissemination products.

Data series should always include totals for the main types of indicators per year:

- **Human resources**: total headcount (**RES.HC**), total FTEs (**RES.FTE**), total support staff (**SUP.FTE**).
- **Financial resources**: total spending in local currency (**EXP.CURLCU.FTE**), total spending in constant local currency (**EXP.CONSTCU.FTE**), total spending at constant prices (**EXP.PPP.FTE**). Note that also the .**HC** versions of these indicators can be used, but the **.FTE** ones are considered more meaningful.

In addition, the following breakdowns are recommended:

- **Human resources**: researchers by gender, researchers by level of education, researchers by age bracket; multiple disaggregations can be represented by individual rows containing multi-dimensional indicators: researchers by each gender and level of education combination (**RES.FEMALE.PHD**, **RES.FEMALE.MSC**...), researchers by gender and age (Tier 2), support staff by gender (Tier 2).
- **Financial resources**: spending by category, funding by source (Tier 2).

Using non-survey data (agency directory, agency metadata) it is also recommended to aggregate results by type of agency: all indicators can be published disaggregated by type of agency: e.g. researchers in governmental agencies (**RES.GOV.FTE**); also multiple disaggregations by agency type

can be represented by multi-dimensional indicators: e.g. researchers by level of education and by type of agency (**RES.FEMALE.GOV**, **RES.FEMALE.HE**).

For disaggregated data, both FTE and HC breakdowns are useful, but FTE breakdowns are considered more meaningful; in breakdowns, also percentage / share values (**.SHRE**) are very meaningful (e.g. **RES.FEMALE.GOV.SHRE**, **EXP.SALARIES.SHRE**).

6.5 Data series releases

Publishing data series is one of the standard formats for making processed data available for wider use. Data series can be updated as soon as the new data has been validated and added or at established intervals that should align with the data collection reference interval (**e.g yearly**).

Data releases should be formally announced and accompanied by dissemination products like a publication, a press release, a communiqué, a factsheet etc. Where capacities are available, an interactive online dashboard can be maintained.

While published data series should include all indicators, reports and dashboards can be selective. Choices include variable selection, the level of geography that is published and the design of tables and graphs and other illustrations.

Along with each data release, in whatever preferred form, it is recommended to release the following:

1. Survey methodology report covering:
    - Data collection methods (here relevant methodological information can be extracted from chapter 5)
    - Response rates
2. Main findings including:
    - Summary tables
    - Key trends
    - International comparisons
    - Policy implications
3. Data quality evaluation addressing:
    - Coverage
    - Precision measures
    - Non-response analysis
    - Methodological limitations
4. Technical documentation on:
    - Data processing procedures
    - Classification systems
    - Calculation methods
    - Metadata standards (for standard-compliant data series: see previous chapter)

6.6 Data series files

Ideally, updated data series should be made publicly available on institutional websites or in dedicated data repositories. These files can be different from the internal archiving format but more importantly, these public files should be in a machine-readable format and follow good practices for data series management. They should:

- have data organized by year and by indicator
- start with the heading row and contain only rows with appropriate data for each column
- be accompanied by metadata (not in the same sheet/table/CSV)

Examples:

A commonly used format for data series is the one with columns for the years and rows for the indicators, as shown in Figure 7, which is an actual example of a file from the former IFPRI-ASTI Data Download page):

Figure 7. Example of data series format (years in columns, indicators in rows)

Indicator	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Researchers, total (FTEs)	122.8	124.4	127.8	150.2	155.0	161.7	170.2	180.8	183.0	157.5	201.5
Spending, total (as a share of AgGDP, %)	0.7	0.6	0.7	0.6	0.7	0.8	0.6	0.5	0.6	0.6	0.6
Spending, total (million constant 2011 PPP dollars per 10	1.5	1.3	1.6	1.3	1.5	1.8	1.3	1.3	1.4	1.5	1.7
Spending, total (million constant 2011 PPP dollars per mi	3.0	2.5	3.0	2.5	2.7	3.2	2.3	2.2	2.3	2.4	2.7
Researchers, total (FTEs per 100,000 farmers)	7.5	7.5	7.6	8.8	9.0	9.3	9.7	10.2	10.3	8.8	11.2
Researchers, total (FTEs per million population)	14.5	14.3	14.2	16.2	16.3	16.5	16.9	17.5	17.3	14.5	18.0
Researchers, government (FTEs)	65.8	64.9	64.9	86.0	88.0	89.0	105.0	105.0	97.0	72.0	79.0
Researchers, higher education (FTEs)	52.0	53.1	56.1	56.0	57.9	62.6	55.5	63.7	72.2	71.2	100.7
Researchers, nonprofit (FTEs)	5.0	6.4	6.9	8.2	9.1	10.1	9.7	12.1	13.8	14.3	21.8
Researchers, government (share of total, FTEs, %)	53.6	52.2	50.8	57.3	56.8	55.1	61.7	58.1	53.0	45.7	39.2
Researchers, higher education (share of total, FTEs, %)	42.3	42.7	43.9	37.3	37.4	38.7	32.6	35.3	39.5	45.2	50.0
Researchers, nonprofit (share of total, FTEs, %)	4.1	5.1	5.4	5.5	5.9	6.2	5.7	6.7	7.5	9.1	10.8
Researchers, total, PhD (FTEs)	65.6	67.8	70.7	79.0	86.1	94.7	85.0	94.8	94.7	98.7	125.1
Researchers, total, MSc (FTEs)	55.7	55.1	55.3	69.1	67.1	65.2	83.7	84.1	86.6	51.1	65.0
Researchers, total, BSc (FTEs)	1.5	1.5	1.9	2.1	1.8	1.8	1.5	1.9	1.7	7.8	11.4
Researchers, total, PhD (share of total, FTEs, %)	53.5	54.5	55.3	52.6	55.5	58.6	50.0	52.5	51.8	62.7	62.1
Researchers, total, MSc (share of total, FTEs, %)	45.3	44.3	43.2	46.0	43.3	40.3	49.2	46.5	47.3	32.4	32.3
Researchers, total, BSc (share of total, FTEs, %)	1.2	1.2	1.5	1.4	1.2	1.1	0.9	1.0	0.9	4.9	5.7
Researchers, government, PhD (FTEs)	24.4	25.1	25.1	32.0	35.0	40.0	36.0	36.0	30.0	31.0	31.0
Researchers, higher education, PhD (FTEs)	38.9	39.9	42.8	44.1	47.9	51.0	47.2	57.0	62.8	65.7	91.2
Researchers, nonprofit, PhD (FTEs)	2.3	2.7	2.8	2.9	3.2	3.7	1.8	1.8	1.9	2.0	2.9
Researchers, government, MSc (FTEs)	41.4	39.8	39.8	54.0	53.0	49.0	69.0	69.0	67.0	41.0	48.0
Researchers, higher education, MSc (FTEs)	12.2	12.6	12.7	11.9	10.0	11.6	8.2	6.3	9.4	5.5	9.5
Researchers, nonprofit, MSc (FTEs)	2.1	2.7	2.8	3.2	4.1	4.6	6.4	8.8	10.2	4.6	7.5
Researchers, government, BSc (FTEs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Researchers, higher education, BSc (FTEs)	0.9	0.6	0.6	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Researchers, nonprofit, BSc (FTEs)	0.6	0.9	1.3	2.1	1.8	1.8	1.5	1.4	1.7	7.8	11.4
Researchers, total, female (FTEs)			18.3			18.9			24.4		33.9
Researchers, total, male (FTEs)			109.6			142.8			158.6		167.6
Researchers, total, female (share of total, FTEs, %)			14.3			11.7			13.3		16.8
Researchers, total, male (share of total, FTEs, %)			85.7			88.3			86.7		83.2

Another commonly used format has columns for all dimensions, including a column for the years (Figure 8) This format is easier to process for data analysis and visualizations (the example below is from FAOSTAT and shows how certain row-level metadata (source, unit) can be included in the file.

Figure 8. Example of data series format (columns for all dimensions)

Area	Indicator (	Indicator	Year Coc	Year	Element C	Element	Source Co	Source	Unit	Value
Afghanistan	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	3832.7
Albania	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	437.27
Algeria	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	1056.16
Angola	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	6897.44
Argentina	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	1401.84
Armenia	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	665.7
Australia	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	329.81
Austria	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	163.18
Azerbaijan	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	1825.3
Bahamas	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	6.37
Bahrain	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	7.6
Bangladesh	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	26053.96
Barbados	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	3.62
Belarus	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	541.22
Belgium	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	46.25
Belize	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	27.46
Benin	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	1301.56
Bhutan	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	196.83
Bolivia (Plurinat	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	1486.32
Bosnia and Her	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	163.28
Botswana	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	150.76
Brazil	21144	Employment in agriculture	2021	2021	6199	Value	3043	ILO - ILO Modelled Estim	1000 No	8744.64

6.6.1 Data series and revisions

Data releases may be subject to revision. In particular, countries that have not collected data for some years or have agencies not reporting data, will have to estimate missing values. Therefore, such estimations in different years can lead to revisions of whole data series, in addition to the changes

caused by changing reference year for certain external indicators. Therefore, ASTI data dissemination products have to be accompanied by revision notes based on a clear revision policy. A revision policy should be determined in consultation with users, documented and publicized. A clear revision policy should:

- **Specify conditions for data revision**: explain on which conditions data are revised, for instance if an external indicator change (like those used for the calculation of the PPP dollar equivalent) or if new higher-quality data reveals different trends and causes the previous estimates to be revised.
- **Document revision procedures**: relate which steps have been taken to which years (e.g. which new trend calculations have been applied).
- **Communicate changes to users.**
- **Maintain revision history.**

7. Dissemination of indicators

This chapter illustrates how ASTI indicators data series can be used to produce visualizations and dissemination products. It then provides an overview of general principles to guide dissemination, and it closes with a larger perspective by giving suggestions for the use of ASTI data analyses for advocacy.

The fundamental purpose of collecting and disseminating ASTI data is to provide actionable information to stakeholders across the agricultural research and development sector. Just as with any other statistical programs, dissemination is the necessary final step of data collection.

7.1 Technical briefs

7.1.1 Proposed structure of technical briefs

Regular ASTI technical briefs should be disseminated at each data release and should follow a homogeneous format. They don't need to be identical in all countries (comparisons are made on the raw data, not on data visualized in fact sheets), but they should be consistent in the same country. The IFPRI-led ASTI program has produced factsheets in the past, which can be used as an example. A recommended structure is provided in Box 9.

7.1.2 Distribution Strategy

A comprehensive approach to dissemination of the factsheets ensures that ASTI data serves its fundamental purpose of informing agricultural research policy while maintaining high standards of statistical practice and user service. The recommendations are as follows:

1. **Primary Channels**
   - Email distribution lists
   - Institutional websites
   - Partner networks
   - Social media platforms
2. **Timing**
   - Fixed release schedule (quarterly/semi-annual)
   - Synchronized with major agricultural policy events
   - Coordinated with international reporting cycles
3. **Follow-up**
   - User feedback collection
   - Impact monitoring
   - Citation tracking
   - Usage analytics

Box 9: Suggested outline of an ASTI Technical Brief

1. **Executive Summary (1 page)**: This is preferably text, possibly in columns or boxes.
   - Key findings: Short summary of the most significant findings, primarily about the core indicators and the advanced derived indicators, like spending intensity.
   - Major trends: Short summary of important trends revealed by the data.
   - Policy implications: Insights on policy implications based on the interpretation of the data.

2. **Statistical Overview (2-3 pages)**
   - **Core indicators trends (charts)**

     Three typical charts that would go in this section are timelines of: total research spending (PPP, FTE), spending intensity, and total researchers (FTE). These charts are self-explanatory and may not need too much interpretation.

   - **Institutional composition (key data by agency type):**
     - Institutional composition of agricultural research (FTEs by type of agency) in 3-4 selected years: as explained above, this needs non-survey data (agency directory, agency metadata) to cluster data by agency type. A stacked bar chart would be suitable.
     - Agricultural researchers by agency type and qualification level in 3-4 selected years (again using the agency directory data). A stacked bar chart would be suitable.
   - **Analysis of selected indicators (tables or charts)**

     This is the space for selected indicators. They can be chosen based on country priorities or the importance of the findings; however, since communiques should be consistent over the years, it is advisable to use the same indicators every year, perhaps leaving one slot open for additional indicators that have special importance or meaning that specific year. Recommended charts for this section are:

     - Distribution of agricultural researchers by qualification level and age bracket
     - Agricultural researchers by gender
     - Spending by cost category (by agency type, or with focus only on NARIs)
     - Funding by source (by agency type, or with focus only on NARIs)
     - Agricultural researchers by area of focus (commodity groups)
     - Spending as a share of agricultural gross domestic product
     - ASTI Intensity Index to calculate feasible levels of investment and investment gaps for individual countries

   - **International comparisons (charts and text)**

     As mentioned above, when data from other countries in the region or globally is available, interesting comparisons or aggregations can be produced. To this end, comparable indicators should be used: for human resources, FTEs and shares, and for financial resources, PPP amounts and shares.

3. **Methodological Notes (1 page)**
   - Data quality assessment (text)
   - Coverage statistics (text and/or table)
   - Technical notes (text)

7.2 Release Calendar

Organizations disseminating ASTI data must publish and maintain a schedule of forthcoming ASTI data releases. This practice builds trust with users and respondents, allows users to plan their analytical work, sets target dates for the survey processing cycle, and demonstrates organizational commitment to transparency.

The release calendar should specify:

- Preliminary data release dates
- Final data publication schedule
- Methodology updates
- Special analytical reports

7.3 Timeliness

For ASTI data, timeliness targets should align with the collection interval of the indicators. In some instances such indicators may be collected biennially, with indicative breakdown estimates provided in between. Following the general rule that the "end-to-end production" process should be shorter than the frequency of data collection. Therefore, ASTI releases of **tier-1 indicators** should aim to:

- Complete data processing within 8-10 months of reference period
- Release preliminary indicators within one year
- Publish final detailed data within 18 months
- Issue analytical reports within 20 months

Tier-2 indicators can be collected at longer intervals and be included in the first subsequent release of tier-1 data.

There may be cases when data that is supposed to be published as annual data series cannot be collected all year and will be collected at larger intervals but still for each year retroactively, thus keeping the yearly data series interval. The timelines of this data will not be optimal but publishing them at the earliest subsequent data release will enrich the data series and provide more precise trends.

7.4 Maintaining confidentiality of respondents

Protection of confidential information has not posed notable issues in the ASTI project so far, as contact information is not disseminated, and most of the data, especially tier-1 data, is not sensitive, at least for public institutions in countries that have transparency policies. Private entities may have reservations about having their human resources or investment data published.

Data that is deemed sensitive by the respondents can still be published in an aggregated way, provided that certain measures are adopted:

1. **Aggregation Rules**
   - Minimum of three institutions for any published figure
   - Dominant institution rules (no single institution representing >75% of total)
   - Special handling of private sector data
2. **Disclosure Prevention**
   - Cell suppression in detailed tables
   - Random perturbation for sensitive indicators
   - Aggregation of small geographic areas

7.5 Ensuring equality of access

ASTI data access could be structured in tiers while maintaining equality within each user category:

1. **Basic Access (Public):**
   - Summary statistics
   - Standard tables
   - Key indicators
   - Anonymized public-use files
   - Country-level time-series
   - Methodological documentation

2. **Enhanced Access (agency focal points):**
   - Detailed agency-level time-series for own agency
   - Analytical tools
   - Develop protocols for researcher access
   - Establish data usage agreements
   - Maintain documentation of access granted

7.6 Metadata to facilitate exchange

The release of metadata should be made concurrently with the release of data. Giving access to metadata provides users with the requisite information on the strengths and limitations associated with the data. The metadata should be made available in standard format to facilitate data exchange and comparability.

Metadata plays a critical role in any statistical process by providing essential information about the origin, structure, definitions, and methods employed in data collection and processing. Its integration ensures accurate interpretation of results, promotes transparency, enables process reproducibility, and supports the effective implementation of quality control measures.

In addition, metadata facilitates the comparison of data across different periods, regions, and sources, ensuring consistency and reliability in the indicators produced. At the international level, standardized conventions for the treatment of statistical data and metadata have been established to harmonize their structure and enable the global exchange of information. One prominent initiative in this area is the Statistical Data and Metadata Exchange (SDMX), developed by multiple international organizations, including the United Nations Statistics Division.

The SDMX initiative supports this effort by standardizing mechanisms and processes for data and metadata exchange between international organizations and member countries. It also offers practical guidance for defining data domains and managing data flows effectively. In summary, while metadata does not include the data itself, it provides essential information to understand its format, content, the methodology used for its calculation, and its quality assessment.

It is crucial for countries to establish basic criteria for organizing the data for their indicators. Developing a metadata structure that aligns with international standards is highly recommended. The following are key aspects to consider when designing the metadata architecture. These elements will enable users to understand the statistical references, general characteristics, and quality controls of the data.

If the agency does not have the capacities to produce SDMX records, metadata can be provided in an accompanying file or in an additional sheet in the Excel file containing the data series (see Data series file under 7.3).

Typical metadata to be included are:

- Title of table
- Description of labels of variables and description of values
- Measurement unit
- Time reference
- Data collection interval
- Date of last update
- Source of data
- Explanation of symbols in tables
- Information about copyright, confidentiality
- Contacts for additional information
- Institution(s) responsible for data collection

And metadata about the methodology:

- Statistical population, geographical coverage, observation unit, classifications applied
- Description of methods used in collecting, revising, calculating and estimating the statistics
- Description of data quality, including information on error sources and accuracy of the statistics
- Comparability with alternative sources, etc.

7.7 Visualization of data and indicators

Dissemination products will typically contain tables and charts. The choice between tables and charts depends on what needs to be conveyed.

Tables are particularly effective when users need to look up specific values or compare individual data points precisely. Data tables are usually recommended when comparing the same indicator data across years, especially if the actual numbers need to be highlighted rather than just the trends (Figure 9) or when users need to perform calculations with the displayed values.

They work best when dealing with datasets where exact numbers matter - like research spending by country, full-time equivalent researchers by gender, or detailed breakdowns of funding sources across institutions. Tables are also useful to show multiple breakdowns for different combined disaggregation, for instance both % and FTEs by thematic area and education level.

Tables are also better when presenting multiple units of measurement simultaneously, such as when showing both monetary investments and researcher counts. Examples of variables and recommended breakdowns that could also be presented in the form of tables were provided in Section 6.4.

Figure 9. Example of data visualization as a table

Agricultural researchers, 2014	FTEs		Share (%)	
	MSc	PhD	MSc	PhD
Plant breeding/genetics (incl. biotechnology)	42	28	7	8
Plant pathology	26	29	4	8
Plant physiology	40	23	6	6
Botany	10	3	2	1
Seed science and technology	7	4	1	1
Other crop sciences	15	21	2	6
Animal breeding/genetics	13	5	2	1
Animal husbandry	–	1	–	0.4
Animal nutrition	11	28	2	8
Dairy science	3	–	1	–
Poultry	3	2	1	1
Veterinary medicine	99	29	15	8
Zoology/entomology	43	30	7	8
Other animal and livestock	4	3	1	1
Forestry and agroforestry	3	2	0.5	0.4
Fisheries and aquatic resources	84	29	13	8
Soil sciences	42	34	7	9
Natural resources management	13	1	2	0.4
Water and irrigation management	9	3	1	1
Ecology	3	5	1	2
Biodiversity conservation	2	–	0.3	–
Food sciences and nutrition	31	11	5	3
Socioeconomics (incl. agricultural economics)	73	32	11	9
Extension and education	62	33	10	9
Other sciences	–	–	–	–
Total	**638**	**356**	**100**	**100**

Charts, on the other hand, are superior for revealing patterns, trends, and relationships within agricultural R&D data. They excel at showing how values change over time, comparing proportions across regions, or demonstrating distributions of research focus areas. Charts make it much easier to grasp the "big picture" at a glance, for instance, spotting trends in agricultural research intensity ratios or understanding the distribution of researchers across different qualification levels across countries. They are especially powerful when presenting data to policymakers and stakeholders who need to quickly grasp key insights about agricultural research systems without diving into specific numbers.

Numerous types of charts can be produced from ASTI data: in the years when data was collected, country factsheets were produced with what were deemed to be the most significant charts. These are nowadays also available as user-generated visualizations through data portals. Some of the visualizations of ASTI data that have been generated and used in communication products in the past are illustrated below:

included (i) demonstration of trends over time (ii) breakdown of categories, either over time or during a specific period, and (iii) comparison of similar datasets over time, geographic region or component. These are illustrated below.

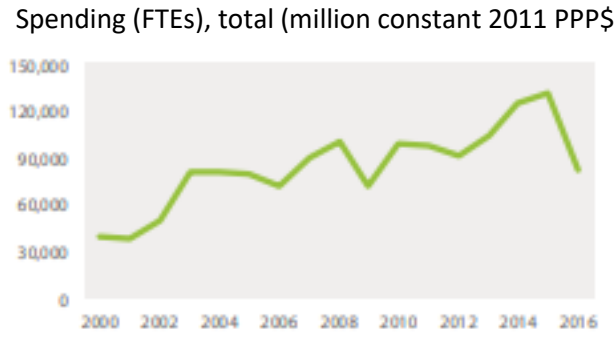
7.7.1 Visualization of trends in core indicators

For single ASTI indicators, or for two related indicators, a chart with a timeline plot gives a clear visual overview. The timeline is perhaps the most used type of chart for ASTI data, as trends over time can provide insights into the future and can help make decisions. In most cases, the timeline is a line chart; however, if a breakdown is useful for each data point, a stacked bar chart can be used, possibly for a limited number of years as the data point takes more space than in a line chart.

An example, specifically in the case of ASTI data, is the trend in agricultural research spending. To build such a line chart, the only data needed is the year as a dimension and the actual spending figure for

each year as a measure. Since it's a trend, the figures can be those of any total spending indicator – e.g. Spending, total (million current LCU), Spending, total (million constant Y* LCU), Spending, total (million constant Y* PPP$) - because, even if the absolute numbers are different, the trend should be the same. The indicators with .PPP and .FTE suffixes are preferred, as they abstract from the currency and are relative only to resources spent on agricultural research (Figure 10). Similar charts can be produced for human resources (e.g. Total researchers FTEs) and derived indicators such as Research Intensity.

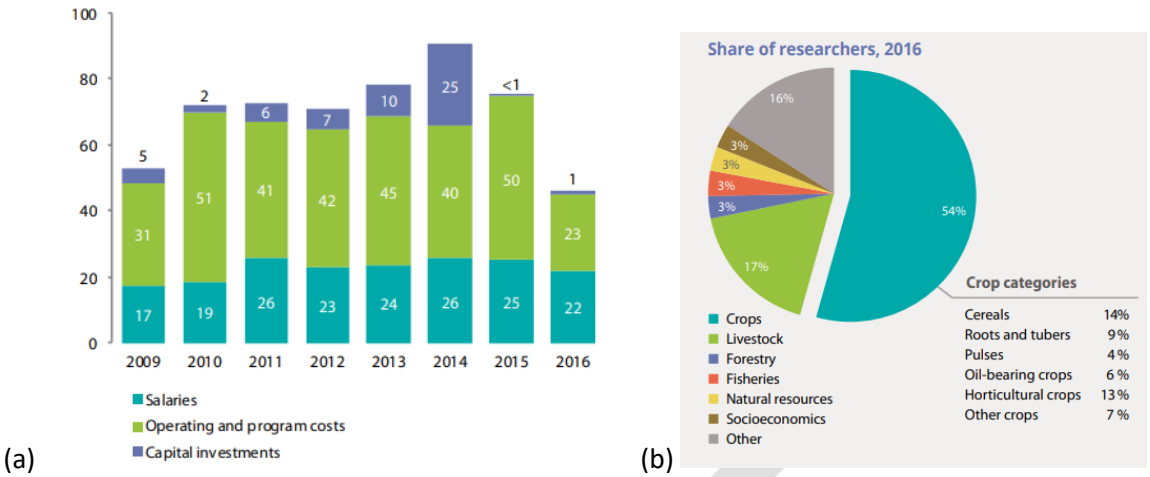
Figure 10. Example of visualization of time series of a single indicator



7.7.2 Segmentation of indicator values over specific periods

Breakdowns provide an additional layer of detail and are better represented only for selected years or as a snapshot for just one year, normally the latest year. Breakdowns can be useful when it is important to show disaggregated data, especially as percentage, or share of the total. Two types of charts recommended for this are (a) Stacked bar charts for proportions shown for selected years, which is useful to convey both trend information and an additional layer of detail (Figure 11a), and (b) Pie charts for share values in one year, especially when the level of detail is high and there are many categories whose share is measured (Figure 11b). Data for multiple years can be overwhelming, while a snapshot for the most recent year can be clearer.

Figure 11. Example of (a) stacked bar charts and (b) pie charts for displaying segment contributions to indicators



7.7.3 Visualization for Comparison

When data is published at the regional level, or when it is published at the national level but data from other countries in the region or globally is available, interesting comparisons or aggregations can be produced. To this end, comparable indicators should be used: for human resources, FTEs and shares, and for financial resources, PPP amounts and shares.

An example of comparison in a region is the distribution of researchers by degree in FTEs in different countries: this can be conveyed in a classic stacked bar chart, either vertical or horizontal, but preferably, in order to show relative sizes, which are more comparable than absolute numbers, a proportional stacked bar chart can be considered (in which the bars have all the same length and the breakdown sizes are proportional, Figure 12). Another example is the aggregation of country data by region and comparison between regions. A suitable chart type for this is a bar chart or, in case multiple years need to be represented, a grouped / clustered bar chart with the different years in the cluster (Figure 13).

Figure 12. Example of a proportional stacked bar chart

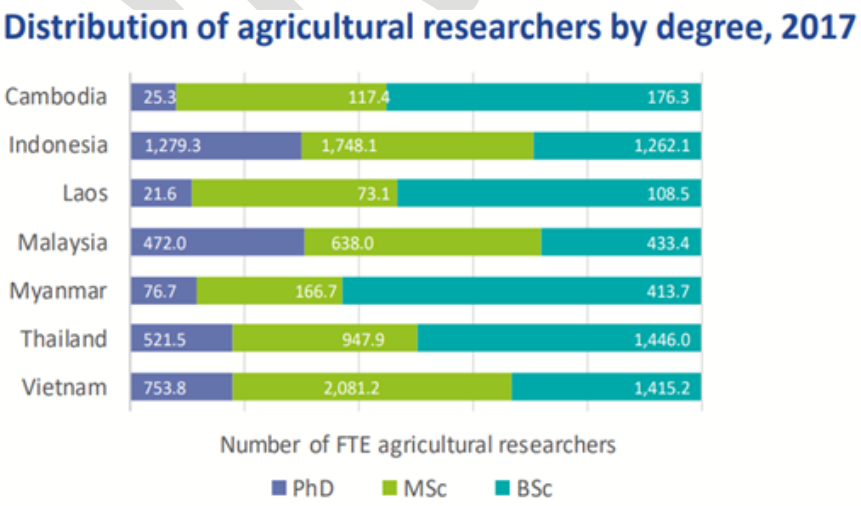
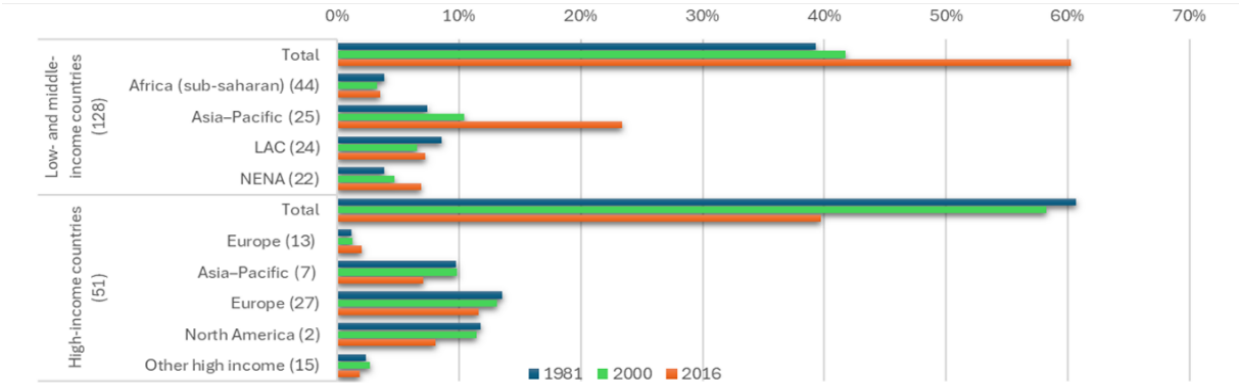


Figure 13. Example of a clustered bar chart with different years in the cluster

Share by region and income level in global Ag R&D expenditure (1981, 2000 & 2016)



7.8 Data archiving & data portals as a national resource

The value of collected data does not end when they are released. The mandate of the institution to collect data officially also comes with a responsibility to preserve it. Each agency collecting ASTI data should develop and implement a data archiving strategy that preserves the data, keeps it accessible and provides future researchers and the general public with sufficient metadata to understand and interpret the archived data. In agencies that do not have the capacities to maintain a data archive, the data archiving system can coincide with the data series publication system, although original survey data should be preserved separately. In this way the data archive becomes a contribution to a national resource.

With advances in the concept of open data systems, such data are also increasingly being made available through data portals which are designed to make datasets accessible, discoverable, and usable for a wide range of users and promotes consistency and reliability across users and applications. Portals can also manage access controls, providing open access for public datasets while restricting more sensitive or licensed data to authorized users. In addition, portals include search and filtering tools as well as built-in data visualization tools, such as maps, charts, and dashboards, which help users interpret complex data more easily without needing advanced technical skills. One of the defining features of a well-designed data portal is its rich metadata. Each dataset is accompanied by detailed information such as its title, source, date of publication or update, format, and the methodology used to generate the data. This metadata ensures that users can understand the context and quality of the data they are accessing, which is essential for informed use and interpretation.

In the context of ASTI, other documents that the portal may contain include documents on the methodology for ASTI measurement, lists of AR&D institutions and maps displaying the location of these institutions, as well as downloadable series of data sets.

8. Data-driven advocacy, country ownership and institutionalization of ASTI

An important part of the ASTI institutionalization process is the engagement with the local institutions, advocacy on and use of ASTI to inform and support decision-making, especially to locally promote further investment in AR&D. This stage of the process is important for countries to acquire real ownership of the data in that they have been able to process data collected, produced insights thereof and used them. The trends in the indicators, visualized and presented in the form of technical and policy briefs, provide input to the decision-making process in the country.

Continued engagement processes with stakeholders and especially policymakers can bring about sustained interest and appreciation in the production of the indicators. With ASTI measurement continuing on a regular basis, institutions may prefer to include the process as part of their regular set of activities: the process of institutionalization. Both measurement and use of ASTI for advocacy are important for the process of institutionalization, and for the institutions in the country to dive deeper into the analyses of the indicators. As a medium- to long-term objective of ASTI, institutionalization is one of the pathways to revive interest in, and the practice of measurement of structural variables (Tier 2) and additional variables, which the local and international stakeholders have found useful for monitoring and evaluation purposes.

8.1 Uses of ASTI data for advocacy

While agricultural research has been shown to improve agricultural productivity, its long-term impact and budget restrictions make it a hard sell to governments. Consequently, evidence of the state of agricultural research in a country receives insufficient attention and spending on improving the foundations for agricultural research remains limited. Over the past several decades, conversations around “evidence-based” policy, especially in funding of Agricultural Research, have gradually shifted towards the idea of “evidence-informed” policy, as the development timelines are long: it can take decades for the benefits of building capacities and committing time and resources to research to pay off in improved agricultural productivity (Pardey and Alston 2012). Evidence-informed policymaking has been integrated in the programming process of donor agencies and such evidence has also to be seen to align with the prevailing political climate, values, and priorities.

Improving agricultural research funding is not a simple task nor something that can be achieved through a few events. It needs an ongoing dialogue and a space where progress and gaps in agricultural research can be raised regularly, and where the benefits of funding agricultural research can be highlighted. In some cases, a forum for this may be found in existing agriculture-related platforms, within which research could have higher prominence.

Figure 14. Examples of multi-country comparisons on AR&D in Africa using 2016 ASTI data

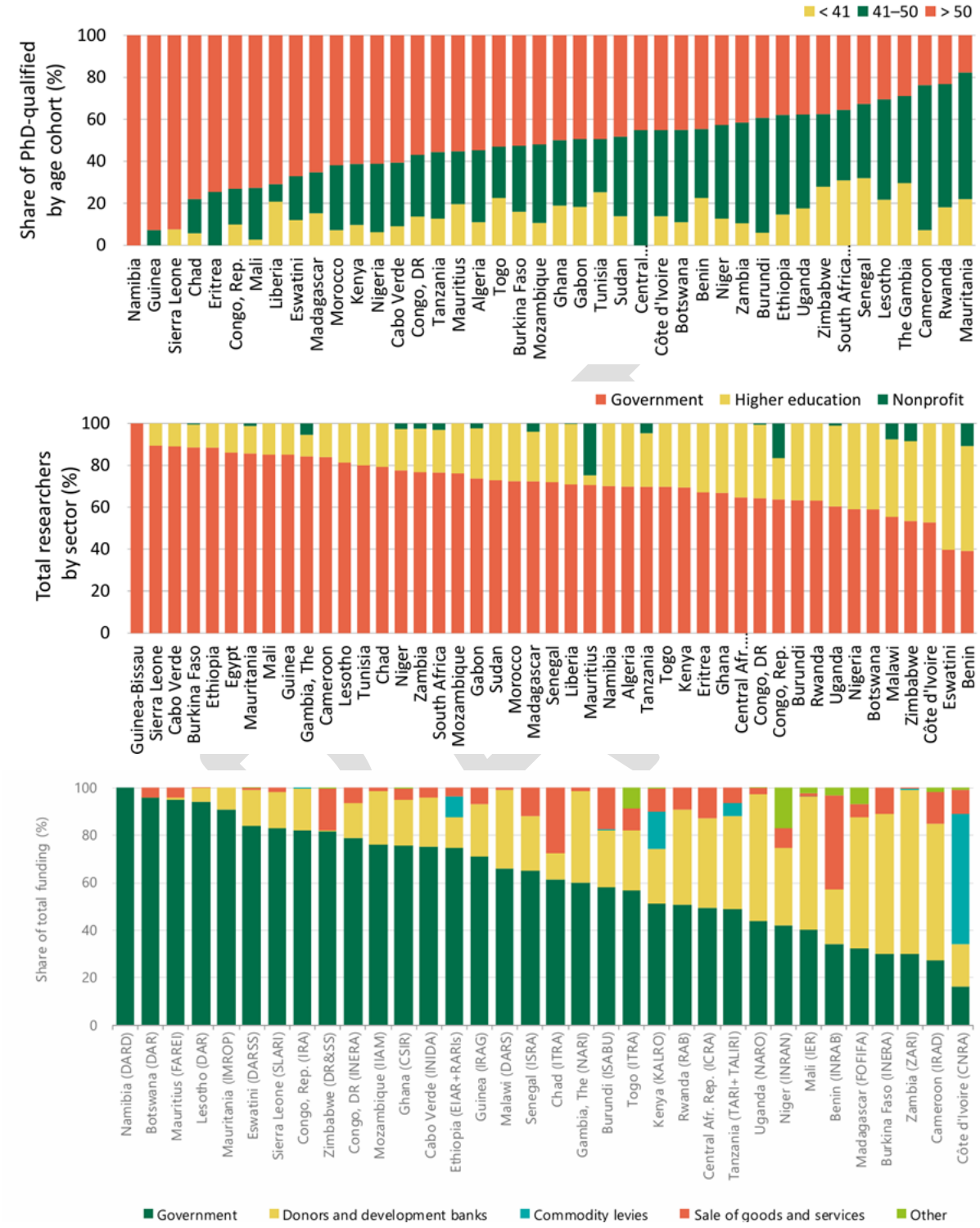


Figure 15. Examples of time-series comparisons on AR&D in Africa informed by ASTI

Figure 5—Spending on agriculture and on agricultural research in Africa, 2000–2016

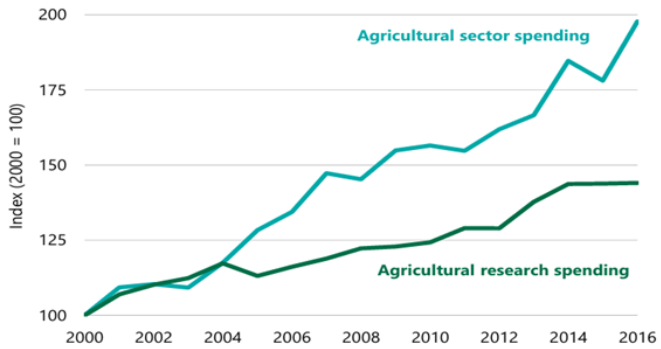


Figure 13—Volatility of agricultural research spending in SSA, 2000–2016

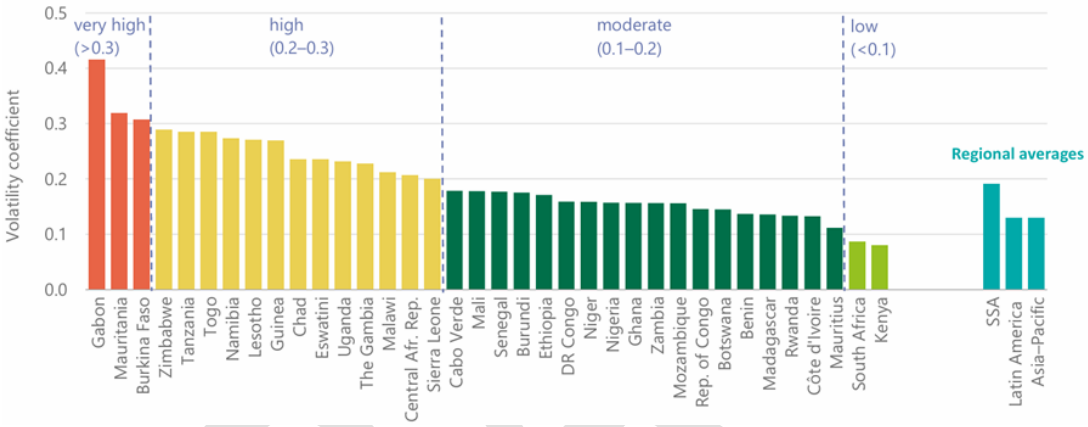
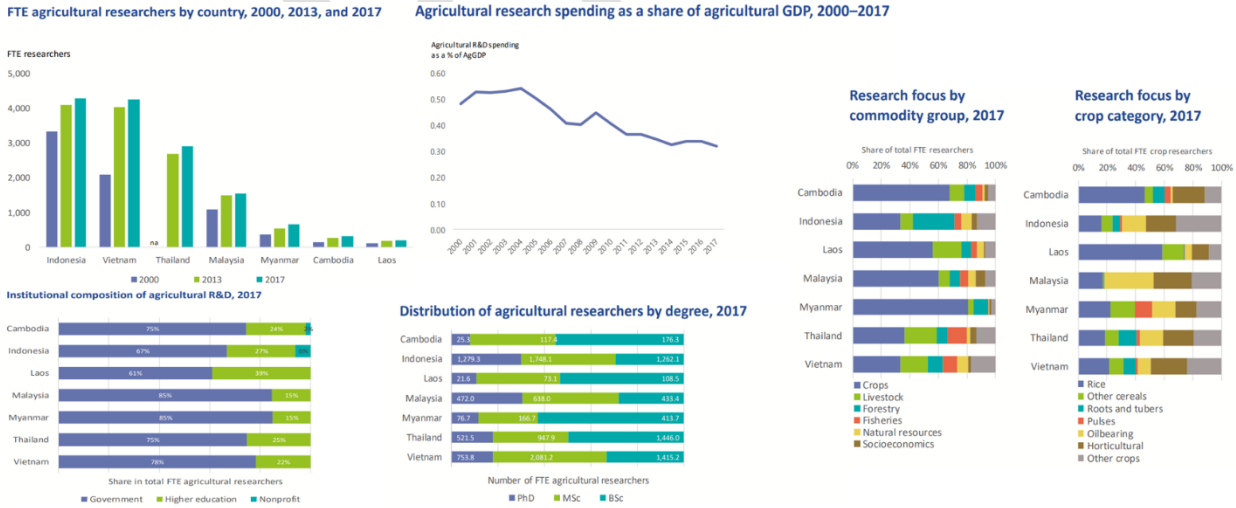


Figure 16. Examples of multi-country comparisons on AR&D in Asia using ASTI data



An example of such a platform is the Comprehensive Africa Agriculture Development Programme (CAADP) of the African Union, which recently launched its 3rd 10-year Strategic Implementation Plan 2026-2035. Documentation during the IFPRI-led ASTI initiative shows that the African Union has made use of ASTI to inform policies on investments in AR&D (Beintema & Stads, 2017). Similar comparisons of ASTI across selected African countries were carried out in 2021, examples of which are shown in Figures 14 & 15.

Figure 16 shows a similar comparison across selected countries in the Asian sub-region. Comparisons of indicators on AR&D across countries in sub-regions have been used in the development of regional plans for regional AR&D organisations. The network of agricultural universities in Africa, RUFORUM, also developed a detailed comparison of AR&D capacities amongst its member Universities.[5]

To date, evidence on AR&D investment, as a public good, remains mostly used at regional and international levels. Comparative data across countries remain important, and internationally developed datasets play important roles. However, it remains critical to support the development of higher quality, locally generated data, at country level, to increase the accuracy and utility of the regional and international comparisons.

During the IFPRI-led ASTI program, a study was carried out in three African countries to gain clearer understanding of how ASTI evidence could be more effectively and consistently used by national governments and other stakeholders to promote the allocation of sustainable resources to agricultural research (Carden et al., 2019). The findings of the study showed that despite the involvement of the NARI in data collection process for ASTI, there was still a lack of linkage between the ASTI evidence and decision-making at the level of the NARI and at national level. The factsheets derived from the IFPRI-led ASTI were seen as 'project evidence' rather than being a tool for ongoing dialogue and awareness-building within the NARS. Furthermore, many governments had established policies stipulating that the country's official data systems are their primary sources of national decision-making data, with no formal connections made between ASTI data and national data systems. Therefore, there is a need to integrate the data into the national statistical systems, such that political and organizational management is better engaged with the collection and use of AR&D evidence than would otherwise be the case.

Several of the recommended approaches from the study from 2019 have been incorporated in the new approach to ASTI production, along with the distinction being made between the generation of core and structural variables, which require different frequencies of data collection. The recent experience of pilot countries using the new approach has demonstrated that strong relationships and networks are needed to increase awareness of ASTI evidence including establishing institutional linkages with official national data systems. Such linkages open up more opportunities for improving the availability, accessibility, appropriateness, and ownership of ASTI evidence to ensure that it contributes more effectively as a valuable resource for decision-making.

Furthermore, there is recognition that reliance on external funding of agricultural research is unpredictable. The capacity to make a compelling case based on evidence, and the ability to highlight gaps in the evidence, are important tools in raising awareness about the strengths and weaknesses of NARS. This has reinforced the need for a long-term perspective to establish effective engagement, and the importance of institutionalization processes within formal systems to ensure continuity as new people and institutions emerge to take leadership in agricultural research systems.

[5] https://www.ruforum.org/MCF/sites/default/files/documents/Uganda-RUFORUM-Universities-Assessment.pdf

8.2 Reinforcing the process of institutionalization of ASTI

To ensure its long-term sustainability and relevance, ASTI should be seen as the product of an active network of relevant national, regional, and international partners, with the foundations being country-owned and institutionalized, producing data and analyses of local policy relevance. In addition to countries taking ownership of their national data, there is a need for countries to carry out effective, policy-relevant analyses, and for advocates of increased support for AR&D to carry out outreach activities to incorporate messages into national and regional decision-making processes. This transformation will enhance the impact of ASTI's data and analyses at the national level.

8.2.1 Institutionalization from global to local levels

While the IFPRI-led initiative on ASTI provided the proof of concept of the need for and use of data on investments in AR&D, especially covering the LMICs, the new approach to the production of ASTI, with the involvement of the FAO as a UN organization, brings about a new relationship and approach to data collection from Member countries. While the evidence has shown the use of ASTI data for planning purposes at regional and global levels, a lack of engagement of the decision-makers at country level with ASTI data has largely stifled the exploitation of ASTI data at country level. Nevertheless, with the new approach described in this guide, of involving the policy-making institutions, the NSO, the STI Agency and the NARS institutions, in particular the NARI, it is a new opportunity to engage with the stakeholders of ASTI.

The process of institutionalization needs to happen at all levels, even at global levels, with the internalization of the process of producing ASTI and making use of the data within the global institutions, including the FAO itself. As the custodian of the ASTI datasets, the FAO will have to find internal mechanisms to support the process of data collection, quality control, analysis, storage and use of the data. The support of FAO and the maintenance of ASTI datasets provides continuity of its global relevance and reputation as the trusted repository for internationally comparable long-term agricultural R&D data and analysis. However, sustainability of data collection relies on improving ownership of the data and systems at national levels which requires an intentional strategy and long-term approach. This has to be carried out in a collaborative manner, through a network approach, in collaboration with the stakeholder groups at each level of organization to reach the local level.

From a regional perspective, the continued interest in, and use of, ASTI by regional policy organizations in their strategic planning and implementation plans, augurs well for the utilization of historical and updated ASTI data. A good example is the proposed incorporation of the ASTI in the reporting mechanism for monitoring the implementation of the CAADP Strategy and Action Plan 2026-2035 across Africa. Using the CAADP process as an example, several of the stakeholder groups within Africa, as well as the Donor Coordination Group have recently made commitments to be engaged and share data and information to ensure better integration of the activities around implementation of CAADP over the next decade. Already, the new approach, tested through a set of pilot countries and described in these guidelines, has shown to be useful to identify the key institutions, with national mandates, to engage around investments in AR&D, to involve the institutions of the NARS, including universities and private sector in data collection around AR&D, and to generate the data required, with devolvement of responsibilities in an effective manner.

At the country level, the guidelines have described the expected approach and pathway to plan and organize data collection, analyze the results and publish the data and interpretation of the findings of ASTI. It is also anticipated, and encouraged, that following the analysis and publication of the outcome of the ASTI data collection, processing and analysis, there will also be a need to address the process of institutionalization of the process within the institutions in the country, especially after all stakeholder institutions have understood the extent of work that will be required for the next iteration of data collection (which should be manageable by most institutions involved).

8.2.2 Local engagement & feedback to improve on ASTI data over time

Evidence on investment in agricultural research is a public good. Its collection, analysis, and use depend on the appreciation of its long-term value by leadership at international, regional and national levels. With improved appreciation of quality data collected at national level, advocacy on the importance of agricultural research to improve agricultural, economic growth and poverty reduction, there will be increased interest in exploring additional aspects of ASTI datasets.

There is also a need to ensure data quality with existing national statistics and address any discrepancies: this may involve coordinating with other ministries to align data collection criteria. In the case of large NARS systems, there may be a need to budget for the implementation of ASTI data collection within one of the major institutions of the country.

In general, the collective actions started with the implementation of ASTI data collection could lead to increased engagement with the actors of AR&D in the country. In addition to online interactions, peer support and knowledge exchange, the collective actions during implementation of data collection can already provide useful opportunities to strengthen linkages and engagement amongst local institutions. These conversations can be continued in between the data collection cycles to improve data collection strategies over time. Some of these actions are listed below.

1. **Validation and controls of the list of agencies**

It is important to thoroughly review the universe of agencies to be included in the survey. In cases where there is doubt about whether an agency conducts R&D in agriculture, it is important to include it in the survey and check with the source. Conversely, it is important to validate that the included agencies truly comply with the Frascati definitions regarding R&D, researchers, and agricultural activities. Maintaining an updated list ensures adequate national coverage. Failing to include relevant agencies will lead to underestimation, while including agencies whose tasks do not correspond to the study's focus will lead to overestimation.

2. **Ensuring the inclusion of key institutions contributing to AR&D**

While it is important to have an updated list that accurately reflects the true scope of agencies conducting agricultural R&D, special attention should be given to those with a significant impact on the national total. It is recommended to consider this variable when searching for data and defining field follow-up strategies. For example, in countries where the agricultural R&D system is primarily concentrated in their National Agricultural Research Institute (NARI), obtaining data from this agency is crucial for reconstructing the aggregate national indicator. Emphasis should be placed on obtaining data from the most relevant agencies, as they will set the trend at the aggregate level.

3. **Improvement of response rates during data collection**

It is important to exhaust all possible avenues to obtain data directly from agencies by increasing response rates. Several strategies have proven effective in promoting greater engagement from responding institutions, including:

- **Virtual meetings**: To improve response rates, virtual meetings can be held before and during the data collection process. These meetings help present the survey's objectives, explain the methodology, and provide guidance on completing the questionnaire.
- **Face-to-face visits**: For agencies that do not respond via email or phone, or that face difficulties, in-person visits may be arranged. In these cases, it is advisable to involve the NSO, which usually has trained field staff experienced in such tasks.
- **Workshops and results dissemination meetings**: It is recommended to organize sessions to share the results of the data collection with participating agencies. This allows respondents to see how their time and input contribute to valuable indicators for decision-making, thereby increasing their engagement in future rounds.

- **Methodology workshops and questionnaire support sessions**: With each successive round of data collection, agencies typically gain experience, leading to improvements in both response rates and data quality. The regular collection of core indicators is essential for ensuring reliable and consistent reporting. Workshops focused on methodological strengthening are an effective strategy to improve both participation and data quality in future rounds.

These modes of interaction are great opportunities for engagement amongst institutions on the issue of investment in AR&D

4. Management of missing data and imputations

Engagement with the NSO is crucial for tasks involving missing data and imputations. Statistical Offices typically have experience in data collection, handling missing data and imputations, as well as interacting with diverse data sources for constructing series and performing quality controls. Therefore, there is a mutual benefit for the inclusion of the NSO in national institutional AR&D frameworks and also to incorporate the AR&D data system within the national statistical system. Establishing cooperation agreements will facilitate information sharing among agencies and foster collaborative work among the technical teams of the involved agencies.

5. Engagement of local institutions with the hosted data portals

One of the more effective and visible methods of illustrating the value of the ASTI data, besides the publication of the analyses, is to engage the stakeholder groups with the data through a portal. As mentioned above, the results of analyses of historical data, as well as the most recent collection, can be displayed in different forms of data visualization, as dashboards on a data portal. They can serve a variety of purposes and stakeholder groups: researchers and innovators rely on them to support analysis, develop new tools, or validate hypotheses. For policy makers, they provide a foundation for evidence-based decision-making in areas like land management, climate resilience, or agricultural subsidies. Data portals also support transparency and public accountability by making government-held data accessible to citizens, journalists, and civil society. They are essential tools for monitoring and reporting, particularly when tracking progress toward national or international goals such as food security, climate commitments, or the Sustainable Development Goals (SDGs). Finally, data portals contribute to capacity building and education. By making high-quality, real-world datasets accessible, they help train the next generation of agricultural professionals, support extension services, and enhance public understanding of key agricultural issues.

9. Conclusion

Agricultural research is a critical pathway for reducing poverty and hunger, addressing climate change impacts, and improving food security. These guidelines represent a significant milestone in the global effort to better monitoring of investments in agricultural research and development (AR&D) capabilities. They provide a comprehensive framework for countries to systematically plan, collect, analyze, and disseminate data on investments and human capacities in agricultural research. By doing so, a country can produce harmonized and comparable indicators that can effectively monitor National Agricultural Research Systems (NARS) and contribute to evidence-based policymaking.

The data generated through ASTI is essential for informed decision-making, allowing stakeholders to analyze investment trends, identify gaps, set priorities, and ensure effective coordination of research initiatives. The transition of the program to the Food and Agriculture Organization (FAO), marks a new era for agricultural research data collection and analysis. The integration of ASTI into national statistical systems is crucial for enhancing data quality and country ownership. The new approach to ASTI aims to reinvigorate, expand, and make ASTI data collection sustainable through a process of institutionalization in countries. It aims to standardize and harmonize ASTI data globally, ensuring sustainability and broader coverage across all UN member states.

These guidelines have provided detailed instructions on designing questionnaires to capture core and structural variables related to human resources, financial resources, and research focus; establishment of a framework for data quality, verification upon receipt, outlier detection and imputation techniques for missing data. The production of indicators, based on the data gathered, is a crucial step in transforming raw data into insights that can inform policy and decision-making. The guidelines outline dissemination of these indicators through technical briefs, visualizations, and data series to support advocacy efforts and ensure that the data reaches decision-makers and stakeholders.

As countries embark on the journey of implementing ASTI, the guidelines provide a roadmap towards a single harmonized ASTI methodology to improve the overall quality, timeliness, and completeness of the global dataset. By institutionalizing ASTI within national statistical systems and fostering collaboration among stakeholders, countries can ensure sustainability and relevance of their AR&D efforts.

This comprehensive approach aims to strengthen NARS through evidence-based policies, ultimately contributing to global agricultural development goals. The guidelines set a path for countries to enhance advocacy for further investments in agricultural research and development, driving progress towards a more resilient and productive agricultural sector. Countries will be better equipped to develop strategies that maximize the national and regional uptake of AR&D data.

Therefore, the guidelines provide a robust framework for countries to enhance their agricultural research capabilities by producing harmonized and comparable indicators, to effectively evaluate and strengthen their NARS. The successful implementation of these guidelines will require commitment, collaboration, and sustained investment in AR&D which will better serve in planning and operationalizing AR&D within NARS and their regional and global collaborative structures.

10. References (Last accessed May 2025)

Beintema, N.; and Stads, G.. (2017). A comprehensive overview of investments and human resource capacity in African agricultural research. ASTI Synthesis Report. Washington, DC: International Food Policy Research Institute (IFPRI). https://hdl.handle.net/10568/146174

Beintema, N., A. Nin-Pratt, and G. Stads (2020): *Key Trends in Global Agricultural Research Investment. ASTI Program Brief.* Washington DC: International Food Policy Research Institute. https://www.asti.cgiar.org/sites/default/files/pdf/Global-update-ASTI-note.pdf

Carden, Fred; Beintema, Nienke M.; Admassie, Assefa; Katera, Lucas; Mboghoina, Thadeus; and Onyekwena, Chukwuka. 2019. Informing policy with agricultural R&D evidence: An ASTI pilot project in Ethiopia, Nigeria, and Tanzania. IFPRI Discussion Paper 1860. Washington, DC: International Food Policy Research Institute (IFPRI). https://hdl.handle.net/10568/147270

FAO (2023), Statistical Standard Series: Imputation, Version 2.0, Rome. https://openknowledge.fao.org/server/api/core/bitstreams/519783f5-8328-4c72-9380-a7b7c57c1a95/content

OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264239012-en

OECD/Eurostat (2018), Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris/Eurostat, Luxembourg. https://doi.org/10.1787/9789264304604-en

Onyango, C.O., Suwa, Y. & Pinto, Y. 2014. *Assessment of the Relevance, Quality and Utility of Agricultural Science and Technology Indicators (ASTI) Policy Data and Analyses for Phase II (2012-2014)*. Assessment Report. Washington, DC, ASTI-IFPRI. https://www.asti.cgiar.org/pdf/ASTI-Phase-2-Evaluation.pdf

Pardey, P.G. and J.M. Alston. "Global and U.S. Trends in Agricultural R&D in a Global Food Security Setting." Chapter 1 in C. Morredu (ed.) Agricultural Knowledge and Innovation Systems: Proceedings of an OECD Conference, OECD, Paris, 2012. https://pdfs.semanticscholar.org/64ff/f4818d5134a6d032d303e6103e2d796674fd.pdf

Rosegrant, M.W.; Sulser, T.B.; Dunston, S.; Cenacchi, N.; Wiebe, K.; Willenbockel, D. 2021. Estimating the global investment gap in research and innovation for sustainable agriculture intensification in the Global South. Colombo, Sri Lanka: Commission on Sustainable Agriculture Intensification. 75p. https://hdl.handle.net/10568/114761

Stads, Gert-Jan; Wiebe, Keith D.; Nin-Pratt, Alejandro; Sulser, Timothy B.; Benfica, Rui; Reda, Fasil; and Khetarpal, Ravi. 2022. Research for the future: Investments for efficiency, sustainability, and equity. In 2022 Global Food Policy Report: Climate Change and Food Systems. Chapter 4, Pp. 38-47. Washington, DC: International Food Policy Research Institute (IFPRI). https://doi.org/10.2499/9780896294257_04.

Silvia Terzi & Andrea Pierini, 2015. "Data Envelopment Analysis (DEA) assessment of composite indicators of infrastructure endowment," Rivista di statistica ufficiale, ISTAT - Italian National Institute of Statistics - (Rome, ITALY), vol. 17(1), pages 5-18. https://www.istat.it/it/files/2015/05/Art.1-Data-envelopment.analysis-infrastructure-endowment.pdf

United Nations. (2008). International Standard Industrial Classification of All Economic Activities (ISIC), Rev. 4. United Nations Publications. Available at: https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

11. Annexes

ASTI questionnaire template

(The questionnaire will be included in the final version of the document. At this stage, the Excel file is available on the Global Consultation website)

12. Glossary of concepts and definitions

(Extracted from the Frascati manual)

Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective.

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.

Capital R&D expenditures are the annual gross amount paid for the acquisition of fixed assets that are used repeatedly or continuously in the performance of R&D for more than one year. they should be reported in full for the period when they took place, whether acquired or developed in house, and should not be registered as an element of depreciation. The most relevant types of assets used for R&D for which capital R&D expenditures should be compiled are: land and buildings; machinery and equipment; capitalised computer software; other intellectual property products.

Current R&D expenditures are composed of labour costs and other current costs (including for *external R&D personnel*) used in R&D. services and items (including equipment) used and consumed within one year are current expenditures. annual fees or rents for the use of fixed assets should be included in current expenditures.

Doctoral students attend "tertiary programmes which lead to the award of an advanced research qualification [and which] are therefore devoted to advanced study and original research and are not based on course work only". such students are usually required to submit a thesis or dissertation of publishable quality, i.e. the product of original research that represents a significant contribution to knowledge. see also *International Standard Classification of Education*.

Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

External R&D funds are the amount of money spent on R&D that originate outside the control of a reporting unit.

External R&D personnel (or contributors) are independent (self-employed) or dependent (employee) workers fully integrated into a statistical unit's R&D projects without formally being persons employed by the same R&D-performing statistical unit.

Full-time equivalent (FTE) of R&D personnel is defined as the ratio of working hours actually spent on R&D during a specific reference period (usually a calendar year) divided by the total number of hours conventionally worked in the same period by an individual or by a group.

Headcount (HC) of R&D personnel is defined as the total number of individuals contributing to intramural R&D, at the level of a statistical unit or at an aggregate level, during a specific reference period (usually a calendar year).

Internal R&D personnel are persons employed by the statistical unit who contribute to the unit's intramural R&D activities. see *persons employed.*

Labour costs, or compensation of employed personnel, comprise annual wages and salaries and all associated costs or fringe benefits, such as bonus payments, stock options, holiday pay, contributions to pension funds. In this manual, the concept of labour costs also includes other social security payments and payroll taxes.

Master's students may in some cases be counted as researchers; in particular, this would include students following an IsCED level 7 research master's programme "…leading to the award of research qualifications that are designed explicitly to train participants in conducting original research but are below the level of a doctoral degree". however, it is important that only Master's students receiving payment for their R&D activity are included in R&D personnel totals.

Other current costs comprise non-capital purchases of materials, supplies, equipment and services to support R&D performed by the statistical unit in the reference year. Examples are water and fuel (including gas and electricity); books, journals, reference materials, subscriptions to libraries, scientific societies, etc.; imputed or actual costs of small prototypes or models made outside the statistical unit; and materials for laboratories (e.g. chemicals, animals, etc.). Other current costs include royalties or licences for the use of patents and other intellectual property rights, the lease of capital goods (machinery and equipment, etc.) and the rental of buildings to support R&D performed by the statistical unit in the reference year.

Other supporting staff include skilled and unskilled craftsmen, and administrative, secretarial and clerical staff participating in R&D projects or directly associated with such projects.

Performers of R&D / R&D agencies consist of statistical units that undertake (i.e. perform) R&D in each of the main sectors covered in this manual: Business enterprise, Government, higher education and Private non-profit.

Pure basic research is basic research carried out for the advancement of knowledge, without seeking long-term economic or social benefits or making any effort to apply the results to practical problems or to transfer the results to sectors responsible for their application.

R&D personnel in a statistical unit include all persons engaged directly in R&D, whether employed by the statistical unit or external contributors fully integrated into the statistical unit's R&D activities, as well as those providing direct services for the R&D activities (such as R&D managers, administrators, technicians and clerical staff). see also *internal R&D personnel* and e*xternal R&D personnel.* R&D personnel are classified according to their **R&D function,** which may be researcher, technician or other support staff.

Reporting unit is the unit *from which* data are reported. This corresponds to the unit that would receive a questionnaire or interview. In the case of administrative data, it would correspond to the unit that is represented by the individual record.

Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge.

Researchers are professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods.

Socio-economic objectives (SEO) classification is used to distribute government budget allocations for R&D. The criteria for classification should be the purpose of the R&D programme or project, i.e. its primary objective. The allocation of R&D budgets to socio-economic objectives should be at the level that most accurately reflects the funder's objective(s).

Statistical unit is an entity about which information is sought and for which statistics are ultimately compiled. It is the unit at the basis of statistical aggregates and to which tabulated data refer.

Technicians and equivalent staff are persons whose main tasks require technical knowledge and experience in one or more fields of engineering, the physical and life sciences, or the social sciences, humanities and the arts. They participate in R&D by performing scientific and technical tasks involving the application of concepts, operational methods and the use of research equipment, normally under the supervision of researchers.