Data collection and analysis tools for food security and nutrition: towards enhancing effective, inclusive, evidence-informed, decision making. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security,

Carlo Cafiero, Maria Blanco Fonseca, Michaël Chelle, Dilfuza Egamberdieva, Rebecca Kanter, Stephen Kimani, Marian Kjellevold Malde, Lynnette Neufeld, Leila Oliveira, Christian Schader, et al.

HLPE REPORT 17

DATA COLLECTION AND ANALYSIS TOOLS FOR FOOD SECURITY AND NUTRITION

Towards enhancing effective, inclusive, evidence-informed, decision making

CFS COMMITTEE ON WORLD FOOD SECURITY

HLPE High Level Panel of Experts

SEPTEMBER 2022

Cover photo: © WFP/Muna Abdelhakim

A little girl is being tested for malnutrition with mid upper arm circumference test (MUAC).

HLPE-FSN Steering Committee

Chairperson: Bernard Lehmann

Vice-Chairperson: Jennifer Clapp

Steering Committee Members: Olanike Adeyemo (Nigeria), Barbara Burlingame (New Zealand), Ruben Echeverría (Uruguay), Hilal Elver (Türkiye), William Moseley (United States of America), Nitya Rao (India), Elisabetta Recine (Brazil), José María Sumpsi Viñas (Spain), Akiko Suwa-Eisenmann (Japan), Stefan Tangermann (Germany), Shakuntala Thilsted (Trinidad and Tobago), Patrick Webb (United States of America), Iain Wright (United Kingdom of Great Britain and Northern Ireland)

Experts participate in the work of the HLPE-FSN in their individual capacities, not as representatives of their respective governments, institutions or organizations.

HLPE-FSN Joint Steering Committee / Secretariat drafting team
Team Leader: Carlo Cafiero (Italy)
Team Members: Maria Blanco (Spain), Michaël Chelle (France), Dilfuza Egamberdieva (Uzbekistan), Rebecca Kanter (United States of America), Stephen Kimani (Kenya), Marian Kjellevold (Norway), Lynnette Neufeld (Canada), Leila Oliveira (Brazil), Christian Schader (Switzerland), Sangeetha Shyam (India)
HLPE-FSN Secretariat
Coordinator: Évariste Nicolétis
Programme Officer: Paola Termine
Administrative Support: Massimo Giorgi
Communication Specialist: Silvia Meiattini

Viale delle Terme di Caracalla
00153 Rome, Italy
Tel: +39 06 570 52762
www.fao.org/cfs/cfs-hlpe
cfs-hlpe@fao.org

Referencing this report: *HLPE. 2022. Data collection and analysis tools for food security and nutrition: towards enhancing effective, inclusive, evidence-informed, decision making. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.*

HLPE report series

#1 Price volatility and food security (2011)

#2 Land tenure and international investments in agriculture (2011)

#3 Food security and climate change (2012)

#4 Social protection for food security (2012)

#5 Biofuels and food security (2013)

#6 Investing in smallholder agriculture for food security (2013)

#7 Sustainable fisheries and aquaculture for food security and nutrition (2014)

#8 Food losses and waste in the context of sustainable food systems (2014)

#9 Water for food security and nutrition (2015)

#10 Sustainable agricultural development for food security and nutrition: what roles forlivestock? (2016)

#11 Sustainable forestry for food security and nutrition (2017)

#12 Nutrition and foodsystems (2017)

#13 Multi-stakeholder partnerships to finance and improve food security and nutrition in the framework of the 2030 Agenda (2018)

#14 Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition (2019)

#15 Food security and nutrition: building a global narrative towards 2030 (2020)

#16 Promoting youth engagement and employment in agriculture and food systems (2021)

#17 Data collection and analysis tools for food security and nutrition: towards enhancing effective, inclusive, evidence-informed, decision making

All HLPE reports are available at www.fao.org/cfs/cfs-hlpe.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF BOXES

FOREWORD

The High Level Panel of Experts on Food Security and Nutrition (HLPE-FSN) is the science-policy interface of the Committee on World Food Security (CFS), the foremost inclusive and evidence-based international and intergovernmental platform for food security and nutrition (FSN). The HLPE-FSN provides independent, comprehensive and evidence-based analysis and advice at the request of the CFS and elaborates studies through a scientific, transparent and inclusive process, ensuring legitimacy among stakeholders, involving broad consultations and incorporating different forms of knowledge and expertise as well as a rigorous scientific peer-review process.

The report "Data collection and analysis tools for food security and nutrition: towards enhancing effective, inclusive, evidence-informed, decision making" has been produced by the HLPE-FSN following a request from the CFS and focuses on the role that data collection and analysis tools play in supporting effective evidence-informed decisions.

Food is a fundamental human right, and yet, too many people in the world do not have secure access to the food they need every day. In 2021, about one in every 11 people in the world (around 800 million people) faced hunger and many more (around 2.3 billion) were moderately or severely food insecure. The world is off track to achieving the SDG targets on hunger, food insecurity and malnutrition. Different and better actions are needed to reverse this trend.

Against this backdrop, **the findings and recommendations of this report are an important contribution to achieve food security and nutrition.** High-quality data and its accurate and timely analysis are essential to design, monitor and evaluate effective FSN policies. Data is also fundamental to ensure accountability of government policies and to monitor their implementation and impact.

We are also experiencing a data revolution, driven by new technologies, which is increasing exponentially the volume and types of data available. This provides **great opportunities** for informing and transforming food systems, but also creates **new risks** and can deepen inequalities within or between nations and societies.

A major challenge in the elaboration of this report has been the **inherent complexity** of the different angles and multiple dimensions of data collection, analysis and use – including economic, social, institutional, political, legal and technical – as well as the types of users involved, namely public and private, and the numerous and diverse purposes data may be used for.

To **determine the scope of the report,** the HLPE-FSN took into account the following elements: 1) the points explicitly made by the CFS in their request; 2) the results of the e-consultation on the scope of the report; and 3) the conclusions of the meeting organized by the CFS Secretariat on the matter.

Addressing some points of the CFS request has been particularly challenging, due to scarcity of information regarding some issues and to the fact that data gaps are country-specific and cannot be described at a global level. Therefore, this report indicates directions for future research and suggests policy measures to improve this in the future.

Moreover, many of the identified issues are not specific for FSN data but apply to all types of data. Therefore, it was necessary to seek an **optimum balance between dealing with general data considerations and specific considerations related to FSN data,** in order to avoid duplication and overlap with other international reports on data.

Well aware of the complexity of this report and its relevance for improving FSN, the HLPE-FSN strived to apply **maximum precision, rigour and professionalism,** working at all times with evidence and academic references and providing sound and balanced arguments and conclusions regarding controversial issues.

The result is a set of **practical recommendations** addressed to the CFS, governments, the United Nations and international agencies, as well as academia.

It is imperative to achieve the necessary transformation of food systems and to embrace the data revolution in support of this effort. Decisive action now, leveraging current political opportunities and public opinion sensitivity and awareness, as well as technological innovation, can steer the course in the right direction. The CFS and its members can take great advantage of this report and its actionable recommendations.

On behalf of the HLPE-FSN Steering Committee, I would like to commend and thank the international experts of the project team led by Carlo Cafiero. They provided impressive work, solely on a pro bono basis.

The report also benefited greatly from suggestions by a large number of experts and institutions who commented extensively on the scope of the report and on its first version. Furthermore, I would like to pay my tribute the peer reviewers for their hard work. Finally, I want to thank the HLPE-FSN Secretariat for its precious support to our work.

The HLPE-FSN has a very noble and important mission, to produce **scientific reports,** which are **public goods** and serve as starting points for debates at CFS, between actors having many different perspectives and, often, objectives. This report can make a real difference on the ground and produce significant changes to alleviate the perils of hunger and help improve nutrition. I hope that policymakers, practitioners, all the actors around food, agriculture and nutrition and all concerned sectors worldwide will make the best use of it.

ACKNOWLEDGMENTS

The CFS HLPE-FSN warmly thanks all the participants who contributed with very valuable inputs and comments to the two open consultations, first on the scope of the report, and second on its advanced draft ("V0"). These contributions were channelled through the FAO Global Forum on Food Security and Nutrition (FSN-Forum). These contributions, as well as all the documents generated throughout the process of elaboration of this report, are available on the HLPE-FSN website: https://www.fao.org/cfs/cfs-hlpe/ .

The HLPE-FSN thanks all the anonymous peer-reviewers for their comments and feedback on the pre-final draft ("V1") of the report.

Participants in the CFS "intersessional event" titled "Closing data gaps and promoting evidence-informed decision-making for food security and nutrition" on 1 July 2021 also deserve a warm thank for their valuable and timely inputs, which can be found at: https://www.fao.org/cfs/events/events-details/en/c/1412339/ .

The collaboration with Canopy-Translation for the layout of the report was pleasant and fruitful.

The HLPE-FSN also acknowledges Ms Dianne Berest for the very careful editing of the English version and provision of excellent and useful comments, and the translators into the other five official UN languages (Arabic, Chinese, French, Russian, Spanish).

The HLPE-FSN process is entirely funded through voluntary contributions. HLPE-FSN reports are independent collective scientific undertakings on topics requested by the Committee on World Food Security Plenary. HLPE-FSN reports are global public goods. The HLPE-FSN thanks the donors who have contributed since 2010 to the HLPE-FSN Trust Fund, or provided in-kind contributions, thereby enabling the process of work of the HLPE-FSN, while fully respecting its independence. Since its creation in 2010, the HLPE-FSN has been supported, including through in-kind contributions, by: Australia, China, Ethiopia, the European Union, Finland, France, Germany, Ireland, Monaco, New Zealand, Norway, the Russian Federation, Slovakia, Spain, Sudan, Sweden, Switzerland and the United Kingdom of Great Britain and Northern Ireland.

ABBREVIATIONS AND ACRONYMS

ABDI	Agrobiodiversity Index
AFI	Acute food insecurity
AgCROS	Agricultural Collaborative Research Outcomes System
AI	Artificial intelligence
AMIS	Agricultural Market Information System
ARS	Agricultural Research Service
CATI	Computer-assisted telephone interviews
CFI	Chronic food insecurity
CFS	Committee on World Food Security
CHNRI	Child Health Nutrition Research Initiative
CSIS	Center for Strategic and International Studies
CSO	Civil society organization
CWIQ	Core Welfare Indicators Questionnaire
DHS	Demographic and Health Surveys
EFSA	European Food Safety Authority
FAIR	Findable, accessible, interoperable, reusable
FAO	Food and Agriculture Organization of the United Nations
FCDB	Food composition database
FCT	Food composition tables
FIES	Food Insecurity Experience Scale
FPIC	Free, Prior and Informed Consent
FSN	Food security and nutrition
FSNAU	Food Security and Nutrition Analysis Unit
GAFSP	Global Agriculture and Food Security Program
GES DISC	Goddard Earth Sciences Data and Information Services Center
GFW	Global Forest Watch
GLDAS	Global Land Data Assimilation System
GODAN	Global Open Data for Agriculture and Nutrition
GSARS	Global Strategy to Improve Agricultural and Rural Statistics
HIES	Household Income and Expenditure Surveys
HiHI	Hand-in-Hand Initiative

HLPE-FSN	High Level Panel of Experts on Food Security and Nutrition
IFPRI	International Food Policy Research Institute
IMR	Institute of Marine Research
INFOODS	International Network of Food Data Systems
INSO	International NGO Safety Organisation
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IoT	Internet of things
IPC	Integrated Food Security Phase Classification
IUU	Illegal, unreported and unregulated
IVR	Interactive voice response
LSMS	Living Standards Measurement Study
MDG	Millennium Development Goal
MICS	Multiple Indicator Cluster Survey
MODIS	Moderate-resolution imaging spectroradiometer
MYPoW	Multi-year Programme of Work
N.A.	Not applicable
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NGO	Non-governmental organization
NIHR	National Institute for Health Research
NSO	National statistical office
Norad	Norwegian Agency for Development Cooperation
ODK	Open-Data Kit
OECD	Organisation for Economic Co-operation and Development
PARIS21	Partnership in Statistics for Development in the 21st Century
RRI	Responsible research and innovation
RuLIS	Rural Livelihoods Information System
SATIDA	Satellite Technologies for Improved Drought Assessment
SDG	Sustainable Development Goal
SIS	Smart information system
SLF	Sustainable Livelihoods Framework
SMS	Short Message Service
SPARS	Strategic Plans for Agricultural and Rural Statistics
SSF	Small-scale fisheries
UFISH	Global Food Composition Database for Fish and Shellfish
UNICEF	United Nations Children's Fund
UNSD	United Nations Statistics Division
USDA	U.S. Department of Agriculture
USSD	Unstructured Supplementary Service Data
VAM	Vulnerability, analysis and mapping
WB	World Bank
WEAI	Women's Empowerment in Agriculture Index
WHO	World Health Organization
WWF	World Wildlife Fund

KEY MESSAGES

- Throughout the world, high-quality, timely and relevant data are key to inform actions that promote better access to food and improved nutrition.

- Despite the abundant and growing availability of data and information relevant to food security and nutrition, often policymakers are not aware of the existence and relevance of such data or do not use them appropriately, due to challenges at each step of the data cycle, which includes: defining priorities and data needs; reviewing, consolidating, collecting and curating data; analyzing the data using appropriate tools; translating data into relevant insights to be disseminated and discussed; and, finally, using data for decision-making.

- Fundamental data gaps still exist to correctly guide action and inform policymaking, especially in terms of timely and sufficiently granular data on people's ability to locally produce and access food, on their actual food and nutrient consumption, and on their nutritional status. Increased and sustained financial investment is needed to overcome these gaps.

- Several other constraints limit the effectiveness of data-informed policy action, especially in low-resource countries. Key among them is the low level of data literacy and analysis skills (for both qualitative and quantitative data) on the part of data and information users at all levels – from data collectors and analysts, to decision-makers, and to the people, as the ultimate beneficiaries of food security and nutrition policies.

- The complexity of the system of public and private actors and institutions involved in food security and nutrition data, coupled with the rapidly changing characteristics of today's data ecosystems due to the digital revolution and the pervasiveness of the internet, brings to centre stage the need for global coordination to improve data governance. Particularly urgent is the need to reach agreement on the nature of FSN data and information as a public good, and, on that basis, to establish a global legal framework that allows for the broadest possible circulation of relevant information, while preserving the rights of the people to whom the data ultimately belongs.

INTRODUCTION

Kenya, 12 March 2021, a chicken farmer inputs data about eggs on a notebook.
© FAO/Luis Tato

When the UN Secretary General, Antonio Guterres, opened the UN Food Systems Summit, on 23 September 2021, he described current **food systems** as "failing".[1] Even before COVID-19 made its unsettling appearance in late 2019 and before the aggression of the Russian Federation against Ukraine, lack of sufficient progress towards the targets of Sustainable Development Goal 2 (SDG2)[2] had made it clear that existing food systems worldwide had been unable to ensure **food security** and adequate nutrition for all, and that significant transformations were needed to correct this situation. Few can doubt the extent of persistent hunger, food insecurity and widespread malnutrition in all its forms in the world today (FAO *et al.*, 2017; 2022). Yet, evidence to highlight the nuanced scope of such failure and approaches to address food system solutions are still lacking.

The actions of public and private agents involved in managing and operating food systems, from production to distribution and consumption, are crucially affected by the extent of data and information they have access to. Despite the rapidly growing amount of data and information available today, this report outlines how its *timeliness, reliability, relevance, depth of analysis, and extent and clarity of communication* require improvement to more effectively guide strategic policymaking in agriculture, food security and nutrition (FSN).[3]

This report, produced in response to a request from the Committee on World Food Security (CFS), focuses on the role that **data collection and analysis tools** play in supporting effective, evidence-informed decision-making by public and private agents. It covers the points explicitly made by the CFS[4] and proposes solutions to support actions intended to reverse the negative trends in food insecurity and malnutrition, which have been linked to political and social instability (FAO *et al.*, 2017), the effects of climate change (FAO *et al.*, 2018) and economic slowdowns (FAO *et al.*, 2019), and which have been exacerbated by the lingering effects of the COVID-19 pandemic and by the Russian Federation–Ukraine conflict.

The CFS has stated the rationale for this report as follows:

> *"Although it is widely recognized that sound decisions are based on good information and data, in many countries, particularly low and lower middle-income countries, timely and reliable rural, agricultural and food security statistics are largely lacking. Despite all efforts,*

1 See https://www.un.org/en/food-systems-summit/news/un-secretary-generals-remarks-food-systems-summit and https://www.youtube.com/watch?v=58tQl6-SaQA.

2 The second goal of the 2030 Agenda for Sustainable Development (commonly referred to at the SDG2s) reads: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". It includes five targets in terms of outcomes and three targets regarding means of implementation. Target 2.1 reads: "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round", while Target 2.2. reads: "By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons". See https://sdgs.un.org/goals for a full description of the SDGs, targets and indicators.

3 Throughout the report, the term agriculture refers to the broader set of activities that involve the use of natural resources (land, water, forests, fish) to produce foods.

4 Namely, to:

- Highlight the benefits of using data and the opportunity costs of not using data for decisions
- Illustrate initiatives that have encouraged evidence-based decisions in agriculture and food security across the public, private, and academic sectors as well as approaches that have not worked.
- Identify specific high priority gaps in data production and analysis not covered by ongoing initiatives.
- Identify the barriers impeding quality data collection, analysis, and use in decision-making.
- Provide insights into how to ensure data collection and its utilization give voice to the people most affected by policies stemming from that data, including farmers and other food producers (CFS 2019/46/7, 2019, p. 9).

See CFS's Multi-Year Programme of Work at https://www.fao.org/3/na703en/na703en.pdf.

most countries still do not conduct regular household and farm surveys, do not meet the minimum data requirements, lack sustainable data systems, and have insufficient capacity to analyse and use the data at their disposal (CFS 2019/46/7, 2019, p. 8). ”

Therefore, **while many may live in places where data and information flow with unprecedented mass and speed, many countries still lack sustainable data systems and related capacities.** Rather than recommending from the onset additional investment in data collection for food security and nutrition, we first propose in-depth ways of thinking about data collection and analysis tools **to ensure full and proper use and re-use of existing data.**

The CFS presented the following additional rationale for this report:

“ *Addressing the gap in quality data is also essential to monitor progress and understand where the world stands in achieving its shared goals – the SDGs. Custodian UN specialized agencies were identified for each SDG indicator to ensure that robust, global statistics were provided to measure progress in achieving the 2030 Agenda. However, the success of the SDGs rests largely upon strengthening data collection and statistical capacity-development at national level, including capacity building that strengthens coordination among national statistics offices (CFS 2019/46/7, 2019, p. 8).* ”

As of this writing, there are still many countries in the world where training is required so that there are sufficient human resources to properly interpret, process and digest new data in the various forms in which it is continuously generated, stored and distributed. Of particular concern is that **this is true also for the scientific community,** where the more traditional research tools are being challenged by emerging ones,[5] which have not yet sufficiently permeated academic curricula. This brings to the fore **the need to invest in capacity development at all levels, starting even in primary school and continuing through specialized training of professionals working in public and private institutions dealing with data.**

This report has been designed to respond to the call of the CFS to Support the process of laying the groundwork for informed decision making, setting standards for improved data-driven policies around food security and nutrition, and strengthening effective monitoring, review and follow-up to deliver SDG 2 (CFS 2019/46/7, 2019, p. 8).

To begin laying this groundwork, the report was developed with an understanding that food security and nutrition (FSN) policymaking at global, national and local levels, involves the use of data, either new or existing, to reach effective, evidence-informed decisions, and that this involves a distributed process, where responsibilities are held by different individuals and institutions, at different levels.

The report is organized around six chapters: **Chapter 1** defines key concepts around the data collection and analysis tools that are presented throughout the report. It provides operational definitions of **data**, **analysis tools** and **data governance**, in an effort to avoid ambiguity in the interpretation of the concepts set forth. Chapter 1 also discusses data as public goods, an aspect that is important when considering improvements to capacity building, institutional arrangements and coordination, which in turn affect data governance arrangements. A conceptual framework (Figure 1) is provided that draws on previous work by the HLPE and others (Bronfenbrenner, 1979; DFID, 1999; HLPE, 2017, 2020; UNICEF, 1990), linking food system policies and actions to the food security and nutritional status of individuals and the context in which they live.

A key feature of the conceptual framework is the distinction in levels based on the proximity of the socioecological factors related to FSN (and corresponding decision-makers) to the individuals who are ultimately affected by FSN

5 This will be discussed more in later sections of the report, but consider for example developments in the theory of measurement that address the problem of quantification in behavioural and social sciences (Bond, Yan and Heene, 2020; Mari et al., 2017), or the epistemological implications of big data for research (Kitchin, 2014b).

policies and actions. Furthermore, inspired by and adapted from the data cycle presented by Data for Decisions to Expand Nutrition Transformation (DataDENT, n.d), the conceptual framework identifies thematic areas for FSN data collection and analysis and provides a schematic representation of the main steps to utilize FSN data for particular objectives. These six steps along a **cycle for data-informed decision-making** begin with identifying the priority question and continue through using the results, insights and conclusions (SEE FIGURE 2). Effective data governance and inclusiveness are described in depth, as highlighted at the centre of Figure 2. This schematization complements the conceptual framework as it highlights how different actors use data to perform different functions while illustrating how myriad roles can coordinate efforts for FSN-related decision-making. Together, the conceptual framework and the data cycle help frame the discussion in the subsequent chapters of the report.

The conceptual framework provides an effective way to **guide the selection and analysis in an organized manner,** by completing a matrix (Figure 3 in the main report), where each step in the data cycle is associated with the elements of the broad system, from distal (or macro), to individual outcomes.

Throughout the report, the conceptual framework and the data-informed decision-making cycle are used to highlight how data and analysis tools relate to each of the six dimensions of food security, as introduced by the HLPE-FSN (HLPE, 2020).

It is important to note that the report adopts **a broad definition of data** that includes all kinds of information – **both quantitative and qualitative** – that can be **codified, stored and transmitted in analogue or digital form,** and recognizes the risks and limitations associated with exclusive reliance on quantified variables in informing decisions.

Chapter 2 reviews existing data and analysis tools for FSN. Despite an abundance of FSN-relevant data at all levels, **there is a lack of broad, shared access to the disaggregated, granular data, at subnational and local levels, needed to inform action.** Existing data could be better shared and analysed, by both public and private agents at national and international levels, in order to extract the wealth of useful information it contains. This will require a rethinking of the way FSN data is governed, especially considering the rapidly changing **data ecosystem**, described later in the report. The review of existing FSN data collection and analysis initiatives provides various examples of good practices that could be further enhanced and used in developing similar initiatives. The review also identifies the most important remaining data gaps and challenges at each step of the data cycle, such as: data on the characteristics of agricultural holdings, such as those produced by agricultural censuses; data on the different characteristics of farms and other operations across the agrifood system at the local level, as provided by farm and other industry surveys; data on household food expenditure; and, most importantly, data on individual dietary intakes. These kinds of data are essential to guide targeted FSN intervention, as they provide focused insights on local food systems and on the extent of inequalities within populations. While surveys and other sources of household- and individual-level data exist, the quality of the data they provide, and the frequency with which they are generated, are still largely insufficient to support effective decision-making, especially in low- and middle-income countries, and to conduct assessments during emergencies and in other difficult contexts.

The second part of Chapter 2 discusses current challenges and opportunities to improve data-informed FSN decision-making at each step of the data cycle. One finding is that **there is a general lack of clarity and coordination among decision-makers with regard to setting priorities when deciding on data collection and analysis,** and this stands in the way of filling in current data gaps. Better coordination in setting objectives for data use will contribute to creating an enabling environment, where institutions at various levels work together to gather, curate and disseminate data. This will be instrumental to favour increased access to existing data and to prevent the unnecessary proliferation of indicators, data-collection initiatives, and data quality assurance which result in fragmented data results that are difficult to reconcile and that are inadequate for informing effective action.

Of special note is the importance of qualitative information for making decisions. A myriad of personal, societal, cultural, religious and other considerations may have direct relevance for decision-making to improve FSN. Many of these aspects may be difficult or impossible to capture with quantitative data, and qualitative data are less amenable to collection by simple, standardized surveys, with the result that this type of information may end up being excluded from data consolidation and dissemination efforts. A final aspect involves communication and the importance of communicating data and the results of data analysis in a way that it is useful and effective for decision-making.

Chapter 3 discusses the major constraints and bottlenecks that underpin many of the gaps in FSN data collection and analysis identified in previous chapters, with a special focus on conditions prevailing in low– and middle–income countries. The constraints are grouped into two main categories: those related to insufficient resources – financial, human capital and data/research/analysis infrastructure; and those related to inadequate institutional arrangements, which lead to problems with data governance. **Timely allocation of sufficient financial resources, in a predictable way, is a key enabling element to sustain an effective FSN data ecosystem in any country.** Notwithstanding, this is a serious problem reported by many countries, where National Statistics Offices (NSOs) identify funding as one of their main constraints, in particular in the agriculture sector. Resource constraints continue to limit data collection in agriculture (where sound decision-making requires regular agricultural censuses and surveys of operations along the food supply chain), and in food security and nutrition outcomes (where up-to-date household surveys and dietary intake information are needed). Although it is recognized that these are expensive initiatives, that demand adequate levels of human capacity, they are essential as they constitute the backbone of any FSN data system.

Chapter 3 also highlights the trade-offs between the financial and human resources needed to secure adequate generation of quality data: while the running costs of field operations, data storage and dissemination might be reduced by shifting from more traditional operations (as still conducted by many National Statistics Offices and other government statistics units in low-income countries) to modern data-generating technologies and digitalization, the process must be accompanied by upfront investments (infrastructure, machinery, etc.), but also by the development of the necessary professional capacity. Effective use of modern technologies for FSN data generation and analysis requires skills that are still in scarce supply. **The lack of adequate investment in human capital, namely, expanding education on data science and statistics to all professionals involved in the FSN data-informed decision-making cycle, is the strongest binding constraint that prevents FSN data systems from developing in most low-income countries.** Thus, it is the area where investments will certainly have the highest returns.

In terms of institutional arrangements, we note the lack of coordination among the various agencies that are involved in generating and analysing FSN-relevant data, which operate often under different administrative and logistic arrangements, for example, as units in different ministries (agriculture, health, economy, environment, etc.). This often results in costly duplication of efforts, leading to redundancy and, sometimes, inconsistency in the information generated by different units. This problem is not only present among government institutions at country level, but also in academia, and sometimes among international organizations, including within the UN System. The review leads to a strong call for increased coordination at all levels, from local, to national, to international, something to which we shall return to in chapters 5 and 6.

A discussion of data and analysis tools cannot be complete without recognizing that we are in the midst of a data revolution, including within agriculture and FSN. Chapter 4 reviews how new and emerging technologies in digital data can contribute in many ways to FSN data and analysis, though perhaps requiring that the traditional ways of thinking about and regulating activities around FSN data collection and analysis be challenged, including the roles and responsibilities of public and private actors.

Several examples demonstrate how each of these technologies can contribute to each phase of the cycle for data-informed decision-making, and how they may provide information that is relevant for each of the six dimensions of FSN. The review confirms that **these technologies have the potential to make a huge contribution, though their broad diffusion also comes with risks.** These include uncontrolled dissemination of digital data collected through devices embedded in machines (from tractors to personal phones), which can threaten privacy; problems of accountability arising from reliance on artificial intelligence, machine learning and other automated or semi-automated decision-making, which raises a number of ethical considerations regarding the use of these modern technologies; data quality and interoperability issues which may be conditioned by the specific technology used; and, finally, the very important issues of equity, scalability and inclusiveness that arise when considering the differential capacity that exists both across countries and between public and private actors/ institutions.

Many of the issues raised and discussed in the previous chapters lead naturally to considerations around **data governance**, to which Chapter 5 is devoted. The chapter begins by addressing two somewhat controversial, and strongly interlinked, issues around data governance. One is the debate on the nature of data: should data be considered public or private goods, and what role can markets play in this? Are market-based mechanisms able to guarantee an adequate supply of and access to data? The other issue is the question of data ownership and the social value of data. Especially when data contain personal information, who should own it? And if the data is considered to be owned by the people to whom the information is linked, should they have the right to sell it? With specific reference to FSN, there are convincing arguments that more disaggregated data is needed to better guide FSN interventions, but that such data might allow personal or group identification, in which case the data would be considered "personal data". The question arises, then, as to whether current mechanisms for personal data protection, such as those based on informed consent, are sufficient to protect the rights of data owners, while ensuring that the information can be accessed to express its full potential for social benefits. One key suggestion in this report is that, from a moral standpoint, **personal data, like blood, is something that individuals may choose to give when that is necessary to obtain a personal service** (for example, when blood is given for medical testing), **but that people should also be encouraged to donate, when there is a clear indication that its use may contribute to a greater good** (such as saving someone's life). What should be crystal clear is that any resale of such data should be deemed immoral and even prosecuted as illegal.

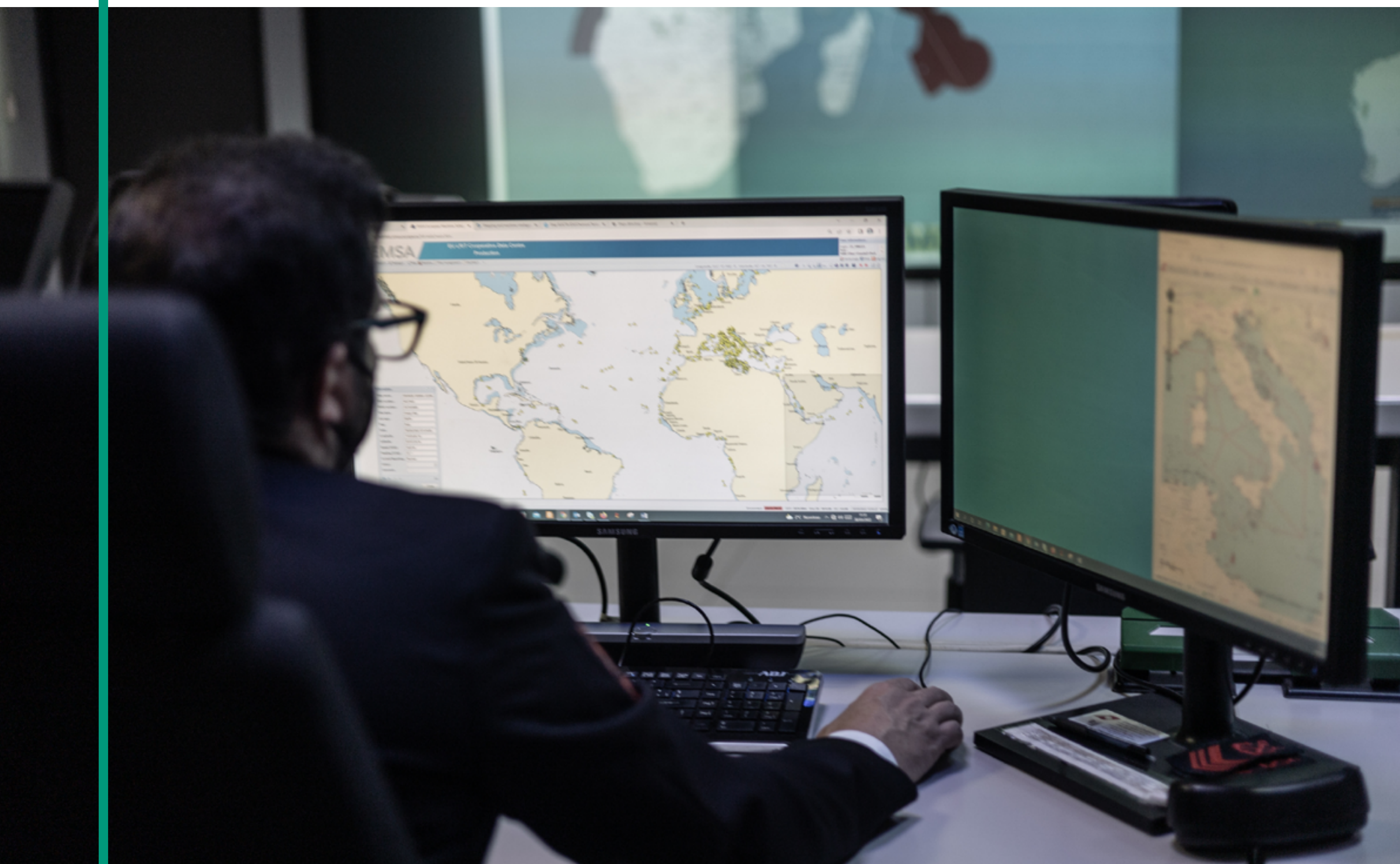
The main conclusion from the discussion in the first part of the chapter is that, because modern data that is recorded, stored and shared in digital forms, can be used and re-used, even simultaneously by many people, they must be conceived as inherently **public goods.** Access to such data should be restricted only when necessary to protect fundamental human rights, such the privacy of the people involved. For this purpose, innovative legal frameworks, such as those based on the concept of **data trusts,** defined by the Open Data Initiative as "legal structures that provide independent stewardship of some data for the benefit of a group of organizations or people" (Open Data Initiative, 2018), are a promising option for moving the data governance agenda forward, including in the agriculture sector and with regard to FSN data.

Fortunately, this is indeed a very active area of research and debate, and the chapter presents examples of existing initiatives, which may serve as models for yet more solutions.

Finally, Chapter 6 summarizes the findings of the report and advances the recommendations as a call for action to all actors who play a role in the data cycle. Recommendations are organized in five areas based on the objectives of: (i) creating greater demand for data in decision making; (ii) optimizing and, if needed, repurposing investments towards data collection, while increasing collaboration among stakeholders to harmonize and maximize the sharing of existing FSN data; (iii) increasing and sustaining investments in essential FSN data collection; (iv) investing in human capital and infrastructure to ensure sustainability of data processing and analytic capacity; and (v) improving FSN data governance and promoting inclusiveness and agency among data users and generators. The proposed actions, if followed, may prove useful in moving towards more effective, evidence informed, decisions that will make food systems more sustainable and ensure food security and better nutrition for all, particularly for the billions of people throughout the world who suffer from various forms of malnutrition, including the seven hundred million or more who still experience hunger (FAO *et al.,* 2017, 2022).

Chapter 1

SETTING THE STAGE



Italy, 30 March 2022, Italian National Coastguard officers monitor vessels fishing.
© FAO/Cristiano Minichiello

Before discussing challenges in data systems for FSN, it is important to lay out the key definitions and conceptual framework that will guide this analysis.

DEFINING KEY TERMS

In the title of this report and in the following sections we use the concepts of *data, analysis tools* and *data governance*, which may mean different things to different readers. A clear definition of the way we define and use the terms is thus critical to avoid confusion on the intended meaning of some of the statements, implicit or explicit value judgements, and recommendations we present in the rest of the report.

DEFINING DATA

A variety of definitions of data can be found in the popular and scientific literature, many of which include *facts, statistics* or *knowledge*, among a variety of related terms. Several definitions emphasize the numeric aspects, while others recognize that data may also take other forms. For this report, we adopt a definition inspired by Kitchin (2021, p. 2), which states that data is:

> “*any set of codified symbols representing units of information regarding specific aspects of the world that can be captured or generated, recorded, stored, and transmitted in analogue or digital form.*”

At initial glance, this phrasing may seem overly complex, yet it represents a substantive difference from many other existing definitions for at least four reasons.

First, the expression *codified symbols* allows a meaningful description of data without use of the terms *fact* or *knowledge*. Knowledge and facts are indeed inferences that can be gleaned following consolidation, analysis and interpretation of data, in relation to a specific question in context (Zins, 2007), but are not, in themselves, data. It is only once such inferences are codified, recorded, stored and transmitted that they become *new data*, thus closing the circle and justifying the image of a data cycle that evolves into an ascending spiral where, at the completion of each cycle, the amount of data and information available for use and re-use grows.

Second, the use of *codified symbols* is appropriately inclusive language, as it makes it clear that **data do not necessarily need to be numeric**. While in many cases data represent measured quantities or proportions, thanks to the increased digitalization of the information, we often deal with datasets consisting of essentially qualitative information, stored in the form of texts, images, sounds and other forms.

Third, referring to data as *codified symbols* has the further advantage of making the importance of codifying explicit: **symbols used to record and store data must be chosen carefully and their meaning must be properly**

communicated. One problem that is too often encountered in human and social science contexts is treating data that are of an essentially qualitative nature as if they represent measured quantities. The problem arises with indexes or scores corresponding to counts of binary (*yes/no*) events, and that are therefore codified with integer numbers, which only contain ordinal information on the involved cases. In those cases, the numeric representation encourages an incorrect treatment of such indexes or scores, with analysts computing averages or other statistics that are only meaningful and appropriate for *interval measures*. Such scores or indexes should instead be properly treated as *ordinal measures*.[6] More generally, qualitative data must be coded following standardized coding procedures, which inevitably begins with the adoption of **clear operational definitions of the concepts, constructs or attributes captured by the data.** This is crucial to avoid ambiguity in interpreting data, but not always easy to achieve. Contrary to quantitative variables reflecting unambiguously defined attributes of the physical world (e.g. length, mass, etc.) that can be directly observed and measured, most qualitative data in social science consists of variables and indicators intended to reflect *concepts* or *constructs* that are not always defined unambiguously and understood in the same way by everyone. Think, for example, of the concepts of *gender* or *ethnicity*, or constructs such as *poverty* or *food insecurity*. This poses several philosophical and practical challenges, as even the apparently simple process of just recording data, for example, might entail active decision-making regarding *which* value to record, which may even have moral implications (e.g. deciding on a person's ethnicity simply by observing them walking down the street or looking at a photograph of them, or on the basis of their name, or by asking the respondent's opinion in a survey; or identifying poverty with monetary levels of disposable income; or food insecurity with inadequate dietary energy intake). These considerations point to the importance of **always accompanying data with clear metadata** which provides sufficient information on the assumptions made in producing them, and of ensuring that sufficient competence exists to correctly interpret them at all levels of the data cycle when the data are used to inform decisions.

> *“The continuing development of sophisticated analytic methods, both in statistics and data science, necessary for proper treatment of non-traditional data, creates a growing need for human resources skilled in the use of such methods.”*

As we shall discuss in more detail in Chapter 3, and stresses the importance of investing in training and education, especially in the current era of **big data** and the new emerging data science (see, for example, Oliver, 2021).

Fourth, an important part of the definition of data is that data are *generated, recorded, stored* and *transmitted* so that – unless artificial barriers are put in place to prevent it – they can be accessed repeatedly and by different users at the same time at little or no additional cost to the owner of the data. This is because, **when data are used, they continue to exist and to be available and useful.** They are neither appropriated, nor consumed. Hence, if we want to ensure their efficient use, there are strong arguments for promoting as open access as possible to any set of existing relevant data. As the issue of open access to data may be controversial, and in light of the ever increasing amount of data being generated and held by private entities and the growth of markets for data, we devote a specific section to discuss this topic in Chapter 5, where, we note how the generation of data has outpaced the consolidation of relevant moral and ethical considerations and their reflections in appropriate national and international legal arrangements.

DEFINING ANALYSIS TOOLS

Another potentially ambiguous expression used throughout the report is *analysis tool*. In the context of this report, it is interpreted quite generally as:

6 For an enlightening discussion on the incorrect interpretations of counts, indexes and scores as measures in human and social sciences, see Wright, 1999.

“a set of formal rules[7] used to guide the processing of available data, aimed at obtaining analytic results for a specific purpose or research question.”

Several aspects in this definition of analysis tool warrant discussion. First, by stressing that analysis is conducted on existing data, we implicitly distinguish *data analysis* from *data generation* in a conceptual data cycle. We recognize that the results of an analysis are often, and usefully, stored and remain available in the form of new data, so that they can be used for further and different analyses. We also explicitly recognize that, in some cases, existing data may be perceived insufficient to address the problem at hand, and may therefore lead to a call for generating new data. Nevertheless, it is useful to distinguish the two steps from a conceptual point of view, as – especially in the era of **big data** – roles and responsibilities for data collection, curation and dissemination are very often distinct from roles and responsibilities in the use of data for evidence-based action. The latter entails decisions regarding which data to use to inform actions aimed at addressing a specific problem and how to analyse such data. These decisions can be made by agents who have had no direct involvement in the collection of **primary data**.

This leads to another aspect highlighted in the definition above, namely that effective analysis tools are *specific*, in the sense that they must be properly designed to respond to well-defined questions. While general analytic methods and specific techniques for data treatment exist (say, for example, ordinary least square methods to estimate parameters of a linear regression, used in the context of an econometric analysis, or pile-sort methods to collect and highlight associations in data collected in the context of an anthropological study) and are necessary components of any analytic tool, these should never be confused with the analytic tool itself. Insisting on the need for specificity of the analytic tool should encourage analysts to carefully consider the problem at hand and select the kind of data needed to answer the question, choosing the most appropriate combination of analytic methods and techniques for data treatment, and – very importantly – present and discuss the various assumptions made in setting up the analytic model. Unfortunately, we have found there to be a discouraging paucity of examples of good analysis tools specific to food security and nutrition, despite a relative abundance of data and of qualitative and quantitative analytic methods and techniques.

The final aspect that the above definition emphasizes is that the rules that define the analysis tool *must be formalized*. That is, they should be explicitly and clearly described in a way that makes application of the analysis tool replicable, consistent and susceptible to scrutiny by reviewers.

“Rigorous analysis tools should never be, or even appear as, “black boxes”, especially to those who will be called to action by the results of the analysis.”

Formalizing the rules to be followed in the analysis of data is one mechanism that reduces the risk of different conclusions being drawn by different analysts, who may be asked to answer the same question, using the same set of available evidence. The goal of explicit formalization is to increase the extent to which results from the analysis of data are objective and trustworthy, especially where data are scarce or where there may be lack of consensus around the constructs involved. This aspect is becoming especially problematic with the diffusion of automated, algorithm-based data processing systems, powered by **artificial intelligence (AI)** and **machine learning (ML)**. Use of these new systems in areas of immediate consequence for human health and well-being raises important concerns regarding how trust and transparency can be sustained. As noted by Burrell (2016) and discussed by Oliver (2021), algorithmic decision-making used in data analysis can be

7 Rules encompass procedures and techniques belonging to different methods of inquiry, both quantitative and qualitative, as appropriate, depending on the nature of the data and the objective of the analysis.

opaque for three reasons: because of deliberate decisions by the owner or creator of the tool to protect intellectual property, because of a lack of technical skills and knowledge among the users of the tool and those who are bound to be affected by the decision, and because these systems may actually be "intrinsically opaque due to the characteristics of many state-of-the-art machine-learning methods" (Oliver, 2021 p.61).

DEFINING DATA GOVERNANCE

Data governance has been defined in different ways. In this report, we define it as a **globally relevant set of principles, strategies, policies, regulations and standards developed by institutions to collect, manage, share and use data.** By establishing rules and standards, data governance aims to enable the broadest possible data sharing, so that data can be used effectively, while ensuring the protection, integrity and transparency of data systems. To be effective, institutions responsible for developing data governance frameworks, including international organizations, national governments, academia, the private sector and civil society organizations (CSOs), must act in a coordinated manner. These institutions must reinforce collaboration to establish and maintain data systems that can inform the design of interventions and policies needed to address FSN challenges. We address all these issues in Chapter 5.

A CONCEPTUAL FRAMEWORK TO INFORM DATA COLLECTION AND ANALYSIS TOOLS FOR FOOD SECURITY AND NUTRITION

One of the main objectives of this report is to support more effective FSN decision-making, by providing guidance on the most appropriate ways to use and analyse data. In order to do this, it is necessary to, first, frame the many factors which influence FSN (and therefore determine which data are needed for decision-making) and, second, emphasize the data-informed decision-making process from a conceptual standpoint Drawing on previous work by the HLPE-FSN and others (Bronfenbrenner, 1979; HLPE, 2017, 2020), our conceptual framework illustrates how multiple levels of factors influence the food security and nutritional status of individuals and aims to help guide data collection and analysis. The conceptual framework can help define pathways to build evidence for decision-making through setting research priorities, with the goal of enhancing the FSN of individuals, households and communities.

One of the challenges for FSN is the complexity of the concept of food security. As noted by the HLPE-FSN:

> *The concept of food security has evolved to recognize the centrality of* ***agency*** *and* ***sustainability****, along with the four other dimensions of* ***availability****,* ***access****,* ***utilization****, and* ***stability****. These six dimensions of food security are reinforced in conceptual and legal understandings of the* ***right to food*** *(HLPE, 2020, p. xv).*

All six dimensions of food security and nutrition can be further understood/analysed by exploring their linkages to food systems, health systems and environment systems in a manner that is not entirely captured by existing conceptual frameworks for food systems (HLPE, 2020), food security (Kanter *et al.,* 2015) and nutrition (Black, Lutter and Trude, 2020). For example, agency and sustainability should be considered as they relate to all three systems (food, health and environment) to better understand how these dimensions shape FSN outcomes. An exhaustive review of the many existing frameworks regarding food systems, food security and nutrition is beyond the scope of this report. However, this chapter illustrates why a synthesis of different frameworks is necessary to provide a coherent conceptualization of the various systems and levels affecting food security and nutrition to inform data collection and analysis tools for policymaking.

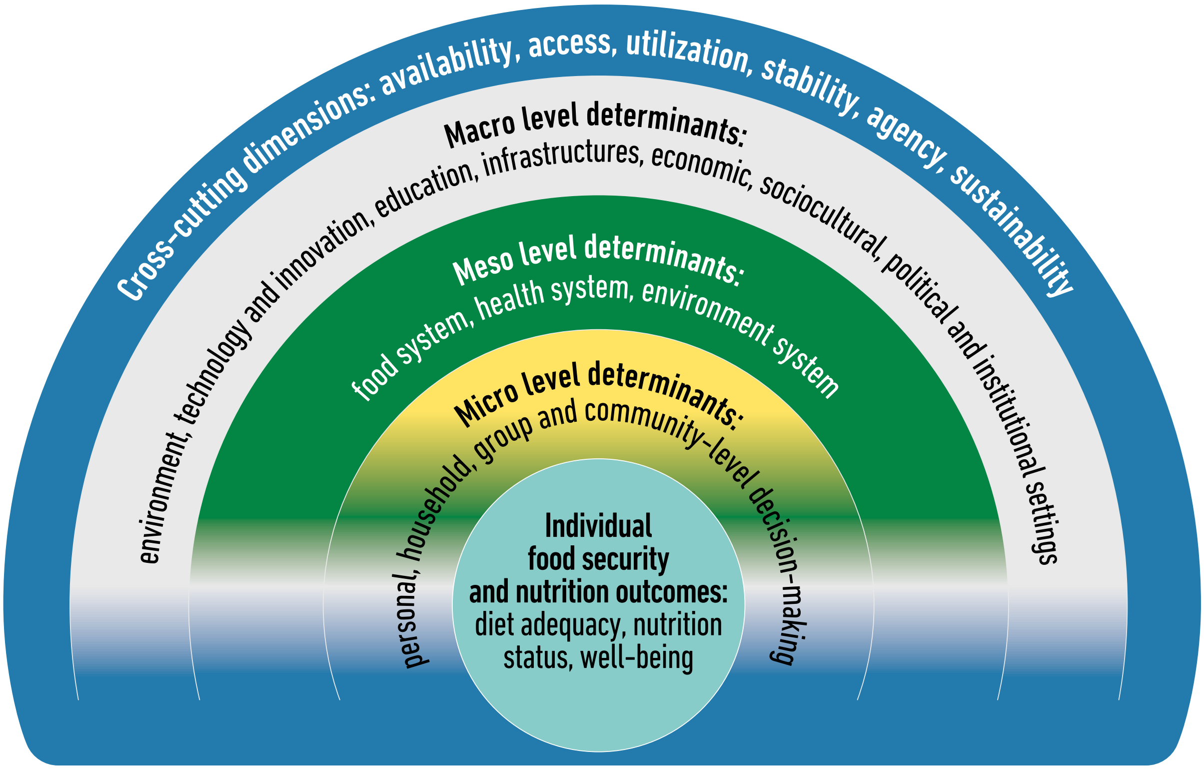
The HLPE-FSN *Sustainable Food System Framework* (2020) advances the understanding that many diverse drivers (e.g. environmental, technology and innovation, sociocultural) interact with both food systems and policy/ governance, which in turn influence food security and, ultimately, nutrition and health outcomes. However, it remains unclear how all food system components interact at different societal levels. To this aim, we elaborate on the HLPE-FSN (2020) framework by placing its overall components (drivers, systems and individuals) in a socioecological context (Bronfenbrenner, 1979). This framing permits a clear view of how the various elements that influence FSN operate at different, but interrelated, levels in a society, ranging from the more distal, macro-level, to the immediate, individual level. Embedding the socioecological context within our conceptual framework reveals how macro-level drivers contribute to shaping food systems at the meso level, and how meso-level systems include elements determined at the micro-level. For example, macro-level infrastructure (such as paved roads) and environment (global climate change, for instance) affect national (meso-level) food systems: the extent of paved roads influences how food is transported from place to place, and global climate change has myriad ramifications for national environmental shifts (such as extended droughts or extreme temperatures) that affect both agricultural production and the relevant infrastructures (including, for instance, greater need for cold storage). In terms of elements determined at the micro-level which impact the meso-level, the most obvious example are the many actors involved in food systems, from farmers and fishers, to intermediaries in charge of transport, to vendors – big (supermarkets) and small (local farmers' markets).

When combining solely the HLPE-FSN and socioecological frameworks, it becomes apparent that health systems and local environments, which are inextricably linked with both food systems and their subsequent impacts on human health and nutrition, are not sufficiently taken into consideration. For this reason, we added health and environment systems to the conceptual framework, which are not explicit in the HLPE-FSN Sustainable Food System Framework at the meso-level. Furthermore, macro-level drivers and meso-level systems do impact individual food security and nutrition outcomes independently; rather, they do so in concert and are interdependent. As expressed by UNICEF (1990), we emphasize the fundamental importance of resources (human, economic, organizational) and agency as basic elements of nutritional outcomes. In this regard, the meso level determinants influences the myriad of decisions that are made at the micro level, which lead to individual FSN outcomes. Thus, continuing to build on Bronfenbrenner's socioecological context, between the meso- and individual-levels of our framework, we have added the micro-level determinants, which reflects how meso-level systems impact individual FSN outcomes via decision-making processes. Finally, the concept of livelihoods as conveyed in the Sustainable Livelihoods Framework (SLF) (DFID 1999) inspired the addition of groups, alongside individuals and households, at the micro-level of the framework. In the SLF framework, the unit of analysis is an "identifiable social group", remaining nonetheless aware of the lack of homogeneity within communities and households (DFID, 1999 p. 7).

Leveraging elements in each of the four aforementioned inspiring frameworks, this report takes a **systems perspective**, recognizing the linkages between the various elements that form what can be termed the *food security and nutrition socio-ecosystem* (Bronfenbrenner, 1979).

Figure 1 illustrates this conceptualization by showing how the boundaries between macro, meso and micro level determinants are blurred and how all of them permeate down to the individual level, jointly contributing to determine food security and nutrition outcomes, such as individuals' dietary adequacy, nutritional status and overall well-being.

FIGURE 1:
FRAMEWORK FOR A SYSTEMIC VIEW OF FSN TO GUIDE DATA COLLECTION AND ANALYSIS



Source: Figure inspired by the HLPE-FSN Sustainable Food Systems Framework (HLPE, 2017, 2020), the UNICEF conceptual framework of the determinants of malnutrition (UNICEF, 1990), the socio-ecological model (Bronfenbrenner, 1979)(HLPE, 2017, 2020), the UNICEF conceptual framework of the determinants of malnutrition (UNICEF, 1990, 2021), the socio-ecological model (Bronfenbrenner, 1979), and the Sustainable Livelihoods Framework (SLF)(DFID, 1999).

Elements of macro-level drivers, such as, those related to climate, the environment and the educational systems within a country, permeate into more proximal levels, represented by local agriculture and food, health and environment systems, influencing them in different ways and at different levels of intensity. One example of the blurred boundaries between the macro- and meso-levels is the geopolitical environment, such as the role of war, armed conflict or civil disturbance, as a proximate driver of food insecurity. These proximal systems are fundamentally shaped by both public and private international and domestic economic and political actors (i.e. civil society, and public and private sectors). For example, public and private international trade and foreign investments related to food and agricultural production (particularly in logistics and infrastructure) have a direct impact on individual FSN though the availability and accessibility of products, despite being beyond the direct, immediate control of the individuals.

> *“In most societies today, the way in which citizens interface with the local food, health and environment systems – and thus contribute to determining their own food security and nutrition outcomes – is through personal, household, group and community-level decision-making and actions, all of which are conditioned by the data and information they have access to.”*

FSN drivers encompass macro-level constructs made up of many fundamental elements which can be grouped into the following categories: trends in FSN outcomes, as well as trends that are occurring in other domains that are drivers of food system change, including: biophysical and environmental; technology, innovation and infrastructure; economic and market; political and institutional; socio-cultural; and demographic. (HLPE, 2020). Environmental, sociocultural and economic determinants, including their externalities, are explicitly included in the macro level because these drivers are only implicit in the "sustainability" dimension of FSN. Taken together, macro-level drivers contribute to shape the more proximal food, health and environmental systems at the meso- level, which jointly determine the enabling environment – comprising availability, affordability, proximity, knowledge and practices related to food – for people to become agents of their nutrition. (HLPE, 2020; UNICEF, 1990).

Deciphering the micro-level or immediate determinants of FSN requires further discussion. For individuals to benefit from the flow of locally available goods and services related to FSN, decision-making must take place both individually and in groups, in coordination with their families and communities. At the micro-level, specific and different territorial settings exist within national and regional levels (e.g. rural areas with livestock, fishery areas), which present highly diverse potentials. Together with individual and collective agency, diverse areas shape the possibility to achieve food security and nutrition for those who live or work in these areas. It is at this immediate interface between the individuals, their local food and health systems and their local environments, that people's food security and nutrition is determined through myriad types of decision-making. This is still nested within, and thus influenced by, the ever-present macro-level determinants in a given society.

Finally, cutting across the four interrelated levels of our conceptual framework for FSN are the six dimensions of FSN: agency, stability, sustainability, access, availability and utilization (HLPE, 2020).

One notable challenge in the design of conceptual frameworks like the one discussed here is to incorporate the complexity deriving from the existence of competing views of life. Many Indigenous Peoples, for example, have a *biocentric* view of life (DesJardins, 2015) that differs radically from the *anthropocentric* approach conveyed in the conceptual framework, where human separation from nature is high, and human intervention is justified to actively attempt to regulate inputs of energy, nutrients, water and/or temperatures to favour production. In a biocentric view of life, ecosystems and their human and non-human co-inhabitants are intrinsically connected. Biocentrism underpins Indigenous Peoples' traditional knowledge, culture, language, values, spirituality and cosmogony, as well as their food systems (FAO, 2021), informing practices of food generation and production and natural resource management. The inclusion of the environment as a proximal and systemic determinant of FSN in our conceptual framework is intended to accommodate this and to allow for considerations related to how biocentrism underpins Indigenous Peoples' food systems.The conceptual framework provides guidance as to the different topics or themes data should encompass for a system approach to FSN data collection and analysis tools. Thus, the framework can be used to visualize potential impact paths and indicators at each societal level for FSN outcomes. The concentric circles in the conceptual framework are inspired by the aforementioned systems approach related to the socioecological model, and are *not* designed to convey a top-down approach that could result in overlooking the needs of local populations, including indigenous communities. On the contrary, the focus on the decision-making sphere at different levels grounds the framework in the human right approach, including for example the consideration of the right of Indigenous Peoples to self-determination, which includes the right to food as per the conjunction of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) (A/RES/61/295) and the International Covenant on Economic, Social and

Cultural Rights[8], by virtue of which Indigenous Peoples freely determine their political status and economic, social and cultural development. Consistent with the United Nations Declaration on the Rights of Peasants and Other People Working in Rural Areas (UNDROP), adopted by the UNGA in 2019 (A/RES/73/165), the framework provides for the inclusion of rural peasants and other local food system actors as important agents in FSN-related policy decisions.

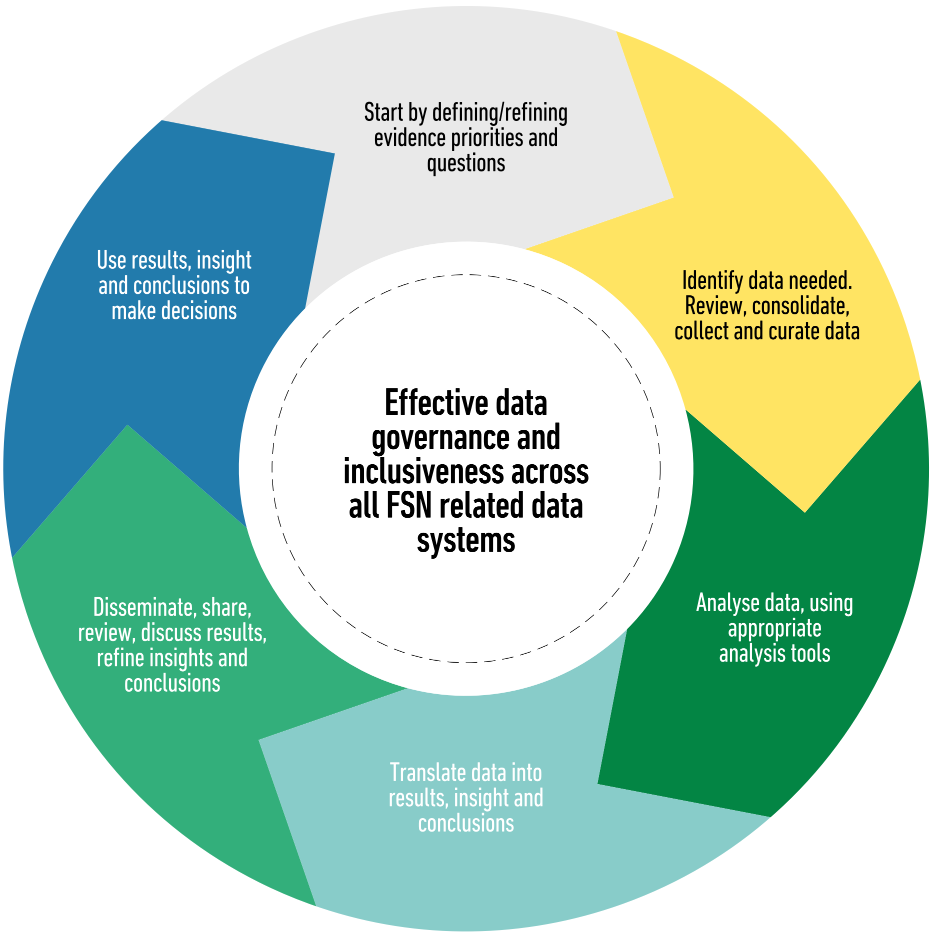
8 Adopted on 16 December 1966 by UN General Assembly resolution 2200A (XXI).

DATA-INFORMED DECISION-MAKING CYCLE

Because the conceptual framework does not provide insights on how priorities for data collection are decided upon, another critical conceptualization involves recognizing the steps needed to ensure more effective and efficient data-driven decision-making.

To this aim, we have adapted the data value chain from the Nutrition Data for Accountability and Action Framework (Piwoz *et al.*, 2019) to illustrate six critical stages in the process of data-informed decision-making for food security and nutrition (SEE FIGURE 2).

FIGURE 2:
DATA-INFORMED DECISION-MAKING CYCLE



Source: Adapted from Piwoz *et al.*, 2019.

Our data-informed decision-making cycle consists of six components. At the centre of the cycle is effective data governance and inclusiveness across all FSN-related data systems, as a fundamental prerequisite to carrying out each of the components in the cycle for improved data collection and analysis. Data governance is central because multiple sectors and stakeholders are needed across the steps, but these may vary from step to step and depending on the nature of the specific issue(s) being addressed. Many users of this data-informed decision-making cycle will be inclined to follow only some of the components. However, the components are presented in a cycle in order to clearly and concisely illustrate the sequence of steps from collecting raw data to ultimately using the information gleaned from this data to guide decisions related to FSN. We distinguish between defining and refining evidence priorities and questions as an essential first step in the cycle, regardless of how many components are subsequently performed. The data-informed decision-making cycle for data collection and analysis for FSN is, precisely, a cycle, rather than a linear sequence, because previously published evidence should be used to facilitate this first step of defining or refining evidence priorities and questions. Thus, as a crucial starting point, prior to any data collection or analysis, it is important to define a clear set of evidence priorities, in line with effective data governance and inclusiveness, and to identify focused questions with clear linkages to said evidence priorities. The evidence priorities and related questions will serve as a clear guide for the subsequent steps in the data-informed decision-making cycle.

The other components of this cycle are: the identification of the required data and the review and consolidation, or collection, of primary or secondary data and the curation of the data; the analysis of the data, using appropriate analysis tools; the translation of data into results, insights and conclusions; the dissemination of the data in order to share it , review and discuss the results, and refine insights and conclusions; and the use of the results, insights and conclusions to make decisions. Depending on the different actors or stakeholders involved, they may perform one or a few of these components, or they may perform all of them sequentially.

Ideally, evidence priorities should be defined though a democratic process involving the decision-makers and the beneficiaries. To guide the process, several considerations, including the concepts in the conceptual framework, should be considered, especially when working with Indigenous Peoples. Both decision-making and prioritization are influence by external factors beyond research agendas, such as the quality of existing data. Once the evidence priorities and related questions are clear, the next step is to review and consolidate any existing data on the topic. If necessary, new primary or secondary data can be consolidated with existing data and used with analysis tools. In many cases, it may not be necessary to collect new data, as it may suffice to organize the existing data in way that it is useful to answer the questions. In other cases, it may be more appropriate to either re-define the questions or use sound proxies based on available data. Once the existing data are organized, if the questions are still not satisfactorily answered, a plan to collect new data can be made. In order to ensure that the data can be effectively translated into results and that those results can be effectively disseminated (these being the next two steps in the cycle) it is extremely important to plan the collection of new primary or secondary data in accordance with both the evidence priorities and the FSN conceptual framework. Locally adapted data and information reduce the risk of one-size-fits-all solutions that can be detrimental to the well-being of Indigenous Peoples and the sustainability of their food systems, as have been observed during the COVID-19 pandemic (FAO, 2020, e-consultation).

Both existing data and newly collected data, be they quantitative or qualitative, will likely need to be transformed (at a minimum, cleaned) and analysed using analysis tools to address the initial objective and related questions. Both new and existing data should be entered into a data management platform to be stored and subsequently organized and analysed in a sensible fashion. Ideally, results and conclusions should be tested for accuracy and taking corrective measures; including field-testing when necessary and feasible and, if needed, corrective measures should be taken. Field-testing aids the ascertainment of the accuracy of the data and the research methods used. Ideally, all stakeholders should also be involved in field testing the results and related conclusions prior to disseminating the results and conclusions.

In the translation step of the data-informed decision-making cycle, the results are translated into meaningful information, designed with a specific audience or user in mind, in way that can eventually be disseminated and used. Data translation is necessary for data dissemination, but it is a separate step. This is why these steps are conveyed as separate components of the data-informed decision-making cycle. Translated data in the form of results should disseminated, reviewed and discussed to provide opportunities to refine insights and conclusions prior to the results being freely used and perhaps, misinterpreted. This process should include recognizing the strengths and limitations of the analysis. Therefore, dissemination is an important step in the cycle, which should be conducted before the results and conclusions are used by diverse stakeholders (including civil society and participants in the data collection process) for decision-making and new, related endeavours.

Ideally, the data, both in its crude and translated formats, and the related analysis tools, should be made available to users at any level of the conceptual framework, from the macro-level, through national-level policymakers, to those involved in the meso- and micro-levels, in group- and individual-level decision-making. The resulting data and results can, in turn, be used as input for subsequent, new, evidence priorities and related questions. It is for this reason that we refer to the data-informed decision-making process as a cycle and have conveyed it as such in Figure 2.

The data-informed decision-making cycle has a simple design; such that it can be adapted to any FSN objective and data type. It is important to acknowledge that this simple design does not negate the inherent complexities, such as bottlenecks, constraints and biases, in such a process. One of these complexities is the need to respect the traditional and customary institutions of Indigenous Peoples, who often maintain their own traditional governance systems. Under the framework of the right to self-determination, stakeholders who establish data-selection priorities must involve the traditional governance systems in the process of data collection and subsequent policymaking and implementation. The practical reality of utilizing a data-informed decision-making cycle such as the one presented here, includes a contested nature of data, the empirical reality of decision-making, and critical issues of power and voice in decision-making. The importance of strong coordination between actors in addressing bottlenecks and constraints, throughout the data-informed decision-making cycle, will be addressed in subsequent sections of this report.

USING THE CONCEPTUAL FRAMEWORK AND THE DATA-INFORMED DECISION-MAKING CYCLE TO ADDRESS ISSUES RELEVANT FOR FSN

To demonstrate how the theoretical guidance presented in the conceptual framework (Figure 1) can be overlaid with the methodological guidance presented in the data-informed decision-making cycle (Figure 2), we have constructed a matrix (Figure 3) showing how both of these can be used together to address evidence priorities and related questions relevant for FSN; with a particular aim of parsing the new data collection that would be necessary for such work. In this matrix, the column headers are the five main components of the data-informed decision-making cycle, after defining and refining the evidence priorities and questions, while the row headers are the levels in the conceptual framework.

FIGURE 3:
HOW TO STRUCTURE A DATA-INFORMED, DECISION-MAKING PROCESS MATRIX

	Data cycle phase				
Level	Review, consolidate, collect, curate, data	Analyse data using appropriate analysis tools	Translate data into results, insights, and conclusions	Disseminate, share, review, discuss results, refine insights and conclusions	Use results, insights, and conclusions to make decisions
Distal (macro)					
Proximal (meso)					
Immediate (micro)					
Individual (outcomes)					

Completing a data-informed decision-making process matrix that combines the levels in the conceptual framework with the phases in the data cycle is not an easy exercise, but it is a necessary one. This is because too often policies and programmes and related objectives (e.g. updating food-based dietary guidelines) are designed without considering all the levels of the conceptual framework, or used to initiate new data collection without a sound understanding of the existing data. As the six cross-cutting dimensions of food security are still new, related FSN polices, programmes and objectives have not yet been purposefully framed with these six dimensions in mind. When thinking about FSN policies, programmes and related objectives it is imperative to think about how the different types of users of data and analysis tools might interact with or be aware of such initiatives. It is for these reasons that we recommend those interested in designing or updating FSN initiatives work through the challenging exercise of completing a data-informed decision-making process matrix (Figure 3).

First, by identifying what data are available (and from where) at the distal level (for instance, national-level data on environment, technology and innovation, infrastructure, economic, socio-cultural, political, and institutional settings, education) one can identify which of the six cross-cutting FSN dimensions are captured, or not, in the identified databases. It is important to note that, for the matrix, *environment* is defined in the broad sense. Thus, environmental data can include data related to food availability (e.g. national fruit and vegetable yields) as well as national climate-related data that one might view being more related to the FSN dimension of sustainability. The proposal is to aim to identify data from as many of the distal drivers as possible, while also aiming to capture as many of the six cross-cutting dimensions as possible within these newly identified existing databases, if possible – all six of them.

Then we suggest continuing by reviewing and identifying the existing data for the subsequent levels in the conceptual framework – in other words, filling in the rest of the first column of the matrix. Thus, at the proximal level, within the country (i.e., at the provincial, district or municipal level) food system data related to availability and access that varies throughout a given country should be identified, especially because this variability will affect the sustainability of a given objective within a given country. Regional and municipal-level databases regarding health and environmental systems should also be identified, which may include identifying existing food- or health-related policies (such as food-based dietary guidelines). At the immediate level, identifying data related to the agency dimension (such as data on community groups that support community gardens) is important for the subsequent steps in the data cycle that are represented as columns in this matrix. The final step will be to determine which databases may be used to identify the individual outcomes related to the objective at hand (such as national health and nutrition surveys).

The subsequent columns in the data-informed decision-making process matrix are likely more challenging to fill out, but are important to think through, and thus, to complete, prior to executing a new policy or programmatic objective that would be inextricably linked with a budget or financial ramifications.

The second step in filling out the data-informed decision-making process matrix is to identify the most basic, or simple, analysis that can be done from the databases curated in the first column and to identify the appropriate analysis tools in which to do so. The process of identifying which analysis and analysis tools are necessary for the objective at hand serves two main purposes: 1) to identify which elements from the previously identified databases must be analysed (such as data on fruit and vegetable yields) and which analysis tools can be used for this purpose (e.g. any statistical software package that can rank values); and 2) to identify which analyses need to be conducted for which there is no existing data in the first column of the matrix (for instance, average distance between farmers' markets and homes), which may or may not serve as an impetus for new data collection, depending on our essential the data is with regard to the objective at hand.

The third step is to identify how the data identified in the first column of the matrix can be translated into results, insights and conclusions. At the distal level, how will the data identified in the first column be used. For example, will the data be used to inform a policy brief, inform new FSN intervention designs, or will it merely be used to identify important national gaps (for instance, in farmers' market coverage). At the proximal level, what types of variability can be identified in the data and, similarly, how is this variability related to the six cross-cutting dimensions? For example, does fruit and vegetable production vary regionally within a country and how will that affect the sustainability of the objective over the long term? Or how will global conflicts affect the national- or regional-level stability of food systems that has proximal impacts and ramifications for local food systems? At the immediate level, how can the existing databases be used to infer or anticipate municipal-level FSN actions (e.g. how should school feeding programmes incorporate regional, or more local, fresh products)? And, finally, what individual-level outcomes might be set as targets if the objective can be addressed according to plan (for instance, can individual-level fruit and vegetable consumption increase?). Just as the six cross-cutting dimensions need to be colour-coded in the first column, they should also be colour-coded in the subsequent columns, after the specific content in each column has been completed. Doing so will help the practitioner more easily identify whether the objective at hand really does tackle the six cross-cutting dimensions across levels and actors in FSN.

The task in the fourth column of the data-informed decision-making process matrix is to identify the actors related to both the six cross-cutting FSN dimensions and the originally identified objective. Thus, who are the stakeholders within the specific sectors related to macro-level determinants in the conceptual framework (i.e., environment, technology and innovation, infrastructure, economic, sociocultural, political and institutional settings, education); such as key stakeholders in the food system at the national level, as well as trade and industry and the education sector. At the distal level, these key stakeholders may be ministers, while at the proximal level the key stakeholders might come from related areas at the regional level. At the immediate level, it is important to identify the key stakeholders at the municipal level. Finally, in terms of individual outcomes, when thinking about how to disseminate, share, review, discuss results and refine conclusions and insights, think about how population disaggregated data, for example, might be used to propose new programmes aimed at improving individual outcomes, and how agency can be incorporated into user-centred design processes to improve individual outcomes related to the previously defined objective.

The last step in completing the data-informed decision-making process matrix is to identify how such (anticipated) findings in the third column (or data translation step) might be used to make related decisions. While the previous column focused on the related actors, the final column in the matrix focuses on what types of decisions (i.e., content) might be made based on the previously anticipated results and key stakeholders at each level. Thus, at the distal level, national-level opportunities for innovation could be made or national-level procurement programmes could be modified. At the proximal level, such decisions could include regional supply chain adaptations, industry incentives and penalties, and improved health sector messaging. At the immediate level, decisions are made at the local level, such as through the local health sector and local schools. And, at the individual level, decisions should be aimed at advocacy and coalition building.

The rest of this section will highlight one example of how such a matrix can be used to guide data collection and analysis in both a comprehensive and simple fashion. It is important to recognize that what follows is only one example to illustrate the utility in using both the conceptual framework and data-informed decision-making cycle to guide data collection and analysis tools. In the supplementary material we have included three additional examples that revolve around the following evidence priorities and questions:

- To identify needs for humanitarian food assistance for districts in Haiti using IPC as the data analysis tool.
- Does the existing evidence support a national school feeding programme mandated through policy that includes 10% of school food to include fish/seafood products from small-scale fisheries (SSF)?
- How to assess a sustainable healthy diet within a given local context?

Although, for the purpose of this report, the examples are being presented from one particular perspective, they are only illustrative examples and can be re-shaped through many different perspectives or country contexts.

Example 1: How to increase population-level fruit and vegetable (FV) consumption based on local FV supply chains?

As previously indicated, the first step to be undertaken, prior to data collection, is to identify evidence priorities and related questions, ideally. This example is based on the following question that could apply to any country: *How to increase population-level fruit and vegetable (FV) consumption based on local FV supply chains.* The matrix is used to respond to this question.

Once the question is framed, the first step is to review, consolidate and analyse existing data, identifying potential additional data that could be collected. In the first column of the table, we listed the types of data that we imagined might be useful for answering the question, also identifying data systems and sources for said data and indicating the levels (from distal to individual outcomes) to which those data apply. Basic suggestions regarding the specific data to analyse are presented in the second column, entitled Analyse data using appropriate analysis tools. The next question is, how will the specific data, such as fruit/vegetable yield and fruit/vegetable supply per capita be analysed? One suggestion is to use statistical packages to rank such data in order of fruit and vegetable with the greatest yield as well as compare with the greatest per capita supply. Perhaps in some countries the fruit and vegetable products with the greatest yield are not those with the greatest per capita supply as the high-yield products may be used primarily for exports. Such analyses comparing between and across levels are imperative to better understand how population-level fruit and vegetable consumption can be increased based on local fruit and vegetable supply chains. As a third step (in the third column) we listed the examples of the kinds of results, insights and conclusions that might be garnered from the data reviewed and/or collected, again, by differentiating the level to which they refer. In this example, data on FV availability, infrastructure and access could be incorporated into a policy brief (e.g. FAO and Ministry of Social Development and Family of Chile, 2021). In the fourth column, we included related examples of how said results, insights and conclusions might be shared or disseminated and with whom. Finally, in the fifth column, we suggest how the information disseminated might be used to facilitate (or not) the development of a policy related to the question prioritized from the outset. When applicable, all information entered in the matrix was colour-coded according to the primary FSN dimension of the cross-cutting FSN dimensions. It is important to note that each stakeholder has different objectives, or priorities; as well as related indicators of success or failure that may occur at each step of the data cycle, or in the case that not all steps are followed, in relation to the specific data cycle steps performed by a respective stakeholder. In many countries, the conclusions from this type of question are different per stakeholder. For example, the interests of the Ministry of Health are different from those of the Ministry of Agriculture, which might be more interested in agro-export, as those from the Ministry of Education can differ from those of the Ministry of Finance.

As alluded to in Section 1.1, data comes in many flavours and – as will be mentioned in subsequent sections – multitudes of resources, both human and financial, as well as appropriate institutional arrangements, are necessary for data collection. The goal of this report, however, especially in terms of what follows, is to provide guidance for many FSN stakeholders, independent of their knowledge or expertise, to understand how both data collection and analysis tools can be more efficiently utilized, including, in some cases, through innovative techniques and technologies. Taken together, the conceptual framework and the data-informed decision-making cycle are meant to be used in tandem, while thinking about existing data (Chapter 2). And with regard to the collection or consolidation of new and existing data for FSN outcomes, given both the disadvantages (constraints in Chapter 3) and advantages of new digital technologies (chapter 4); while always being aware of the central role of effective data governance (Chapter 5).

FIGURE 4:
EXAMPLE OF HOW TO USE THE CONCEPTUAL FRAMEWORK (THEORETICAL GUIDANCE) AND DATA-INFORMED DECISION-MAKING CYCLE (METHODOLOGICAL GUIDANCE) FOR FSN

Level in the conceptual framework	Action along the data cycle: Review, consolidate, collect, curate data	Analyze data using appropriate analysis tools	Translate data into results, insight and conclusions	Disseminate, share, review, discuss results, refine insights and conclusions	Use findings to make decisions
Distal (macro)	-Vegetable yield and Losses of vegetables and fruits (data system: Food Systems Dashboard; Databases: FAO; Ministry of Agriculture Databases)	-Rank vegetable yield and Losses of vegetables and fruits by type	-Incorporate data on FV availability, infrastructures, and access into a policy brief (e.g. the FAO Policy Brief on Promoting Fruit and Vegetable Consumption (available here: https://www.fao.org/documents/card/es/c/cb7956en)	-Engage key stakeholders: food system, trade and industry, social protection, health sector to design political actions (i.e. policies and/or programmes) to promote FV consumption	-FV innovation opportunities based on culturally appropriate and sustainable recipes
	-Databases on FV infrastructure (e.g., transport/trip duration-talk to country-level experts)	-Determine if sufficient FV infrastructure for local supply chains	-More interventions should be implemented to promote FV consumption, especially in early life		-Adaptations to procurement programme efforts/ new policies related to school feeding programmes
	-Average distance of homes to farmers markets	-Determine average distance of homes to farmers' markets (nationally)	-X% of municipalities do not have multiple farmers' markets		-School-based diet and health campaigns (e.g. to shift preferences to FV consumption, such as "Let's Move!" (*) or Jamie Oliver's Learn Your Fruit and Veg Programme and Jamie Oliver Food Revolution Campaign)
Proximal (meso)	-Per capita supply of FV (data system: food systems dashboard)	-Determine regional per capita supply of FV	-FV production varies regionally within a given country	-Engage key stakeholders: food system, food industry, health sector, actors who can identify regional FV access to be able to refine insights and conclusions	-Supply chain adaptations (e.g., cold storage) -Industry incentives and penalties -Health sector to reinforce messaging -Revise food composition databases -Revise and adapt food safety guidelines
	-Prices and trends (data system: https://ourworldindata.org/food-prices)	-Regional FV prices and trends	-Global conflicts and pandemics affect stability of global supply chains, which support the need to leverage local FV production		
	-Existence of food-based dietary guidelines (database: Nourishing database)	-Analyze regional means of dissemination of food-based dietary guidelines (if applicable)	-Are all fresh FV safe to eat?		
	-Average distance of homes to farmers' markets	-Determine average distance of homes to farmers' markets (regionally)			
Immediate (micro)	-Number of farmers' markets per municipality	-Rank municipalities by number of farmers' markets	-School feeding programmes should incorporate more locally/ regionally or nationally procured FV	-Engage key stakeholders at regional and local level: regional and/or municipal governments, regional and/or municipal school programmes	-Local health sector to reinforce messaging -Messaging at schools FV incentives
	-Community groups that support community gardens and local FV distribution	-Analyse gaps in existing community groups			
Individual outcomes	-Individual FV intake (National Nutrition and Health Surveys)	-Analyse individual FV intake in terms of % FV portions per capita per day	-Individual FV intake should increase by at least one serving per capita per day based on new interventions and/or policy programmes	-Population disaggregated data essential to understand issues and propose solutions, such as the EU school fruit and vegetables programme -The user-centred design process in community garden initiatives	-Data used for advocacy, and to raise awareness of issues and relation to dietary intake of FVs

(*) https://letsmove.obamawhitehouse.archives.gov/(*) https://letsmove.obamawhitehouse.archives.gov/
(**) https://www.thegoodfoundation.com.au/courses/jamie-olivers-learn-your-fruit-and-veg-online/
(***) https://www.jamieoliver.com/campaigns/(***) https://www.jamieoliver.com/campaigns/

Legend colour-coded six dimensions of food security:
- Agency (orange)
- Short-term stability (purple)
- Long-term sustainability (asparagus green)
- Access (dark blue)
- Availability (periwinkle)
- Utilization (dark grey)

Chapter 2

A REVIEW OF EXISTING FSN DATA COLLECTION AND ANALYSIS INITIATIVES

PHILIPPINES, 05 July 2018, Development of an Enhanced Production and Risk Management in Agriculture Integrated Decision Support System (EPRiMA).

The conceptual framework for this report (Figure 1) highlights the multiple levels and systems relevant for tracking progress and informing actions for better FSN decision-making. The myriad types of data that may be relevant at all levels for the different decision-makers is an important challenge for FSN. A comprehensive review of all existing data would be a monumental task indeed and beyond the scope of this report. Here we focus instead on an illustrative review of some of the main frameworks, data systems and repositories that hold data relevant for FSN (summarized in Annex Table 1). Each of the listed data repositories and initiatives has been designed for a specific purpose or set of purposes. Considering the multiple sectors and topics implicated in the conceptual framework, It is no surprise that no single system currently exists that contains all types of FSN-relevant data, as it is difficult to imagine how such a system could ever exist.

In this chapter we have two main objectives. The first one is to provide an overview of FSN-relevant data, discussed with reference to the conceptual framework (Figure 1) and linking them to the relevant FSN dimension. The illustrative overview of data sources will provide a sense of the wealth of FSN-relevant data that is available and will also help to highlight remaining gaps in data generation. The second objective is to draw from this overview a list of gaps and challenges at each step of the data cycle and highlight good practice examples of how they have been addressed in on-going efforts.

ILLUSTRATIVE OVERVIEW OF EXISTING FSN DATA

As reminder, the distal-level factors relevant to FSN are those that are far removed from the sphere of influence and control of the individual. They may be global in perspective (e.g. the extent of integration and functioning of international food commodity markets), regional (e.g. regional food trade arrangements), but also national (e.g., political structures) or even local (e.g. sociocultural norms related to gender and land tenure). They influence factors at the meso level (e.g. food systems), which in turn influence factors that are more immediately in the sphere of inference and control of the individual (e.g. community markets, and household behaviours).

FSN DATA AND INFORMATION SYSTEMS RELEVANT AT THE DISTAL (MACRO) LEVEL

The top row of Annex Table 1 lists data on elements that are distal influences on FSN. These include the **natural resource base** used for agriculture and food production, **climate and the global environment**, the extent of integration and functioning of **international**

food commodity markets. As noted, several of these elements cover ground that goes beyond individual countries. For such data, therefore, strong international coordination is critical to ensure comparability, transparency and similar considerations. International organizations play a crucial role in supporting and enabling such efforts.

Data and information on distal factors that may influence *food availability* include natural resource use (mainly land, water and fisheries), input use, agricultural production and food trade. Large amounts of data covering these aspects are available, mostly housed in the statistical system of the Food and Agriculture Organization of the United Nations (FAO) (SEE BOX 1).

BOX 1:
FAO STATISTICAL SYSTEM

Coordinated by the Office of the Chief Statistician and operated by various departments, FAO regularly compiles data reported by Member Nations (e.g. official national statistics, agricultural or population censuses and surveys, etc.) and from other sources (such as international commodity market reports) related to all aspects of agriculture and food. Statistical activities fulfil the objective to provide open access data and information, reflecting one of the foundational components of the Organization's mandate.[9] FAO statistical activities involve the compilation, curation and dissemination of data; the development and promotion of rigorous statistical methods and standards; and statistical capacity development for member countries (FAO, 2020a).

The FAO Statistics Division manages the Organization's system of food and agriculture statistics, compiling from different sources, with the explicit aim of covering almost all countries and territories in the world. Data are used for global purposes (including the development of statistical yearbooks covering food security and nutrition, crop and livestock, and economic, social and environmental statistics), but also at national and regional levels. Statistics are disseminated through two major dissemination platforms: FAOSTAT and the Rural Livelihoods Information System (RuLIS).

FAOSTAT food and agriculture data is the largest and oldest repository of data and information on food and agriculture in the world. In its latest configuration, it includes eight different domains covering (a) statistics on crop, livestock and food production and trade; (b) agricultural and rural economic statistics; (c) environmental statistics; (d) food security and nutrition; (e) social statistics; (f) data and statistics derived from censuses of agriculture; (g) data and statistics derived from agricultural surveys; and (h) statistical methodological innovations.

FAOSTAT aims provide harmonized data and statistics that are comparable across time and space. The system is designed to facilitate extraction of time-series of variables for the 245 countries and territories, but also for groups of countries, entire regions, and at the global level.

FISHSTAT, managed by the Fisheries and Aquaculture Division, provides open access to fisheries and aquaculture data covering 245 countries and territories. It comprises 9 different data domains covering all aspects of the fish products value chain: from aquaculture production and fisheries' capture to information on the global trade, processing and distribution of fish and fish products. It also publishes statistics on employment in fisheries and fish farms and the size and characteristics of the fishing fleets.

AQUASTAT, another global FAO database, contains information on water use in agriculture throughout the world, which is fundamental for food availability and sustainability considerations. This database also provides data and information for individual countries, regions or at the global level.

9 In defining the functions of the organization, Article 1,1 of the FAO Constitution includes the following: "The Organization shall collect, analyze, interpret and disseminate information relating to nutrition, food and agriculture" (FAO, 1945).

Data at this level may also be important for considerations related to *food access*, given the importance of international trade and the links between international and domestic prices, particularly for staple cereal grains and cooking oils. The food price crisis of 2007-08, for example, revealed how the lack of data transparency may compromise the efficient operation of international commodity markets, leading to instability and price shocks. This spurred a series of initiatives aimed at increasing coordination and transparency within international food commodity markets, including the commitment of the Members of the Organization for Economic Cooperation and Development (OECD) to disclose the information on public stocks held of major food commodities (wheat, maize, rice and soybean). Such information is crucial to understanding the implications of international food price movements for food security. This led to the creation of the Agricultural Market Information System (AMIS) (Box 2), a tool that has proven extremely useful to reduce tensions in international food markets and contributed information on food security *stability*.

BOX 2:
THE AGRICULTURAL MARKET INFORMATION SYSTEM (AMIS)

The Agricultural Market Information System (AMIS) is an interagency platform to enhance food market transparency and policy response for food security. It was launched in 2011 by the G20 Ministers of Agriculture following the global food price hikes in 2007/08 and 2010. Bringing together the principal trading countries of agricultural commodities, AMIS assesses global food supplies (focusing on wheat, maize, rice and soybeans) and provides a platform to coordinate policy action in times of market uncertainty.

By enhancing transparency and policy coordination in international food markets, AMIS aims to provide timely information on the state of the main food commodities traded on international markets. This is useful to anticipate and prevent possible tensions, reduce price uncertainty and, thus, strengthen global food security.

AMIS comprises G20 members, Spain and seven additional major agricultural commodity importing/exporting countries.

To carry out its functions, AMIS consists of:

- the Global Food Market Information Group, which assembles technical representatives from AMIS participants to provide reliable, accurate, timely and comparable market and policy information;
- the Rapid Response Forum, comprising senior officials from AMIS participants, which promotes early discussion about critical market conditions and ways to address them; and
- the Secretariat, involving ten international organizations and entities, which produces short-term market outlooks, assessments and analyses and supports all functions of the Information Group and the Forum.

A very important contribution of existing international data systems to FSN is the information provided on environmental *sustainability*. The environmental statistics domain in FAOSTAT, for example, publishes estimates of emissions from crop and livestock production, emissions and removals from land use, land use change and fossil fuel energy use, at the country, regional and global levels.

Closely related to sustainability is the biodiversity of an agroecosystem, the monitoring of which is required to improve management practices in food production systems for ecological health

(Gemmill-Herren, 2020). The Agrobiodiversity Index (ABDI) tool is used to collect data, in order to provide stakeholders, businesses and policymakers with information about consumption and markets, production systems and genetic resource conservation. However, there is a lack of globally consistent data for several vital components of agrobiodiversity, including consumption, production and less reliance on local and wild species. Therefore, shared international data collection, detailed analyses and reporting systems are required to help fill critical data gaps (Jones *et al.,* 2021).

This illustrative review shows that there is indeed a wealth of information relevant to the *availability, access, stability* and *sustainability* dimensions of food security at the distal level. It highlights the critical importance of data *harmonization* to permit comparability over time and across context, as well as data *transparency*. Substantial progress has been made with regards to both, as illustrated in the FAOSTAT and AMIS examples. There are, however, important ongoing limitations. Much of the food and agriculture data remains at highly aggregate level (i.e., national level), which is understandable given the cost and complexity of collecting disaggregated data (for instance, through farm and population surveys).

Particular fundamental areas of FSN where lack of sufficient data is especially relevant include, the impact of pests, natural calamities, conflicts or other shocks on food security and nutrition. (SEE BOX 8).

Another area where granularity of data is crucial is that of meteorological and soil fertility data. These data have important implications for drought monitoring and early warning regarding possible risks to local food availability. When meteorological data are available, those derived from ground-based stations may record variables such as rainfall, temperature and wind, but not more technical measures such as humidity and solar radiation. This may lead to significant data gaps and inaccuracy. Earth Observation (EO) climate data products, based on broad hydrometeorological monitoring tools such as Global Land Data Assimilation System (GLDAS), can fill gaps by substituting missing data and generating data sets (Colston *et al.,* 2018). However, these data disaggregated by agroecological zones are largely lacking.

Overall, this is an area where more granular, georeferenced data collected through different means and technologies (such as the Google earth engine), holds great promise (see further discussion of technologies in Chapter 4).

FSN DATA AND INFORMATION AT THE PROXIMAL (MESO) LEVEL

The structure of the agriculture, food, health and other related sectors have strong implications for food security and nutrition. National food and agricultural data (on food supplies, prices and inflation, for instance) and the structure of national food supply chains, among other factors, shape the social and economic environment in which citizens live and operate and are vital to inform most dimensions of food security at the meso level, including availability, access, stability and sustainability. Ideally, such data should be included in national official statistics, regulated in most countries by national statistical laws and coordinated by national statistical offices (NSOs). Despite efforts, there are still gaps and notable differences among countries in this regard. The *timeliness*, *completeness* and *quality* of official statistics on agriculture, fisheries and other sectors of relevance to food security and nutrition, is still largely insufficient in many low- and middle-income countries (LMICs). According to the latest FAO assessment for example, 92 countries have not conducted an agricultural census in the last ten years, 52 of which have not done so in the last 20 years (Annex Table 3). Ten of these countries (including Cuba, Ukraine and South Sudan) have no agricultural census on record at all. This is particularly problematic in terms of updating and refining food and agriculture policies, considering the rapid transformation of the agricultural sector in most LMICs. Paramount among the gaps in information is the lack of availability of agrifood data and statistics. Globally, annual agricultural survey data are available approximately for 60 percent of the countries (Committee on World Food Security, 2021). The availability of data to compute indicators of productivity and income of smallholders, of food loss, food waste and secure right over agricultural land is currently sufficient for less than 4 percent of the countries (Committee on World Food Security, 2021). There is also a lack of improved agricultural forecasting and other techniques that can augment traditional agricultural surveys. For developing countries, this poses a huge challenge, as agriculture and food production data are important to understand the links between food security, livelihoods and poverty (Committee on World Food Security, 2021). Gaps also exist, for example, in understanding the contribution of fisheries and aquaculture to FSN and the sustainability of these operations (SEE BOX 3).

BOX 3:
IMPROVING THE ANALYSIS OF FISH DATA

Several studies (see Hicks *et al.,* 2019 and Vaitla *et al.,* 2018) have highlighted the potential importance of fish as a source of micronutrients, especially in middle- and low-income countries. Despite this, little information is available regarding the nutrient values of fish.

To fill this data gap, GitHub (2022) developed the Fishbase Nutrient Analysis Tool, a Bayesian hierarchical model that uses both phylogenetic information (which considers the relationships between fish species) and trait-based information (which considers key aspects of fish diet, thermal regime and energetic demand) to estimate the concentration of calcium, iron, omega-3, protein, selenium, vitamin A and zinc in marine and inland fish species. The FishNutrients component of Fishbase estimates the specific nutritional content of a vast array of aquatic species caught around the world (see https://www.fishbase.in/Nutrients/NutrientSearch.php).

While recognizing the potential of fish as a source of key nutrients, FAO also recognises the need to monitor the sustainability of fishing activities. In an effort to address the sustainability of fishing, FAO has developed a definition for illegal, unreported and unregulated (IUU) fishing – a broad term that captures a wide variety of fishing activities. IUU fishing is found in all types and dimensions of fisheries and is reported to occur both on the high seas and in areas within national jurisdiction (https://www.fao.org/iuu-fishing/background/what-is-iuu-fishing/en/).

Several initiatives aim to further our understanding of the sustainability of global fishing activities, their yields and their contribution to livelihoods. Illuminating Hidden Harvests is an upcoming FAO, WorldFish and Duke University study that seeks to quantify and standardize the immense contribution of small-scale fisheries to global fishery yields and livelihoods: https://sites.nicholas.duke.edu/xavierbasurto/our-work/projects/hidden-harvest-2/.

Another initiative, the Global Fishing Watch platform, is being designed to enable the use of multiple open-source technologies and data sources to evaluate and manage fisheries: https://globalfishingwatch.org/news-views/mapping-a-new-world/.

Some of the data gaps are partially filled by efforts led by international organizations or other institutions, mostly operating in high-income countries, which collect country-level information to guide their operations and make their data and information available for other uses. Particularly relevant in this area are the Global Information and Early Warning System (GIEWS) on food and agriculture, managed by FAO; the activities coordinated by the Vulnerability, Analysis and Mapping (VAM) team at the World Food Programme (WFP) and those of the International Production Assessment Division (IPAD) of the Foreign Agricultural Service (FAS) at the U.S. Department of Agriculture (USDA) (SEE BOX 4). Through their data dissemination portals, these initiatives make available country briefs, country profiles and other periodic reports on crop production and forecasts, food prices and food security. Extremely important in his context is the timely information on local food prices available through the GIEWS Food Price Monitoring and Analysis portal, which contains the latest available information and analysis on the domestic prices of basic foods in developing countries.

BOX 4:
GIEWS AND OTHER INFORMATION SYSTEMS

FAO's Global Information and Early Warning System on Food and Agriculture (GIEWS) continuously monitors food supply and demand and other key indicators for assessing the overall food security situation in all countries. It issues regular analytical and objective reports on prevailing conditions and provides early warning of impending food crises at country or regional level. At the request of national authorities, GIEWS supports countries in gathering evidence for policy decisions or planning by development partners, through its Crop and Food Security Assessment Missions (CFSAMs), fielded jointly with the WFP. Through the use of tools for earth observation and price monitoring at the country level, GIEWS also strengthens national capacities in managing food security-related information.

To guide its operations, the WFP requires large amounts of data, some of which is accessible to others through "DataViz", a web-based platform (see https://dataviz.vam.wfp.org/).

The International Production Assessment Division of the Foreign Agricultural Service at USDA offers a rich set of data products, including reports and brief, geospatial data, crop calendars and production maps, easily accessible through their web portal at https://ipad.fas.usda.gov/Default.aspx.

Though very useful, these initiatives should not substitute national data systems, and efforts should be made to ensure they are fully "owned" by national governments and to avoid that they crowd out national capacities. To that end, the United Nations Statistics Division plays an important role developing standards and norms for statistical activities and supporting efforts to strengthen national statistics systems in many countries. It must be noted here that the continued evolution of data technologies is rapidly changing the information landscape on crop production conditions, yield forecasts, etc. (see further discussion of data-related technologies in Chapter 4), allowing for much more frequent and rich data generation. However, this trend widens the divide that already exists between LMIC and high-income countries (Kitchin, 2014a; 2021). Notable efforts to fill these gaps are ongoing. FAO's Hand-in-Hand Initiative (Box 5) supports national policymaking by facilitating easier access to relevant geospatial and other disaggregated available data on all dimensions of agriculture and FSN. The 50x2030 initiative aims to close the food and agricultural data gap in 50 countries (Box 6). An additional initiative, the Global Strategy to improve agricultural and rural statistics, a large technical support and capacity development programme established in 2015 with important implications for data governance, is discussed in Chapter 5.

BOX 5:
FAO HAND-IN-HAND INITIATIVE

The FAO Hand-in-Hand Initiative (HiHI) was launched by the FAO Director-General in September 2019. FAO Member Nations expected to be facing challenges(*) were invited to participate in this initiative, which aims to accelerate agricultural transformation and sustainable rural development, through an evidence-based, country-led and country-owned process supported by FAO. As of today, 48 countries have joined.

The initiative is designed as an inclusive process that builds partnerships, alliances and synergies among public and private sectors, and with international development partners. The objective is to identify investments that could have the highest impact on agrifood system and rural transformations and to achieve SDG goals of eradicating poverty and hunger and reducing inequalities. It aims to channel resources – technical, financial, institutional and human – to where they are needed most and where the potential for reaching the SDG 1, SDG 2 and SDG 10 targets is greatest.

Data are at the core of HiHI. Situation analyses needed to identify intervention opportunities in areas with high levels of poverty and malnutrition and extensive inequalities may call for complex analyses on cross-domain data, aggregating and enriching existing information from geospatial and socioeconomic data, as well as information gathered from non-conventional sources. HiHI emphasizes timely information and sophisticated analysis of data on biophysical phenomena and agroecological and livelihood conditions, at all levels – from highly aggregated global data to the most granular local data. This requires analytic tools and capacities that do not exist yet in all participating countries. To support these situation analyses, HiHI offers its Geospatial Platform, described as the world's largest and most capable platform for geospatial data and information exchange and analysis (https://www.fao.org/hand-in-hand/en/). The platform brings together over 20 technical units from multiple domains across FAO, from animal health to trade and markets, integrating data from across FAO departments focusing on soil, land, water, climate, fisheries, livestock, crops, forestry, trade, social and economic statistics, among others. In addition, the platform continuously and increasingly integrates vast amounts of georeferenced data in specialized domains (maritime food trade, climate risks and other vulnerabilities for small island developing nations and other at-risk nations) gathered from partners in academia and other public and private entities, making them available free of charge to users at large.

Another initiative, the Data Lab for Statistical Innovation supports HiHI by addressing specific challenges related to timeliness, granularity, data gaps and automation of analysis for faster in-depth analyses. To achieve these objectives the Data Lab:

- promotes the use of non-official, unstructured data and data science methods to fill in data gaps in domains and geographical areas where official data is scarce;
- validates official data reported by countries in order to identify areas of future collaboration and technical assistance;
- identifies relevant data sources and appropriate analysis techniques to produce evidence and build insights;
- develops geospatial tools and tagging systems at subnational level, to increase data granularity, especially in tropical and dryland areas where the most vulnerable populations live;
- builds data systems for HiHI that will facilitate the identification of target areas and highlight aspects of their agricultural potential;
- provides tailored text-mining tools to extract, summarize and categorize information on effective policy interventions that can be applied in similar situations.

Note: (*) Eligible countries include countries classified as Least Developed Countries (LDC), Landlocked Developing Countries (LLDS), Small Island Development States (SIDS) and countries included in the group of Food Crisis Countries covered in the Global Report on Food Crises.

BOX 6:
THE 50 × 2030 INITIATIVE TO CLOSE THE AGRICULTURAL DATA GAP

The 50 × 2030 initiative to close the agricultural data gap was launched in 2019 by FAO, IFAD and the World Bank to improve country-level data in 50 countries in Africa, Asia, the Middle East and Latin America by 2030, by building strong nationally representative survey programmes. Depending on the conditions in each country, this may take some time. But while new data are being generated, it is also important to demonstrate the usefulness of this information by making the best possible use of the available evidence from farm surveys, even if scattered, including by integrating existing data with data and information from other sources, or by devising creative ways of analysing the data. The 50x2030 initiative builds on the Global Strategy to Improve Agriculture and Rural Statistics (GSARS), and promotes research, for example by offering data research grants to local researchers.

FSN DATA AND INFORMATION AT THE IMMEDIATE (MICRO) LEVEL

There are essentially two types of data and information relevant to FSN at the immediate level – *supply-side data* and household level *demand-side data*. Data and information on the supply side should address dimensions of food availability, stability, sustainability and accessibility (to the extent that they include food prices). A variety of sources of such data are needed at the immediate level including farms; fisheries; production, processing and distribution operations; retail distributors and restaurants. These may be local or regional businesses (from micro- to large businesses) or local affiliates of national or multinational companies. Immediate-level data on these dimensions of FSN would capture some elements of the food environment, which has been described in previous HLPE-FSN reports (HLPE, 2017; 2020) as the point of interaction of the individual with the food system. The analogy is not perfect however, even for what has been described by some as the external food environment (availability, price, market and vendor properties, and marketing and regulation related to food) (Turner *et al.,* 2020). In our conceptual framework, marketing and regulation, for example, would sit at the proximal or even distal level as it may have an influence on availability, price and market and vendor properties.

Regardless of whether the food environment framing is used or not, there are enormous gaps in the availability of FSN-relevant data at the immediate level (Turner *et al.,* 2020). Key among these are data on the operation of local markets. The highly diverse local and national food markets that are embedded in territorial food systems have been defined by the Committee on World Food Security (CFS) as *territorial markets* (CFS, 2016). Despite their importance in linking food supply and demand at the territorial level, data on territorial markets are seldom included in national data collection systems (FAO, 2022; CSM, 2016; CFS, 2016), a gap that FAO is trying to fill with a recent initiative (SEE BOX 7).

BOX 7:
FAO'S APPROACH TO MAPPING TERRITORIAL MARKETS

To address the evidence gap in the contribution of territorial markets to food availability and to other factors that may influence consumers' food purchasing and consumption, in 2017, FAO, together with several academic and civil society organizations, began developing a methodology for the collection of reliable and comparable data on territorial markets (FAO, 2022). The methodology consists of a set of guidelines and questionnaires for consumers and for retailers, and uses a harmonized approach for collection and analysis that permits comparisons across contexts and over time. It is designed to inform policy and market-level interventions aimed at improving the food offering (from nutritional, safety and environmental perspectives) of the market environment and fostering healthier food choices among consumers.

Based on existing evidence at the time, the expert group developing the methodology identified several key aspects of markets, retailers and consumers that should be captured through the questionnaires: (i) women retailers' inclusion in markets http://www.fao.org/3/a-i3953e.pdf; (ii) enabling/disabling aspects of the business environment; (iii) length of the supply chain; (iv) food diversity; and (v) contribution of the market to healthy and diversified diets. The main criteria used to identify these aspects included: their degree of influence on the foods on offer and on consumer choice and their degree of influence on market inclusivity and responsiveness to interventions. These aspects are represented by five multidimensional and synthetic indicators, which were created as part of the methodology, in order to evaluate market performance on these particular aspects.

The methodology has been piloted in two countries, one in Africa and one in Latin America, and implemented in six additional countries. To date, data has been collected on 60 markets and is available on FAO's Hand-in-Hand geospatial platform. In each country, the mapping process followed the same steps: 1) joint selection of the markets by stakeholders and policymakers, based on the perceived relevance of these markets for the local communities; 2) adaptation of the questionnaires for the local context; 3) training of enumerators, including a field trial of the questionnaire; 4) data collection; 5) data processing and analysis; 6) reporting on the findings; and 7) a final validation workshop focusing on reviewing the findings to understand whether they resonate with current knowledge, and exploring the potential implications of the findings for policy and programmatic interventions to promote healthy food market environments and healthier food choices among market consumers. For the data collection itself, a user-friendly, open-source questionnaire (the KoBoToolbox, adapted for online and offline use), was developed to aid in standardized data collection and analysis approaches.

Another area in which data is lacking is the extent of food losses along the supply chain, which has important implications for food security and nutrition policy (FAO, 2019a). Data relating to the food systems such as consumer behaviour and its drivers, impact of household interventions to reduce food water/loss for instance, food-utilization data or dietary diversity data are notably scarce (Committee on World Food Security, 2021; Deconinck *et al.,* 2021).

There are important challenges to improving the availability of these data, including no consensus on key data types needed and, therefore, no *harmonization* of data standards; no repository into which such data are regularly channelled; and little to no incentive for businesses to publicly share data related to local production, price, sales, market characteristics and other relevant aspects. With regard to the concept of a food environment, this continues to evolve and there is still little clarity of the core constructs for which data are required to inform FSN policies and programmes. In the area of food losses and waste, countries may need to ensure cost-effective data generation, improve the reliability of existing data by benchmarking international standards in terms of methods and metadata, enhance the accessibility of information for policymaking and encourage transfer of innovative practices among countries and improve transparency (Fabi *et al.,* 2021). Unfortunately, no examples could be found of good practices from a country, region or globally in addressing these challenges.

The other type of data at the immediate level – framed as demand-side data – includes data generated at the household level. These data may capture the FSN dimensions of accessibility, utilization and even agency, provided they are appropriately designed. It may include relevant data on food purchases, gifts and home production; income; assets and social protection benefits; but also water; sanitation; health services and many other aspects relevant for FSN. Most of this data comes from population-based surveys. As such, the collection of such data tends to be *resource-intensive* and has been plagued by a lack of stability in the availability of resources needed to maintain the data up-to-date. Infrequent data impedes the adjustment of policies based on changing circumstances of the population. Data-related technologies and big data are rapidly evolving and may help change this in some contexts. (This is discussed further in Chapter 4).

As discussed previously, granularity and disaggregation at the subnational level is also a challenge in many contexts given sample size and thus, resource implications to implement sufficiently large population surveys. Several standardized survey platforms collect relevant data at this level, including income and budget surveys, household consumption surveys, Living Standards Measurement Surveys (LSMS), Demographic and Health Surveys (DHS) and Multi-Indicator Cluster Surveys (MICS), among others. These have done much to overcome different barriers, including data harmonization and the provision of technical support to countries where capacity gaps exist.

The recent proposal to include agency as one of the dimensions of FSN has an immediate application in the data domain (Clapp *et al.,* 2021), from the distal to the immediate levels of decision-making. In this context, agency means the ability to identify one's own data needs, to undertake analysis and share data and knowledge to address these needs and to guide individual and collective decision-making regarding food production and consumption and other aspects concerning food systems. Agency also means having access to and using local data at the local level to make informed choices, enhancing the two-way flow of data.

Data can indeed be a strategic instrument of empowerment, just as lack of data and information is a driver of vulnerability. This is true for FSN as it is for other domains of policy and decision-making affecting people's well-being. Examples on the importance of data for agency abound: accurate information on producer prices (and price forecasts) would enable smallholders to decide what to cultivate, when and where best to sell; data on markets and prices can be used by smallholders to build a credit or sale history so as to be able to access bank loans or procurements by government or private urban wholesalers; rain gauge data at the local level can be instrumental to predict rainfall or to claim rainfall insurance; soil quality measures, traceability of inputs (such as certified seeds) and what become of their produce will empower farmers; forest conservation can be monitored with drones, etc. Indigenous peoples and grassroots organizations are collecting, analysing and disseminating data, using new technology, to mobilize collective action in food systems. In India, the POSHAN (Partnerships and Opportunities to Strengthen and Harmonize Actions for Nutrition in India) initiative has mobilized citizens as data generators and users to improve nutrition (WHO and UNICEF, 2020) (SEE BOX 16).

Despite these advances there is still a paucity of data on many considerations critical for policymaking, such as the interests and values of individuals and stakeholders at all levels (Deconinck et al., 2021). This and other data may not be amenable to the largely quantitative orientation of most, if not all, of the data sources described thus far.

BOX 8:
DATA COLLECTION IN CONFLICT SETTINGS

Armed conflict and other situations of violence have remained one of the primary drivers of food insecurity, malnutrition and famine in many countries. All five famines declared over the last decade in Ethiopia, Nigeria, Somalia and twice in South Sudan were essentially driven by the consequences of armed conflict and violence. Hotspots for violence tend to be blind spots for information, especially for survey and household data, which are necessary to ascertain the severity of the situation and determine whether famines should be declared and the responses required. Challenges in this regard are multiple and concurrent: data may be impossible to collect, it may be collected but not released, or it may be collected but lacking in completeness, quality or timeliness. Remote methods are increasingly viable to support data collection in areas that cannot be reached in person, but the usefulness and accuracy of the data collected are still limited.

In these contexts where complete and reliable data cannot be collected, to the extent possible, it is recommended that a combination of sources of evidence be used (IPC Global Partners, 2021). For example, useful data can include those collected at assistance distribution points, those collected from people arriving at camps and those collected in accessible areas that share similar conditions to inaccessible areas. Because of the limited reliability of these data (as adequate sampling cannot be executed) it is necessary to carefully process and interpret these data. For example, information gathered from new arrivals at camps needs to carefully consider origin and travel time of the displaced populations. Whenever possible, data collected in conflict settings should be supported by quantitative and qualitative data collected at the community level during missions to the areas affected by conflict. Helicopter missions, for example, were crucial to classify the 2016 Famine in South Sudan.

In conflict situations, there is also likely an entire ecosystem of data collection and analysis unique to the given context. Data on the extent of the conflict itself (number of people involved, causalities, etc.) may be more available than data on the food security and nutritional status of the affected population. Many conflict contexts have a range of publicly accessible reporting by various UN bodies, including Panels of Experts mandated by the UN Security Council, Joint Mission Analysis Centres or Human Rights Divisions within UN peacekeeping operations, and other analysis by specialized agencies, such as the International NGO Safety Organisation (INSO) and the Nigeria Security Tracker. A variety of academic and other research institutions also provide conflict analysis and other analysis directly relevant to the conflict, such as the Rift Valley Institute’s work across the Greater Horn of Africa. Regular media reporting can also supplement these sources.

The main lessons we derive from this overview of existing FSN data, and data gaps, are the following:

1) There exists already an abundance of data across several levels of our conceptual framework and dimensions of FSN. In order to effectively use this data and information for FSN decision-making, continued efforts must be made to *ensure harmonized data standards and availability* (as illustrated by examples of FAOSTAT), to improve data access, to transform data into relevant insights and to build capacity to capture and use data (as illustrated by the HiHI and AMIS). The abundance of data at several levels offers an opportunity to reflect on its utility and to explore areas where data can be streamlined and prioritized, ensuring efficient and effective use of scarce resources.

2) There are, however, notable gaps in the availability and accessibility of data. While it is difficult to provide a universal list of high-priority data gaps, as the gaps are country-specific, it is a fact that relevant FSN data are particularly scarce in most low-income countries. Even where data exist, their *frequency* and *granularity* are often insufficient to track progress over time, guide needed policy reform, or adjust programmatic responses to the changing reality of local contexts. It would be extremely helpful to compile lists of FSN data priorities by country, with technical and financial assistance from international organizations and donors. The 50x2030 initiative (SEE BOX 6) seeks to address this for many types of agricultural data, which are relevant for FSN, but more needs to be done, especially in terms of timeliness and completeness of information at the household and individual levels, covering people's ability to access food and the actual diets they consume, which are crucial to guide effective FSN policy.

CHALLENGES AND OPPORTUNITIES FOR FSN DATA-INFORMED DECISION-MAKING

In the previous section we highlighted several strengths and weaknesses of extant data across the levels of our conceptual framework and across the dimensions of FSN. This section explores how those strengths, gaps and limitations may influence data-informed decision-making for FSN, by reviewing each of the steps in the data for decision-making cycle (Figure 2). The gaps and limitations are translated into the primary challenge(s) that may impede each step in the cycle and good practice examples and opportunities to overcome those challenges are identified. Due to the growing interest in food systems transformation and the recognition of the centrality of diets to many health outcomes, there are many efforts and examples to draw on.

Before moving to the data cycle, however, let us explore the role of target setting to motivate the data generation and utilization for FSN. Target setting for internationally agreed upon goals, and the resulting tracking of progress towards their achievement, has been an enormous stimulus for data collection and dissemination. Such data provides a tool for accountability and supports evidence-informed advocacy for FSN. International agreement on common goals is a powerful incentive to bring together stakeholders from across multiple sectors. This was indeed one of the overarching objectives of the United Nations Sustainable Development Goal Indicator Platform (Box 9).

BOX 9:
FSN AND THE SDG MONITORING FRAMEWORK

Food security and nutrition is now high on the development agenda thanks to the deliberations of the World Food Summit held in 1996 (FAO, 1996); the commitment to end hunger by 2015, included in the United Nations Millennium Declaration in 2000 (A/RES/55/2) which established the Millennium Development Goals (MDGs); and – most recently – the 2030 Agenda for Sustainable Development, endorsed by the UN General Assembly in 2015 (A/RES/70/1). This emphasis on food security and nutrition, and the accompanying commitments, have created incentives for the production of data on FSN globally and in most countries.

The 17 Sustainable Development Goals (SDGs) represent some of the most urgent and universal needs of the world today, and for over a decade have formed the backbone of nearly every development initiative in the world. As a mechanism to facilitate the implementation of the 2030 Agenda, on 6 July 2017, the UN General Assembly officially adopted a framework composed of 169 targets and 241 indicators to monitor progress towards the 17 SDGs and to inform policy and ensure accountability of all stakeholders towards their achievement (A/RES/71/313).

The monitoring framework has been of enormous importance to raise awareness regarding the importance of data and statistics in all areas covered by the SDGs. Agriculture and FSN feature directly as the focus of SDG 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture", but are relevant to many other goals as well, including SDGs 1, 3, 10, 12 and 16.

The Inter-Agency and Expert Group on SDG indicators, established under the UN Statistical Commission, supports coordination among Member Nations towards the harmonization of data, indicators and reporting, and has created a dedicated web-based platform (https://unstats.un.org/sdgs/). Specialized UN agencies have been assigned as custodians of SDG indicators in their respective areas of competence. The role involves the responsibility to establish and maintain standard definitions of the indicators, to provide capacity development and technical support to countries for the production of the indicators, and to collate and report on the indicators produced by countries. FAO has been nominated the custodian agency for 21 of the 241 SDG indicators. Of particular note in response to this responsibility is the annual publication by a consortium of five UN agencies of *The State of Food Security and Nutrition report* (FAO *et al.,* 2017). Despite the coordination and standardization achieved through the SDG monitoring framework, its implementation is incomplete in 2022, more than halfway through the SDG time frame. For example, the reporting rate for the 21 SDG indicators under FAO custodianship, in 2020, was only 51 percent (FAO, 2020a). Moreover, in many cases, the indicators reported by countries do not adhere to the standard definitions and have been replaced by proxy indicators. This hinders cross-country comparisons and may lead to misinterpretation of results in terms of progress made.

Despite the growing recognition of the costs of not basing policy decisions on data, this is still not a widespread practice with respect to FSN. Drawing on examples from business, Gartner, a business support company, estimated in 2018 that poor quality data costs businesses an average of USD 15 million per year in losses. When profits are the bottom line, as is the case in business, these figures make a compelling case for better data. Gartner proposes a 5-step process to develop the business case for better quality data: understand business priorities; carefully select the right metrics; develop the approach to consolidating and using the data from the outset, including benchmarks; set targets; estimate the financials – both cost of data quality improvements and the quantified benefits of using it.[10] The first four steps are similar to those of our data cycle. The FSN data

10 For more information, see https://www.gartner.com/smarterwithgartner/how-to-create-a-business-case-for-data-quality-improvement.

community has been remiss not to quantify the cost of not using data and the potential cost savings of doing so. We did find one example of this in the literature relevant for FSN data. In Cameroon, researchers used optimization modelling to illustrate the potential impacts and cost savings of alternative approaches to addressing vitamin A deficiency in the population. The data collection and related expenses required for the modelling cost approximately USD 900 000. The authors estimate, however, that this reflects only 5 percent of the cost savings if the government were to implement the modified programmatic approach resulting from the modelling over a period of 10 years (Vosti *et al.,* 2015). Such estimates could substantially mitigate the concerns related to the cost of data collection.

These examples demonstrate that the existence of data, the cost of not using data and even the linkage of data to agreed targets are insufficient for that data to be brought to bear on FSN decision-making. In order to address this, it is necessary to examine the challenges and opportunities across the data cycle. These are set forth in the following sections.

SET PRIORITIES FOR DATA

- **Lack of clarity on how to prioritize:** The various sources of data highlighted in Annex Table 1 illustrate the abundance of topics that hold relevance for FSN. The criteria used to set priorities for data gathering or compilation are often allusive. This is due, at least in part, to the multitude of reasons for which existing data have been collected and the multitude of purposes for which data systems are compiled and used. Articulating clear objectives for data utilization and being explicit in the types of data-informed decisions to be made, and by whom, can help navigate the abundant data and identify gaps. For example, the Countdown to 2030 initiative (Box 10) was developed to prioritize data for advocacy and accountability for women's and children's health and to enhance the capacity for its utilization.

BOX 10:
COUNTDOWN TO 2030

The Countdown to 2030 initiative aims to improve coverage, measurement and monitoring of health interventions for women, children and adolescents, and to strengthen¬¬ the regional and country capacity for evidence generation in this regard. It builds on the Countdown 2015 initiative that was set up to enhance accountability for the related 2015 Millennium Development Goals. Countdown seeks to strengthen in-country evidence and analytical capacity, creating partnerships among global, regional and country analysts from public health institutions, research institutions and ministries of health.

As of the writing of this report, Countdown 2030 has established data collaborations in 19 countries in Africa and Asia (see https://www.countdown2030.org/country-collaborations). They have held numerous workshops with participants from over 150 countries, published many documents, reports, technical notes and other medium on good practices related to data and on the results of the data themselves. The latter have been included in global monitoring and accountability reports, such as Leaving No One Behind, the UN Every Woman Every Child progress reports, the UNFPA State of World Population Report and the Global Nutrition Report.

Prioritization of data for inclusion in the Countdown efforts is enhanced by the establishment and following of a clear set of guiding principles. Coverage, that is, the proportion of individuals needing a service or intervention who receive it, is the central focus of Countdown. Data are tracked only for interventions that have been scientifically proven to reduce mortality among women and children and are feasible for delivery in low- and middle-income countries. Data are also collected for coverage of services that serve as delivery platforms for interventions such as antenatal care and family planning, among others. Included interventions must have coverage indicators that are reliable and validated across multiple country contexts and over time. Countdown does not collect primary data, so sources must be from nationally representative surveys and must be regularly available for inclusion.

Fanzo *et al.* (2021) call for the establishment of a similar rigorous, science-based monitoring framework that can provide a countdown on advances to transform food systems for nutrition. The authors propose the adaption of the HLPE-FSN food systems framework to guide priority setting for data inclusion, focused around five thematic areas: diets, nutrition and health; environment and climate; livelihoods, poverty and equity; governance; and resilience and sustainability. Setting such priorities for data that are both relevant for policymaking and feasible to collect rigorously across settings is an important first step to establishing a data system that can support accountability and inform decision-making.

GATHER, CURATE AND DISSEMINATE DATA

- **Lack of availability and access to data:** As highlighted previously, both availability of and access to data continue to be important constraints for some of the domains relevant for FSN. Some of the data sources listed in Annex Table 1 are proprietary, generated and held by private-sector data firms. Even public data (e.g. some national surveys, or information on the extent of food reserves) may be held behind firewalls that restrict access to authorized users, or there may be lengthy delays before such data are made publicly available. For several topics in the table, we were able to identify reports that consolidate relevant data, but the data themselves may not be available and accessible in the public domain. To improve data sharing and accessibility, having clearer objectives and setting priorities could help adapt existing data systems, focusing on the most important gaps and exploring feasible solutions. However, as discussed in Chapter 5, some of the problems in data sharing derive from unresolved issues regarding data governance and the associated legal and ethical aspects of **open data**. Such issues are well recognized, and several initiatives are already underway to address them, including the previously mentioned Agricultural Market Information System (AMIS) (Box 2) and the Global Open Data for Agriculture & Nutrition (GODAN) (Box 11). Another relevant example is the Rural Livelihood Information System, a joint initiative of the FAO Statistics Division, the World Bank and IFAD, to support policies for reducing rural poverty. This system provides open access to standardized indicators produced from household surveys and time series data from official national statistics. Additionally, a very promising initiative has been recently established as a collaboration between the nutrition, fisheries and statistics divisions at FAO, aimed at creating a new food and diets domain in FAOSTAT that will disseminate harmonized food, diet and nutrient statistics from different data sources (food balance sheets, household surveys and dietary intake surveys).

BOX 11:
GLOBAL OPEN DATA FOR AGRICULTURE AND NUTRITION (GODAN)

Few would question the importance of improving data access, but insufficient attention is often paid to why data are not accessible and to the policies, procedures and institutional arrangements that constrain or act as disincentives to make data accessible. The Global Open Data for Agriculture and Nutrition initiative seeks address these challenges by building high-level policy and public and private institutional support for open data. GODAN is an innovative voluntary alliance of over 1 000 national governments, non-governmental and international organizations, and private sector companies. Members contribute directly to GODAN activities, which include guiding and assisting organizations and companies to develop open data policies, advocating for access to data and linking partners to required technical expertise. The GODAN website provides several tools useful for organizations interested in developing open data policies, and holds a repository of those that have such policies, providing convenient links to access them. Additional resources include training courses, webinars and certification of open data policies and procedures.

DATA ANALYSIS

- **Poorly conceived or inappropriate measures, indicators or scales:** As discussed in Chapter 1, it is common that insufficient attention is given to defining FSN-relevant constructs and to selecting appropriate measures, indicators and scales. This is particularly pertinent as there is often a lack of transparency about the cross-context validity of measures, indicators and scales. Lack of agreed-upon standard vocabulary, measures and constructs makes data collection, analysis and interpretation very problematic. How to effectively measure household food security in surveys, for example, has been long debated. Existing approaches to food security measurement were found to be incapable of gauging shocks and had poor nutritional relevance a decade ago (see for example Headey and Ecker, 2012) and some of the challenges identified remain (Cafiero, 2020; Cafiero *et al.,* 2014). Similar problems exist with respect to other variables targeted in surveys. This shows how important it is to develop standards and to use standardised methodologies in surveys to ensure comparability. Since it was introduced by FAO in 2014, through the Voices of the Hungry project, the Food Insecurity Experience Scale (FIES) (Cafiero, Viviani and Nord, 2018) is rapidly gaining acceptance as a relatively inexpensive, yet theoretically and empirically valid, survey tool to be included, with proper adaptation, in virtually any household or individual survey.

- **Inadequate data-collection designs:** The usability of data may depend heavily on decisions made at the design stage. Cross-sectional designs for FSN surveys, for example, may limit the usefulness of data collected for evaluating causal drivers of food security and nutritional status and changes over time. Farm and population surveys are often designed in ways that make them less inclusive of what would be needed to represent the diversity of the reality they intend to represent. Household survey frames based on lists of residents, for example, exclude the homeless and incorrectly represent transient populations in FSN surveys. Also, special survey design may be needed to adequately represent Indigenous Peoples who live in remote areas or do not have formal titles to housing or land. Similarly, agricultural data mainly obtained through interviews with farmers or through surveys, may lack sufficient representation of small farmers (Lowder, Skoet and Raney, 2016). Surveys designed to collect information by only interviewing the head of household, predominantly an adult man, fail to adequately record information on the relevance of women's activities with regard to crops, income, needs (including childcare) and decision-making. As a result of these various issues in data collection, some FSN data may not represent the reality of small farmers, women, migrants and Indigenous Peoples. Furthermore, available data may be insufficient because it lacks the granularity needed to make group-specific decisions. For example, data on the nutritional status of specific groups over a long enough period to track trends may be unavailable, although overall estimates may exist. The level of granularity required to evaluate disparities in nutritional status by gender, for instance, is currently absent in many countries (MTR Foresight report 2020; UNSCN, 2018). Individual-level data is needed to track progress not only on food security and nutrition, but also on gender equality and women's empowerment in food and nutrition spheres.

BOX 12:
AN EXAMPLE OF AN AFFORDABLE, GLOBAL DATA MANAGEMENT PLATFORM: REDCAP

REDCap stands for Research Electronic Data Capture. REDCap was created by the University of Vanderbilt in the United States. The secure REDCap web application permits users to create and manage surveys and the associated databases quickly and securely, including by collecting data offline. REDCap is used all over the world. At the time of this publication, it is used in 145 countries, by 5 961 institutions, working on 1.5 million individual projects, with a user base of 2.1 million users. REDCap is designed for use by institutions. Installation is free and the only costs involved are for server space and for certificates of security. However, licenses are only issued to non-profit organizations having sufficient internal IT infrastructure to self-host. According to the REDCap website, it is not permissible for a business, company or other for-profit organization to hold a license or self-host. However, REDCap Cloud (https://www.redcapcloud.com/) is a third-party company which offers fee-based hosting in their custom version of REDCap. Because a license is always required to gain codebase access, REDCap is not considered open source. However, the license or institutional agreement, codebase and all consortium support are provided at no cost to any non-profit organization. REDCap works as a programme for data entry within a data (survey) form previously created by a REDCap user. There are multiple benefits of REDCap over spreadsheets used for data entry. Primarily, REDCap allows for simultaneous data collection, online or offline, and data management. REDCap offers many advantages over spreadsheets as all the following features are much more difficult to execute in spreadsheets and related programmes:

- Allows for multi-language management: "Create and configure multiple display languages for projects, surveys, data entry forms, alerts, survey invitations, etc. Data collection instruments may be designed to display in any language that has been defined and translated, so that data entry persons can view the text in their preferred language. This eliminates the need to create multiple instruments or projects to handle multiple languages. When entering data on a data entry form or survey, users and participants will be able to choose their language from a drop-down list to easily switch to their preferred language for the text displayed on the page. All text related to the data entry process (both for surveys and for data entry forms), various survey settings and email text can be translated." (See https://www.project-redcap.org/software/).

- Validating ranges for dates and numbers (for instance, a mother in a study cannot be born the day of the survey or the number of portions in a food package is probably not more than 250).

- Standardized variable names (one institution could call question 1-date on the same form "q1" and another institution "date").

- Allowing for double data entry (for example, each of these birthdates is plausible for a mother in a study (15/10/1976 and 15/12/1976), but without double data entry, it would not be possible to determine the correct birthdate that was written down on the paper survey form.

- Designing data entry forms that are nearly identical to those on paper that facilitates the speed and the precision of data entry, for instance, through the easy incorporation of skip patterns.

- REDCap offers a long-lasting data storage, prevents potential errors in handwriting information and minimizes potential errors arising during data entry by typing, for instance, by having standardized codes for questions with more than one response (such as categorical variables: 0 = No health claim, 1 = Health-related ingredient claim, 2 = nutrient content claim, etc.). Such codes are often not standardized within and between countries, which often delays or inhibits harmonized data analyseis because there are not enough human resources available to both clean and standardize databases within or between countries.

- Export of data ready for analysis within a statistical programme (that is, little or no clean-up of dataset prior to analysis).

All of these characteristics greatly facilitate pooled analysis of data from multi-country studies, especially longitudinal studies and those with mother-child dyads, because all data entry and related data management has been standardized when the data was collected.

Confidential data stored on REDCap is secure. REDCap's webpage – while based on an open-source platform – is hosted through an institution that must have certificates of security to enter into an installation agreement with REDCap. Therefore, all the data entered into REDCap are saved within a secure server with extra antivirus protections on the REDCap server hosted by the given institution. Only institutional administrators can access all the data and study-specific data can only be accessed by those involved in the study or project who have the required rights and permission.

See http://project-redcap.org/ for the installation guide for institutions and https://projectredcap.org/about/faq/ for more information about REDCap.

- **Lack of harmonization and poor data quality:** Data collection, processing and storage protocols often vary considerably by context and over time, limiting the utility of the data to analyse trends and to identify specific areas of risk and vulnerability. Even simple common data types (such as dates) are often collected in non-standard ways, creating issues for merging or comparing data sources. Data cleaning protocols (including data range checks, treatment of out-of-range data and many other considerations) are not always applied or vary substantially in their approach across data sources. One relevant example of this is the lack of harmonization in the way in which food consumption data are captured in household consumption and expenditure surveys. To address this, the Inter-Agency and Expert Group on food security, agricultural and rural statistics (now known as the United Nations committee of Experts on Food Security, Agricultural and Rural Statistics [UN-CEAG]) convened a series of technical workshops, between 2014 and 2016, involving professionals and decision-makers from national statistical and international agencies to discuss solutions. The process led to the publication of a set of guidelines on collecting food -consumption data in household consumption and expenditure surveys for low and middle income countries, which was endorsed by the forty-ninth session of the United Nations Statistical Commission in 2018 (FAO and The World Bank, 2018).

- **Timeliness:** Where primary data are needed, data collection and analysis can be a slow process and data may not be available in a timely manner for decision-making. This may be particularly problematic in emergency and crisis situations where analyses are needed to inform immediate humanitarian action. The Integrated Food Security Phase Classification (IPC) initiative is a multipartner initiative designed to provide timely data to inform emergency response assistance for people exposed to acute severe food insecurity (Box 13).

BOX 13:
THE INTEGRATED FOOD SECURITY PHASE CLASSIFICATION (IPC) INITIATIVE

The Integrated Food Security Phase Classification (IPC) initiative is a formal partnership of UN, non-governmental (NGO), intergovernmental and other organizations at global, regional and country levels. The IPC is used to assess the extent and severity of food insecurity and malnutrition in emergency situations to inform the rapid mobilization of humanitarian assistance. The IPC was originally developed in 2004 by the FAO Food Security and Nutrition Analysis Unit (FSNAU) in Somalia, in response to the growing need for rigorous, neutral and objective actionable information to facilitate evidence-based, effective and coordinated humanitarian response in the context of a country that had been undergoing repeated crises. IPC has since grown to a partnership of 15 organizations and intergovernmental institutions active across all IPC activities. IPC is now implemented in over 30 countries, with findings used to make decisions on allocation of food and other forms of assistance.

One of IPC's distinct features is the high degree of ownership by governmental institutions, whose representatives participate in the country teams that make the assessments. From a methodological standpoint, the IPC is predicated on consensus, creating a space for rapid, objective analysis of the relevant available data and evidence (which is often scarce and of less-than-ideal quality). Experts from the various agencies that share the responsibility for a humanitarian response openly consult on the available data, analysing it according to established protocols organized according to four functions: 1. Consensus building, 2. Analyses, 3. Communication, and 4. Quality assurance. Assessments provide estimates of current and projected food insecurity and malnutrition in the areas analysed, which are typically subnational areas, including refugee camps and the local communities that host refugees, when appropriate.

To be useful, IPC assessments must be very rapid, yet reliable. Several features facilitate that timeliness and relevance. First, analysis is guided by a formal set of tools and procedures designed to formulate simple, actionable statements regarding the classification of the areas at risk, including providing rough estimates of the number of people potentially affected. IPC Global Reference Tables provide analysts with benchmarks for three different kinds of assessments, one for acute food insecurity, one for acute malnutrition and one for chronic food insecurity. Each reference table is designed to define four or five potential phases or levels of severity of the situation, which are described in qualitative terms, and then provide guidance on how the evidence conveyed by various indicators can be used to classify the areas by level of risk. For example, an area is classified under IPC Phase 4 of acute food insecurity (labelled as "Emergency") when evidence points towards a situation where at least 20 percent of households in the area either likely have large food consumption gaps (which are reflected, for example, in remarkably high levels of acute malnutrition in children or excess mortality), or are able to mitigate large food consumption gaps but only by employing costly livelihood coping strategies. To ensure timeliness, all relevant available data are considered, even when less than ideal or incomplete. All available evidence is assessed for reliability, considering the conditions under which the data has been collection, and for time and spatial relevance. Data found to be sufficiently sound and relevant are then used in the analysis, and results are critically reviewed in relation to the specific area's context and the typical local livelihoods, as well as in relation to other indirect evidence and past trends.

- **Data protection:** There have been substantial improvements in standard approaches and governance processes to ensure research and data collection ethics are upheld. However, the expanding use of mobile and electronic methods for data collection and sharing, including crowd sourcing and the ever-growing cloud storage of data, can present particular challenges for FSN-related data protection (see further discussion in Chapter 4 and Chapter 5).

- **Heavy reliance on quantitative data:** Reliance on quantitative data has important advantages as quantitative data are amenable to harmonization, systematization and reproducibility (when issues of cross-context validity are addressed). But this quantitative data bias also has important disadvantages for the utilization of FSN data. Moving from the outer to inner circles (distal to individual) of our conceptual framework, it is necessary to understand the nuance and unique contexts in which communities, households and individuals interact to produce, procure, prepare, share and consume food. A myriad of individual, societal, cultural, religious and other considerations may have direct relevance for decision-making to improve FSN. For example, understanding policymakers' motivations and how they perceive and balance the many trade-offs that each of their decisions inevitably entail would be enormously important. Many of these aspects may be difficult or impossible to capture with quantitative data. As a result, these considerations are often omitted from decision-making processes. As qualitative data are less amenable to collection by simple, standardized surveys, they may end up being excluded from data consolidation and dissemination efforts. The Exemplars in Global Health programme (Box 14) is an interesting example of how such data can be included in data platforms and initiatives.

BOX 14:
EXEMPLARS IN GLOBAL HEALTH

The Exemplars programme seeks to highlight success stories and the factors that have contributed to them by conducting in-depth case studies in public health. Rigorous methods are applied to prioritize topics for analysis, identify exemplar countries and consolidate vast amounts of quantitative data on the topic, from published literature, websites and national resources, among many other sources. This is complemented by qualitative analysis, including dozens of in-person interviews with in-country experts who designed, implemented, or have deep first-hand knowledge of the most impactful policies and programmes. In this manner, Exemplars is still resource-intensive in that it requires primary (qualitative) data collection. However, its uniqueness and relevance for this report lies in the utilization and combination of this information into a public data portal that allows the comparison and contrasting of situations across countries and regions.

TRANSLATE DATA AND USE FOR DECISION-MAKING

- **Translating data into results, insights, conclusions and recommendations:** Data are often presented in long reports with complex graphics, tables and considerable detail. This is insufficient to glean decision-focused results, insights, conclusions and recommendations for action to improve FSN. Busy policymakers do not have time to review multiple data sources nor the necessary technical skills to consolidate the information from those sources, highlight the gaps and identify specific actions. This requires a purposeful and complementary set of activities. The Food Systems Dashboard (Box 15), with its *diagnose and decide* functions, seeks to address this issue.

BOX 15:
THE FOOD SYSTEM DASHBOARD

The Food Systems Dashboard was developed in 2020 by Johns Hopkins University and the Global Alliance for Improved Nutrition (GAIN), along with several other partners. The dashboard combines data from diverse sources to give users an overview of a food system, using the HLPE-FSN 2017 food systems framework (HLPE, 2017) as the basis for data organization. With over 150 indicators, users can review the current status across all domains for a particular country or compare components of food systems across countries within a region or globally, or by other variables, such as food system type or national income classification. The developers of the dashboard have prioritized 41 key indicators that can also be used to provide more in-depth insights into food system issues and opportunities in individual countries.

The dashboard also contains a compendium of 42 actions that have been identified to have potential (through clear pathways to impact) to enhance the availability, affordability, acceptability or safety of food. These are organized according to their primary sector of action: agriculture, international trade, research processing and technology, supply chain infrastructure, financial, public institutions, business initiatives, regulation and law, education and public awareness, and national guidelines.

Ultimately, the dashboard aims to go beyond *describing* food systems to providing the basis for *diagnosin*g food systems in a given context and for *deciding* on specific actions to address the gaps and issues identified. As such, there is a clear intent on the part of the developers to contribute to translating knowledge into action. To this end, several workshops have been held in countries building on the description and data diagnosis to explore policy and programmatic options.

Efforts are now underway to develop subnational Food Systems Dashboards in several countries. This is an important step, in view of the diversity of food system issues and opportunities that exists at subnational level. In many contexts, these local or regional adjustments to policy and action may be critical to adapt food systems. This may be particularly important to ensure that the unique needs of those most vulnerable to food insecurity and malnutrition are not missed in general, national-level efforts.

• **Using data for decision-making requires buy-in and involvement on the part of those with the responsibility to make decisions, and clarity on the decisions to be made:** As noted in Chapter 1, and illustrated again in this review, multiple stakeholders and sectors are relevant to FSN. Although FSN data relevant to these different stakeholders and sectors often overlap and are complementary, there are also gaps in the data, and too often, the intended users of the data are not engaged in data-related activities. The POSHAN Network in India (Box 16) was specifically designed to address these challenges and enhance the effectiveness of data-informed decision-making for FSN. The network draws on different sources of data and brings together a variety of stakeholders who work together to apply the data in initiatives aimed at improving child nutrition in the country. It is a clear that programmes of this type should be strengthened – increasing spending on them, integrating them with local food systems and expanding their reach. In the current economic situation, however, such programmes have come under considerable strain and the budgetary allocations for them have contracted. Institutions and governance (the centre of the data cycle in Figure 2) have a critical role to play in this regard, as is discussed in detail in Chapter 5.

BOX 16:
THE POSHAN NETWORK

In 2017, the Ministry of Women and Children of the Government of India launched the POSHAN Abhiyaan programme, aiming to substantially reduce the prevalence of all forms of child undernutrition, particularly stunting, wasting and low birthweight, by reducing the evidence gap in Indian nutrition and supporting efforts to generate, synthesize and mobilize diverse types of nutrition data and evidence to support policy decisions. POSHAN is led by IFPRI (International Food Policy Research Institute) Delhi and funded by the Bill & Melinda Gates Foundation.

The programme has brought together many different schemes that have played a very important role over the last few decades in extending nutrition services to children and women in India. The need for a mechanism to coordinate and support evidence-informed dialogues and decision-making at national and state levels in order to inform the needed actions was identified early on as a critical element for success. Thus, the POSHAN Network (Partnerships and Opportunities to Strengthen and Harmonize Actions for Nutrition in India) has the objective of "[...] generating, synthesizing, and mobilizing nutrition data and evidence, by engaging a variety of stakeholders, to support strategic nutrition policy and programme actions in India."

POSHAN works across all six steps in the data cycle, working with counterparts to identify and prioritize evidence and knowledge needs; consolidating and analysing data, including qualitative data in the form of success stories of change; translating data into policy briefs and similar media; and disseminating results through workshops and similar activities.

Chapter 3

CONSTRAINTS, BOTTLENECKS (AND SOME SOLUTIONS) FOR EFFECTIVE USE OF FSN DATA

Kyrgyzstan, 13 May 2019, Head of Laboratory Gulay Abdymambetova checks vegetables for nitrates in Logistic food center in Kemin some 80 km from Bishkek.

The discussion in Chapter 2 points to the wealth of existing FSN-relevant data and information. It also suggests, however, that significant data and information gaps still exist, especially for low-income countries. This chapter examines the most relevant constraints and bottlenecks that underlie those gaps and hinder the effective collection, analysis and utilization of FSN data. The intent in doing so is to derive recommendations that may lead to feasible solutions.

The identified constraints and bottlenecks are broadly categorised as relating to insufficient resources for data collection and analysis, and to inadequate institutional capacity and arrangements and problems with data governance.

One area of special interest in this chapter is the human capital needed to achieve effective use of data in all areas that contribute to FSN, from policymaking and the actions of food system actors, all the way through citizens' food choices. Data are crucial to inform all these levels of the food system, yet, despite the abundance of data (but perhaps, in part, also *because* of it), **there is still very limited ability across the board to make full sense of the continued flow of data**. Only a small minority of people in the world possesses the necessary skills to properly interpret, process and distil information from data in all the various forms – numbers, images, texts, words – in which it is continuously generated, stored and distributed. Of particular concern is that **this is true also for the scientific community,** where traditional mental frameworks and research tools (experimenting, quantification, surveying, interviewing, conducting participant observation, ethnography, etc.) are being challenged by emerging new tools (data mining, web scraping, text mining, sentiment analysis, etc.),[11] which have not yet sufficiently permeated academic curricula. This brings to the fore **the need to invest in capacity development at all levels, starting even in primary school and continuing through specialized training of professionals working in public and private data-driven institutions.**

INSUFFICIENT RESOURCES FOR DATA COLLECTION AND ANALYSIS

Insufficient resources refer to both financial and human resources. These are discussed separately in the sections that follow.

11 Consider, for example, developments in the theory of measurement that address the problem of quantification in the human behavioural and social sciences (Bond, Yan and Heene, 2020; Mari *et al.*, 2017), or the epistemological implications of big data for research (Kitchin, 2014b).

FINANCIAL CONSTRAINTS

Insufficient allocation of financial resources to agricultural development and FSN programmes is a long-standing concern for many countries The inability to allocate needed financial resources from the public budget to FSN initiatives has been noted and linked to the limited tax base in many low- and middle-income countries (Tinsley, 2010), with repercussions on the production of official statistics. Further exacerbating the lack of data and information for effective FSN policies, national research funding programmes in these countries are also less likely to invest in research to promote food security, nutrition and health, as these are considered less marketable than research in other fields (Neema and Chandrashekar, 2021). Lack of public funding has clear consequences for FSN data. Kalibata and Mohamedou (2021) estimate that 90 percent of the national statistics offices (NSOs) in low- or lower-middle-income countries lack agricultural data due to funding limitations. Calls for external support have been less effective than hoped. The review of financing data for low- and middle-income countries, conducted by the Secretariat of the Partnership in Statistics for Development in the 21st Century (PARIS21), shows how the increased commitment on the part of external partners to support statistics has been mostly directed to economic and demographic statistics, with less focus on environmental and agricultural statistics (OECD, 2019). According to a recent report on *The implementation of the Cape Town Global Action Plan on Sustainable Development Data* (World Bank, UNSD and Paris21, 2022), two-thirds of NSOs in International Development Association (IDA) countries[12] experienced either moderate or severe delays in budget disbursement in the last fiscal year, which hampered the implementation of their work programmes, and nearly 70 percent of them prioritized the need to address funding shortages in business and agricultural census programmes over the next three years.

Solutions have been sought in exploring ways to reduce the cost of data generation, for instance, through increased reliance on secondary data rather than collecting primary data, imposing, however, additional requirements in terms of analytic capacity to ensure that data from different sources is integrated properly and avoid compromising the quality of the data series and comparability over time.

Another solution has been recourse to services for data collection, analysis and dissemination offered by private companies and professionals. While useful to partially fill the data gaps, such initiatives may raise various concerns, for example regarding privacy, data access and data governance.[13] Additionally, increased reliance on private data services may further erode the relevance and independence of NSOs.

A third solution, entailing the adoption of new technologies for data generation and collection, may certainly help (see more in Chapter 4). However, new technologies usually require initial investments and sustained support to ensure that the technologies are effectively used. One important aspect related to finance that has prevented useful innovations from becoming a permanent feature of data generation has been the difficulty in securing stable funding to keep the operations in place. When innovations have been promoted through externally funded projects, despite positive results, lack of sustained funding has halted their large-scale implementation.

In some cases, attempts to reduce costs to cope with limited resources may have detrimental consequences on data quality and relevance. In sampling-based inferences, such as when conducting farm or population surveys, or

12 These are countries considered eligible for support, according to the criteria established by the International Development Association, based on per capita gross national income being below an established threshold, or lacking the creditworthiness needed to borrow from the International Bank for Reconstruction and Development (IBRD). Currently, 74 countries (39 in Africa, 14 in East Asia, 6 in South Asia, 4 in Europe and Central Asia, 8 in Latin America and the Caribbean, and 3 in the Middle East and North Africa) are eligible. For a full list, see https://ida.worldbank.org/en/about/borrowing-countries.

13 See for example: https://www.oecd.org/digital/trusted-government-access-personal-data-private-sector.htm.

conducting food-composition studies, one way to reduce costs is by reducing sample size, but these reduced samples may be too small to produce indicators at the needed level of precision. In other cases, particularly for time-sensitive decisions, the need to secure the necessary funding may delay the survey operations to the extent that the usefulness of the information they provide may be compromised (Box 17).

BOX 17:
THE HIGH COST OF FSN-RELEVANT SURVEYS

Population surveys that provide key information on respondents' dietary intake and nutritional status may require enumerators to perform individual nutrition assessment (collecting anthropometric, biochemical, clinical assessment and dietary intake data). Training the enumerators and implementing the necessary field operation is a costly and labour-intensive process.

Similarly, food production surveys that seek to reach small farmers and fishers in interior areas require the mobilization of many enumerators over large distances, all of which increase overall survey costs. While newer methods, such as the use of smartphones, may reduce the time spent in face-to-face data collection, and therefore potentially reduce the number of needed enumerators, it is important to evaluate disparities in the ownership of digital devices and access to technology and knowledge among the vulnerable group, including women and small farmers.

In countries or even the regions with multiethnic populations, many languages are spoken and understood. This adds a layer of complexity to the process of data collection (such as the validation of tools in different languages, verifying the language competencies of the enumerators, etc.) and is expensive. When these demands arise in the context of existing financial constraints, feasibility is usually prioritized over representativeness.

In many countries, the cost of validating dietary assessment tools, such as food-frequency questionnaires or screeners with objective biomarkers, has been a major constraint and resulted in limited validation efforts. This has often cast doubts on the quality of the data and, thus, on the validity of results arising from the dietary surveys. Validation of self-reported dietary intakes, estimation of micronutrient intakes or levels of toxicity require biochemical analysis. This is an expensive, resource-intensive process that requires elaborate logistical arrangements, which are prohibitive in many projects. The lack of objective validation of dietary intake remains a consistent challenge in interpreting dietary data.

Finally, dietary data needs further processing in terms of nutrient analysis. Such analysis, followed by the creation of comprehensive food composition databases, is an expensive undertaking and unaffordable for many low-income countries.

Inadequate research infrastructure

Insufficient funding and the lack of well-trained human capital also result in **inadequate research infrastructure** at the national level to support every stage of the data cycle (Figure 2). Beyond the insufficiency of human and financial resources, inadequate research infrastructure influences how institutions set their priorities and actions for research. Under-funded NSOs, overwhelmed by competing priorities, tend to focus less on food production statistics and certainly not (due to underfunding and to a lack of capacity for system thinking) on generating statistics from across FSN-relevant sectors (agriculture, social protection, health, industry and trade) or covering the six dimensions of FSN. This is especially so in developing countries where inadequate funding further stresses organizational capability and makes it necessary to prioritize just one aspect of FSN. In such countries, the inadequacy of research infrastructure is evident in the lack of research quality frameworks and methodological expertise for timely, relevant and sufficient data collection and validation; lack of prior data; lack of data processing and analysis capabilities; and poor practices in data dissemination and communication (Filter *et al.,* 2022; Jones *et al.,* 2017). Finally, infrastructure and resource constraints also hinder **data-digitalization** efforts, further limiting data availability and accessibility.

The lack of adequate modern data infrastructure, especially in low-income countries, also limits effective data collection, analysis and use. Due to lack of access to broadband infrastructure in some developing regions, such as Sub-Saharan Africa and South Asia, where Internet usage gaps are as high as 49 and 64 percent, respectively (Lishan and Minges, 2018). **Social gradients** also influence the placement of cellular and mobile services and, thus, the penetration and quality of services in remote areas. Social divides in digital access and literacy is a further impediment to reaching disadvantaged stakeholders, such as women in low and middle-income countries and smallholders (LeFevre *et al.,* 2021). Thus, while technological advances may reduce costs and widen the reach of surveys and help to fill some gaps in data availability, the social divide may lead to the underrepresentation of those with poorer digital access and literacy (LeFevre *et al.,* 2021). This can result in policies and interventions that are based on data generated from skewed sampling, which may not serve unrepresented stakeholders who may have the greatest need for data-driven policy and support (Bell *et al.,* 2017; LeFevre *et al.*, 2021). Therefore, the adoption of newer technologies without considering the local context and the impact of their use on users and beneficiaries can further exacerbate inequalities, as illustrated in boxes 18 to 21.

BOX 18:
THE COMPLEXITY OF NUTRITION ASSESSMENTS

Nutrition assessments are a resource-intensive undertaking and, therefore, many of the constraints and bottlenecks discussed in this chapter limit the complete range of assessments (including anthropometry, biochemical and clinical and dietary intake). As previously mentioned, resource constraints can affect the availability of data and capacity constraints can affect the quality of the data available. In particular, biochemical and clinical assessments are resource-intensive and, therefore, multiple constraints acting in parallel result in a serious lack of data in this regard.

An important domain of nutrition assessment is the accurate estimation of dietary intake in populations. Data in this area is inconsistent, outdated, national food composition databases are incomplete, due to lack of support for institutions involved in developing the databases; all these factors challenge the accuracy of nutrient intake estimations in various countries and prevent their utilization by multiple users. The lack of comprehensive food composition databases with adequate representation of both plant and animal, aquatic and land-based foods consumed in the country, means that many countries rely on the databases of neighbouring countries or global databases to estimate nutrient intakes. The use of inaccurate food composition data may lead to erroneous research results, flawed policy decisions (particularly in nutrition, agriculture and health), misleading food labels, false health claims and inadequate food choices (Charrondière, 2017).

The Malabo Montpellier Panel report (2017) clearly states that "African governments continue to lack the data necessary to effectively combat malnutrition", as "few national governments collect the data required to inform decision makers about what people eat, and there is no functioning global dietary database." (Malabo Montpellier Panel, 2017, pp. 11–12). A recent review on global dietary surveillance (Micha *et al.,* 2018) confirms the non-availability or inadequacy of country-specific food composition tables (FCT) and food composition databases (FCDB) as one of the major challenges linked to the limited availability of global dietary data which are needed for a wide variety of purposes, including modelling, designing and implementing context-specific dietary policies to reduce disease and disparities at national and regional levels. Strengthening regional collaboration and establishing reference laboratories may provide a cost-effective solution. Another issue which must be tacked in nutrition assessment, is the lack of representation of **indigenous and forest foods** in food composition databases. This hinders the accurate evaluation of dietary intakes in indigenous populations (FAO, 2013a). INFOODS also tackles constraints in paucity of food composition data.

BOX 19:
ON FOOD SAFETY DATA

Low- and middle-income countries often lack resources to invest in improving their own national food safety regulatory frameworks and, therefore, rely on Codex standards as the basis for such legislation. However, Codex standards may overlook practices that are common in small-scale food production and their connected value chains (Humphrey, 2017). Both the European Food Safety Authority (EFSA) and Codex Alimentarius have databases containing food safety parameters, but these are not available as open access. Food safety data, specifically, may be regarded as sensitive to a country as levels above maximum limits can result in export bans and affect trade. Also, financial and human resources for food safety monitoring programmes are major constraints in enabling timely and relevant data collection related to food safety.

BOX 20:
THE WOMEN EMPOWERMENT IN AGRICULTURE INDEX

The Women's Empowerment in Agriculture Index (WEAI) has been designed to track gender equality and the transformation of gender norms (Malapit *et al.,* 2019). The granularity of data allows for disaggregation by age-group; gender; location; agroecological region; urban, peri-urban or rural residence; ethnicity and socioeconomic and occupational class. This, in turn, also allows for in-depth understanding and targeted action. Sampling that allows for such disaggregation along the food supply chain facilitates understanding of the contribution to food production from both formal and informal sectors, and their disaggregated food consumption patterns. When disseminated efficiently to the relevant stakeholders, this information can facilitate the involvement of the vulnerable groups in decision-making and aid in their ownership of targeted initiatives. Such efforts are important to promote equity in access to FSN data for policies and decisions at grassroot and local levels, taking into account local diversity and context.

BOX 21:
SATELLITE TECHNOLOGIES FOR IMPROVED DROUGHT ASSESSMENT (SATIDA)

To improve reach, granularity and affordability in data collection, some countries have developed accessible digital technologies for monitoring food security that help bridges many of the constraints referred to in this section, improving the granularity of the data while applying a simple and affordable process. One such example is the SATIDA (Satellite Technologies for Improved Drought Risk Assessment) project, which was developed to support Doctors without Borders. At the regional and national levels, timely and granular data that allow for evaluation of impact of innovative value-chain solutions and factors that can improve their uptake are also lacking (Committee on World Food Security, 2021).

HUMAN RESOURCE CONSTRAINTS

The lack of adequate human capital within public institutions responsible for FSN data generation, curation and dissemination, is often cited as a major constraint to data collection and analysis in many countries. Human resources and staffing have a huge impact on the availability of sufficient, timely and high-quality data.

Constraints related to data collection

The need for well-trained personnel in data collection using traditional survey methods has been acknowledged time and again (Krosnick, Presser and Husbands, 2015). Dietary data collection, for example, requires specific skills, including the ability to select and properly use the most appropriate dietary assessment data collection instrument, to assist respondents in estimating portion sizes, and to ensure completeness of the reporting.

Although new technologies can facilitate data collection, they do not eliminate the need for considerable numbers of adequately trained competent personnel (Aweke *et al.,* 2021). Technology used to interview people from remote locations, such as computer assisted telephone interviews (CATI) or internet-based technologies, might reduce the need for human resources, as might automating some of the routine or time-consuming tasks, but does not replace them entirely. For example, reliable measurement of certain outcomes, such as anthropometry and the measurement of local food environments, will always require the physical presence of enumerators at the location. Furthermore, harnessing the newer technologies to organize, analyse and disseminate multidimensional data usually requires technical skills that existing data collection and analysis staff may not have. Effective implementation of these technologies also demands soft skills, including management and leadership. The lack of these skills among existing staff can collectively affect institutional capabilities and arrangements for data processing, analysis and dissemination. The training required to develop these capabilities may be difficult to put in place and take time, and this could limit or delay the adoption and use of these new technologies (ILO, 2016, 2020).

While the importance of well-trained personnel in data collection and analysis for FSN is acknowledged, resource constraints make it imperative to balance between the need for specialization and the **sustainability of training and capacity-building** efforts. Capacity-building programmes such as those included under the EAF-Nansen Programme, where students are provided a stipend and trained in Norway with the opportunity to collaborate with the host institution upon return, is one example of a sustainable capacity-building programme (https://www.fao.org/in-action/eaf-nansen/news-events/detail-events/en/c/1309584/). Many European Union Funding Programmes also have consideration for the sustainability of the capacity-building efforts they fund. Despite these efforts, the sustainability of capacity building is oftentimes challenged by shortcomings in local environments, such as lack of job opportunities, poor remuneration and existing environments which do not provide autonomy. This results in the brain-drain that afflicts the Global South.

To address constraints in data analytical capabilities, the FAO provides statistical support to member countries. The success of these initiatives is documented with countries in the Southeast Asian Region have shown the highest gains in terms of statistical competency over the last decade (OECD, 2019). However, the ultimate impact of the support provided to build capacity is limited by the narrow assessment of capacity of national statistical systems.

With reference to the challenges posed by the diffusion of new technologies in agriculture, Florey, Hellin and Balié (2020) highlight that:

1. Many binding constraints faced by smallholder farmers are associated with basic capacity issues. For instance: smallholder farmers "are not organized collectively, they have limited experience of market negotiation, and little appreciation of their capacity to influence the terms and conditions upon which they engage with the market, and they have little or no information on market conditions, prices, and quality of goods (Shiferaw et al., 2011).

2. In geographies where markets for increased inputs do not exist because the private sector initiative and participation have not been sufficiently stimulated (Ricker-Gilbert et al., 2011; Ghins et al., 2017), pushing for higher-yielding technologies (such as modern crop varieties) to increase productivity merely ensures that input prices can be more readily controlled by the low number of agro-dealers. As a result, the market power exercised by too few operators will lead to depressed farm-gate prices because of continuing high input prices.

3. There are many farmers for whom increasing productivity and greater access to markets are not a priority, instead, they focus on off-farm or non-farm activities with a view to temporarily or permanently exiting from farming (Mausch et al., 2018).

Constraints related to the lack of data processing, analytical and dissemination capabilities

The reliability and availability of FSN data are often limited due to (i) lack of capabilities in data processing and analysis and (ii) lack of data analytical capabilities.

The analysis of dietary assessment data, for example, requires specific skills, such as the ability to choose an appropriate food composition table given the list and detail of dietary intake data and the ability to match food listed in food composition databases with the description of food items included in the data collected, even when there is no perfect match. Similar considerations can be made with respect to the analysis of food security data from surveys. For instance, in the initial implementation of the FIES food insecurity in survey tool, FIES data was collected in a large number of surveys throughout the world before a sufficient number of trained analysts had the time to acquire the necessary analytic skills to process the data properly, especially in low- and lower middle-income countries. Consequently, various reports were produced in which results were misleading, as they were based on incorrect assumptions made during analysis.

Concrete examples of how processing capabilities affect the quality of dietary data are seen in performing dietary intake assessment, food composition analysis and biomarker assessments relating to micronutrient intake and food toxicity assessments. To facilitate data processing and analyses, various automated procedures have been proposed, which presents opportunities, but also risks (SEE BOX 22).

BOX 22:
OPPORTUNITIES AND RISKS IN THE USE OF AUTOMATED DATA ANALYSIS

Recent technological advances in dietary assessment have integrated the various steps in dietary analysis, using dietary analysis platforms that have offline and online capabilities (https://www.fao.org/infoods/infoods/software-tools/en/). This reduces the potential for errors arising from manual data entry and its subsequent transcription. However, many of these software that allow for modular usage of local food composition databases are not open-access, and their lack of affordability limits widespread uptake in low- and middle-income countries. Another limitation is that they require capabilities in the appropriate use of food coding in dietary intake analysis. Standardizing data coding as part of quality assurance and data processing is another important step that may not be properly addressed owing to lack of expertise, specifically when quality research frameworks do not exist. For instance, standardization of food coding is an important step in dietary analysis that matches foods in the dietary assessment obtained with foods in the nutrient database. As diets are complex and the variety of foods consumed is greater than those reflected in the food database, matching of foods is challenging and requires expertise, including knowledge of the local cuisine. Additionally, foods consumed simultaneously, like coffee with milk, are given codes that identify these recurring combinations. The combination codes, when appropriately used in the database can aid holistic dietary pattern and quality analysis and reveal more visible and accountable patterns that may impact nutrition security and health (Mason *et al.,* 2015).

An attempt by the European Food Safety Authority (EFSA) to provide a common link to data sources across different food safety domains is the FoodEx2 project (Nikolic and Ioannidou, 2021). FoodEx2 provides descriptions of a large number of individual food items aggregated by food groups and broader food categories within a hierarchical structure. The Food Ex2 facet descriptors included in the classification system are also mapped to national food composition database compilers from 14 European countries. This expands the dataset to include harmonised information on the most common composite recipes of European countries and harmonised information on food supplements and provides an updated food composition database with over 1 750 foods (Roe *et al.,* 2013).

Apart from the data processing abilities, several constraints related to analytical capabilities have been identified in FSN areas. Analytical challenges can involve deficiencies in data measurement capabilities (measurement techniques, independent from human resources training) or insufficient capabilities in data analysis based on limitations in computing software. One example with regards to lack of analytical capabilities is the challenges faced in assessing dietary biomarkers. While the use of dietary biomarkers improves the accuracy of dietary intake estimations, its implementation requires extensive sample collection, storage, transportation, processing and analytical abilities. Micronutrients and toxicity analysis in food require sophisticated laboratory equipment and related methods that are prohibitively expensive to the LMICs. This lack of food and biochemical analytical capabilities results in incomplete nutrient lists in the food composition tables of many countries.

A related constraint is the insufficient **data analytic capacity** (that is, powerful computers) needed to process large amounts of available data and information. The collection and use of multidimensional big data sets also introduces complexities that may require upskilling of the current staff.

Insufficient capacity to effectively disseminate, interpret and communicate data limits the utility of the data and hinders advocacy efforts for continued investment in FSN-related data collection. After data collection and analysis, results are often communicated only in the form of tabulated data, with relatively **little interpretation and analysis** (FAO, 2015; OECD, 2019). While awareness is growing of the importance of supporting data use with proper analytical briefing on how the data are obtained from elementary information (Hicks *et al.*, 2019; Vaitla *et al.*, 2018; Sethi and Prakash, 2018), the lack of such products can hamper data-informed policymaking and targeted interventions to address the problem (FAO, 2015). Moreover, skills restricted strictly to statistical domains may be insufficient with the emergence of advanced technologies in data production with increased complexity, and the involvement of new data providers and users. There is also a lack of emphasis on data communication and dissemination. Additionally, lack of availability of the information in local languages hinders data utilization by creating language barriers. Given that too few NSOs in developing countries monitor the use of their data (Sethi and Prakash, 2018), it is difficult to gauge the actual utility of the data. It is important to obtain this data and estimate bottlenecks that prevent effective data usage to strategize remedial measures.

INADEQUATE INSTITUTIONAL ARRANGEMENT AND DATA GOVERNANCE

This section describes issues relating to data governance that arise from the lack of stakeholder engagement, lack of coordination among agencies and lack of transparency and appropriate regulatory frameworks.

CONSTRAINTS THAT LIMIT STAKEHOLDER ENGAGEMENT

The usability of data is limited when stakeholders have not been involved in the survey planning and there is inadequate dissemination or access to information on what data are available and how they can be used by the stakeholder. These constraints to the access and use of data for improved decision-making make it difficult to advocate for further funding and commitments towards the collection and analysis of FSN data.

Specific concerns with regards to **human rights and privacy** arise when stakeholders are not involved in the collection of data, specifically among vulnerable populations, including indigenous populations. (These issues are discussed in detail in Chapter 5). Adequate representation of diversity and inclusion of minorities and the ability to disaggregate data for specific populations are also closely related to lack of stakeholder engagement and the limitation this poses to the utility of the data in decision-making in these contexts. Inadequate participation on the part of certain segments of the population requires greater evaluation worldwide. In some instances, the digital technologies employed may be designed without obtaining user input. This is problematic when knowledge and technological divides across the stakeholders are not bridged through appropriate engagement. For instance, some farming communities in rural areas may have barriers to using technology because of the cost of adoption, lack of awareness, and accessibility or connectivity issues. In such circumstances, efforts to harness the latest digital technologies may be limited by lack of understanding of working conditions, requirements and end-user expectations. The deployment of digital technologies may sometimes take the focus and spending away from the primary objective, which is to improve the nutrition and health of the population. End users may sometimes not have the connectivity, familiarity with or digital literacy required to operate these devices. Also, continuity of efforts is needed to evaluate the benefits of technological intervention. In case of replacement or updating of a software, application or device, the advantages and benefits of the previous version and the need for improvement should be considered in tandem in order for the revised version to be useful and accepted by the end users (Johari, 2021). Thus, careful consideration of the local cultural and social context and stakeholder engagement is important for the successful adoption of newer technologies for FSN data collection and analysis.

Finally, among the challenges to evaluation and decision-making in FSN, relating to SDG 2 indicators, is the lack of transparency, ownership and open access to agricultural statistics. Thus, constraints relating to **ownership of and access to** the information generated from data collection and analysis on the part of relevant stakeholders must be addressed.

CONSTRAINTS RELATED TO THE LACK OF COORDINATION AMONG AGENCIES

The collection of data on FSN indicators related to the SDGs may involve multiple agencies within a country. Fragmentation of the data collection landscape within government agencies occurs in many countries as agricultural, food and nutrition data are not collected by NSOs but by different ministries. The lack of coordinated effort among these agencies at times leads to the duplication of efforts and can unnecessarily burden financially constrained projects and initiatives. Moreover, this hinders the interoperability and linkage between datasets, which is necessary to have a holistic understanding of FSN status and its drivers in a population. For instance, some of the required data may be collected by academia, involving individual researchers whose smaller surveys may not necessarily aim to reflect the nation at large, while other data may be collected by the private agencies and may be archived behind a paywall, limiting access to the data.

At the **global level,** much of the food security, agriculture and nutrition data are collated and disseminated by FAO. Data in the domain of health and nutrition, including those relating to maternal and child nutrition indicators such as exclusive breastfeeding,[14] are collected and disseminated by the World Health Organization (WHO) and United Nations Children's Fund (UNICEF). However, in both these instances, the raw data comes from the individual member states or regions. As such, the quality and richness of the data typically depend on the capacity of the individual nations (OECD, 2019). The **lack of coordination between national and international agencies** sometimes creates gaps between objectives and delivered outcomes. For instance, 50 percent of African NSOs perceived that capacity-building programmes did not involve sufficient consultation between national and international stakeholders, and over 30 percent of NSOs worldwide expressed that the programmes did not meet their needs (PARIS21, 2018b). This demonstrates lack of sufficient country ownership of statistics capacity building programmes. Furthermore, the lack of a shared vision and accepted consensus among countries on the importance of collecting data and resistance to harmonization of indicators and data collection methodology hinder international comparisons (Veillard *et al.,* 2010). Different UN agencies propose different methods and standards. This results in an inability to integrate and collect data across related datasets and some duplication of efforts. Some of the global constraints are reinforced by the lack of coordination between the large number of stakeholders involved and a lack of clear mechanisms for reporting and the means to deliver on their respective commitments (see BOX 23).

14 See the WHO Tracking Tool to improve maternal, infant and young child nutrition at https://extranet.who.int/nhdtargets.

BOX 23:
A CRITICAL VIEW OF FAO STATISTICAL SUPPORT TO MEMBER NATIONS

The need for better coordination of efforts is further elucidated by an evaluation of FAO statistical activities conducted by FAO itself in 2020. The aim of the evaluation was to provide Members with an assessment of FAO's statistical contribution to agricultural and rural development and food and nutrition security from 2012 to 2018. The evaluation team concluded that FAO's current internal statistical governance did not provide a solid basis for well-coordinated, coherent or satisfactory statistical work. This was attributed to weak enforcement of internal governance arrangements and the confusion over roles and responsibilities arising from a profusion of units and divisions conducting statistical activities (including at regional level), diluting their effectiveness. The need for FAO to better capitalize regional statistical expertise and regularly evaluate its programme resources allocated to statistical activities to ensure its appropriateness for the objectives of the work plan was recommended. The evaluation also identified that the limitation in statistical assistance provided to countries was further exacerbated by FAO's dependence on extra-budgetary resources for statistical capacity-building, which creates uncertainty on the sustainability of this capacity-development work. Thus, despite some progress in terms of quality, the statistics produced and disseminated by FAO were deemed to be only partly compliant with its Statistics Quality Assurance Framework (SQAF). The evaluation team further recommended that FAO expedite its efforts to improve the quality of its data and IT infrastructure support and organize and enforce an integrated statistical quality management system to ensure compliance with current and new internationally accepted statistical standards and norms for all its activities (FAO, 2020c).

In response to the evaluation, the Organization has taken several steps:

a) FAO statistics and data for statistical purposes are governed by and already adhere to three overarching frameworks: (i) the Fundamental Principles of Official Statistics (though mostly geared toward national statistical agencies); (ii) the Principles Governing International Statistical Activities, which focus on international organizations and whose second edition (2014) was endorsed by the Director-General; and (iii) the International Statistical Institute (ISI) Declaration on Professional Ethics, which provides ethical guidance for all professional statisticians working both in academia and in national and international organizations. In particular, Principle 6 of both the Fundamental Principles of Official Statistics and the Principles Governing International Statistical Activities, as well as Principle 12 of the ISI Declaration on Professional Ethics, focus on data protection and confidentiality.

b) Key FAO databases, which publish only aggregated statistical information, adhere to the open-data policy Creative Commons 3.0 Intergovernmental Organization (IGO) license. With the development of the FAO Statistics Data Warehouse (PC 132/5, paragraph 27), this license will apply to all corporate statistical databases available on the FAO website. FAO is currently also initiating discussions to upgrade to Creative Commons 4.0 IGO (CC-BY-4.0) to adhere to the Digital Public Goods Standard for Open Data, which stems from the UN Secretary-General's Roadmap for Digital Cooperation.

c) In 2019, FAO established a corporate platform for the dissemination of food and agriculture microdata (the Food and Agriculture Microdata [FAM] Catalogue) which applies the most advanced international standards and best practices in the treatment of personal data (personal data anonymization, use of statistical disclosure procedures and terms of use of microdata).

d) FAO has developed corporate standards requesting the informed consent of the respondents for all surveys directly carried out by the Organization.

CONSTRAINTS THAT CREATE A LACK OF TRANSPARENCY AND OF APPROPRIATE REGULATORY FRAMEWORKS

A third issue in terms of institutional arrangements for effective data collection and use is the need for governments to disclose data so that it can be easily accessed and used. In some cases, a lack of political will and hesitancy to share sensitive information may prevent the collection of data and publication of results on issues such as moderate levels of food insecurity, due to the fear that they may imply challenges far greater than those perceived and accepted by the national governments (Asian Development Bank, 2013; Banik, 2016; Thow *et al.,* 2018; Wan and Zhou, 2017). In other instances, access to food safety data may be regarded as sensitive information as this information could affect export opportunities.

Another important issue in terms of data collection and dissemination is the need for strong legal and regulatory frameworks that protect human rights and privacy. This is particularly so with the increasing involvement in FSN data generation and analysis on the part of private agencies.

BOX 24:
SATIDA COLLECT

SATIDA COLLECT is an Android application that allows for rapid and simple collection of data related to malnutrition and access to resources to support humanitarian aid organizations involved in drought and food security management.

SATIDA COLLECT is a freely available, flexible and efficient mobile application that was developed using and open-source toolkit for data collection "Open Data Kit (ODK) aggregate". SATIDA COLLECT also standardises data collection on malnutrition, socio-economic factors, access to resources, food prices, coping capacities and other related data. All assessments using SATIDA include GPS coordinates and are automatically uploaded to a database for storage. Its application programming interface (API enables data to be immediately displayed on web viewer The SATIDA database provides immediate access to the data and allows further analysis through features that enable sharing and export of assessments. In addition, it facilitates the visualization of drought risk with satellite-derived data. More importantly, from the user standpoint, it is an easy-to-use tool. SATIDA Collect was used in Central African Republic for monitoring food Security and analyse the drought risk and impacts.

Note: For more information, see: https://m.apkpure.com/satida-collect/com.satida.collect.android.

Source: Enenkel *et al.,* 2015

There have been advances in methods used to collect and instantaneously process food production including agricultural data are through the use advanced **sensor technologies and digital agriculture.**

Aquatic food is a vital source of food for people, and fish production requires constant monitoring and ready to use data. Such data access will prevent overexploitation or depletion of fish stocks and provide valuable information for effective fisheries management (Grilli, Curtis and Hynes, 2021).

Moreover, smart livestock farming also uses several technologies that analyse data to improve production with reduced environmental impacts. For example, new data analytic architectures that generate farm and field level data allows farmers and stakeholders to monitor processes and make a decision for the precision livestock farming. (Fote *et al.,* 2020). The use of these advanced technologies provides a level of granularity and immediate access to data that was lacking in traditional surveys.

BOX 25:
TACKLING CONSTRAINTS IN FOOD COMPOSITION DATA AVAILABILITY AND QUALITY

Food composition data are often used for assessment and planning of human energy and nutrient intakes, providing information for which many public health and nutrition policies and programs are based. The International Network of Food Data Systems (INFOODS) (https://www.fao.org/infoods/infoods/en/https://www.fao.org/infoods/infoods/en/) was established in 1984, aiming at stimulating and coordinating efforts to improve the quality and availability of food composition data globally. The network provides guidelines (e.g., quality assessment of data from journal articles for use in food composition tables, food matching, conversion of units), and standards (e.g., food nomenclature, terminology, classification systems, tag names), overview of food composition data management systems and software tools for dietary assessment. In addition, a comprehensive e-learning course on food composition data is available on their webpage.

To circumvent the lack of availability of nutrient content of aquatic foods, that are important in diets and nutrition in many regions of the world, the INFOODS' Global Food Composition Database for Fish and Shellfish (uFiSh) is a global database made available in Excel. uFish provides nutrient values for selected fish, crustaceans, and molluscs in raw, cooked, and processed form, covering data on proteins, minerals, vitamins, amino acids and fatty acids, primarily major finfish species. To further address the contribution from a diverse range of aquatic foods a new collaboration was launched in 2022 with multiple partners including the FAO, the University of Lancaster, WorldFish, and the Institute of Marine Resources, Norway, to increase accessibility and use of high-quality food composition data on aquatic foods to better inform public health and nutrition policies and programs based on updated and recent evidence.

Chapter 4

NEW AND EMERGING DIGITAL TECHNOLOGIES FOR FSN DATA

Colombia, Precision agriculture.

One of the most impressive and rapid developments of the last few decades has been the "data revolution" (Kitchin, 2014a) – a series of innovations that affect the way in which data are produced, managed, analysed, stored and utilized, which is dramatically changing the very nature of data and information. As eloquently put by Kitchin (2014a), in the past, data was so "time-consuming and costly to generate, analyse and interpret" that "good-quality data were a valuable commodity, either jealously guarded or expensively traded." Nowadays "the production of data is increasingly becoming a deluge; a wide, deep torrent of timely, varied, resolute and relational data that are relatively low in cost and, outside of business, increasingly open and accessible" (Kitchin, 2014a, p.1). Navigating this torrent presents challenges and opportunities, but it is unavoidable, including for agriculture, food security and nutrition.

In order to address FSN needs and opportunities associated with data, specific tasks need to be undertaken, primarily associated with the FSN data cycle (as introduced in Chapter 1), the six FSN dimensions (HLPE, 2020; Clapp *et al.,* 2021) and some of the constraints mentioned in chapters 2 and 3. This chapter begins by identifying and defining key new and emerging digital technologies that are relevant to food systems and FSN. Next, the specific tasks associated with the FSN data cycle, FSN dimensions and data constraints are described in detail, including how specific technologies can be utilized in those tasks.

The chapter closes in by highlighting risks associated with digital technologies that affect the extent to which the technologies can be successfully implemented and utilised and suggests appropriate mitigation measures.

LANDSCAPE AND RELEVANCE OF NEW AND EMERGING DIGITAL TECHNOLOGIES TO FSN

New and emerging digital technologies, such as big data, artificial intelligence (AI), sensors and the **internet of things (IoT)** and blockchain technology, feature prominently in precision agriculture, smart farming, and Agriculture 4.0 (the latter being defined as agriculture that integrates a series of technological innovations in order to enhance the agriculture value chain [Santos Valle and Kienzle, 2020]). Agriculture 4.0 has also been extended to Agri-food 4.0 – to include food supply chains (Lezoche *et al.,* 2020). Consequently, much data are being produced, collected, processed, analysed and disseminated in the context of FSN and are influencing the FSN supply chain (Wolfert *et al.,* 2017).

Box 26 presents definitions of the key new and emerging digital technologies that are, or have a potential to be, applied to FSN.

BOX 26:
DEFINITIONS OF NEW AND EMERGING DIGITAL TECHNOLOGIES

Artificial Intelligence: Artificial intelligence (AI) is the theory and development of computer systems able to perform tasks commonly associated with human intelligence. AI includes specific fields such as machine learning, perception, robotics and natural language processing. Computer vision and deep learning can be used to support visual perception.

Big data and cloud computing: Big data refers to high-volume, high-velocity, high-variety and high-veracity information assets that demand cost-effective, innovative forms of information processing for enhanced insight, decision-making and process automation. Cloud computing centralizes resources and services remotely and facilitates their use by multiple users without the need for the users to store the resources or install the services on their individual hard drives.

Blockchain technology: Blockchain technology (or distributed ledger technology) refers to a decentralized, distributed record such that the data units are broken up into shared blocks that are chained together with unique identifiers. The use of blockchain technology has increased, especially due to its application in cryptocurrencies, non-fungible tokens (NFTs), smart contracts, etc. A cryptocurrency is a virtual or digital currency secured by cryptography, designed to work as a medium of exchange through a computer network that is not reliant on any central issuing or regulating authority. A non-fungible token (NFT) is a non-interchangeable unit of data stored in the form of a digital ledger that can be sold and traded. Smart contracts are contracts or agreements that can be automatically executed, enforced, controlled and documented, partially or fully, without human interaction.

Crowdsensing (or community sensing) is a paradigm in which a community leverages devices with sensing and computing capabilities to collectively share data and extract information to measure and map phenomena of common interest (Kraft *et al.,* 2020). Crowdsensing differs from the paradigm of **personal sensing** as, in the latter, the phenomena that are monitored belong to an individual user, while crowdsensing applies to scenarios where the phenomena of interest cannot be easily measured by a single user or device (Ganti, Ye and Lei, 2011).

Crowdsourcing: Crowdsourcing is the practice of engaging a group of people (*a crowd*), usually via social media and the internet, to assist in collecting information, ideas, opinions or other input for a common goal, such as problem solving, innovation, etc.

Decision-support system (DSS): This refers to a software-based system that gathers and analyses data from a variety of sources in order to facilitate the decision-making process for management, operations, planning or optimal solution path recommendation.

Digital twin: A digital twin is a virtual representation that serves as the real-time digital counterpart of a physical object or system and that helps in decision-making.

Geographic information system (GIS): GIS is a system using software tools to capture, store, analyse and visualize location-relevant data often used to study and monitor land area usage, impact of weather events, etc.

Information visualization: This is the process of transforming data into an interactive, visual form that enables or triggers users to use their mental and visual capabilities to further understand and gain insight into that data.

Interactive voice response (IVR): This is a technology that allows humans to interact with a computer-operated phone system using voice and dual-tone multi-frequency (DTMF) user interface, allowing them to provide and access information.

Online social media: This refers to user-generated information, opinions, video, audio and multimedia that are shared and discussed over digital networks.

Semantic web: Semantic web technologies enable the creation of web-based data stores, the construction of vocabularies and ontologies, and the writing of rules to process the data. At the top of the Semantic web stack is inference, which is reasoning about data using rules.

Sensors and internet of things (IoT): A sensor is a device that measures a physical or chemical feature. Sensors include, but are not limited to: standard sensors (to detect soil moisture or for tracking animals, for instance), weather stations and remote sensing (for example, using satellite technology). Sensors that capture digital images or video are increasingly used to capture reality. These sensors can be fixed or mobile (mounted on tractors, robots, drones, etc.). The development of nano-computers and microcontrollers has facilitated and popularized the use of these sensors, making them accessible to a wide population. Sensors are commonly used in IoT applications. IoT refers to the network of physical objects that have sensors, software and other technologies to connect and exchange data with other devices and systems over the internet. IoT is often used together with other technologies such as machine learning, analytics, computer vision and robotics.

Ubiquitous computing: Ubiquitous computing is a concept where computing is made to appear or occur anytime and everywhere. Ubiquitous computing has become widespread, especially through mobile computing, where end users carry their devices (such as mobile phones) and use them in everyday activities and contexts. Mobile computing applications can be based on Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), chatbots, computer-assisted telephone interviewing (CATI), and other forms of applications, such as Open Data Kit (ODK)-based technologies.

Virtual reality and augmented reality: Virtual reality (VR) is a computer-generated simulated environment with objects and scenes that seem real, making the user feel immersed in the simulated environment. Augmented reality (AR) is an interactive experience of a real-world environment where the objects in the real world are enhanced by computer-generated information and features.

New and emerging digital technologies can support all the stages of the data cycle for FSN decision-making. They can also support the FSN dimensions and address some of the data-related constraints mentioned in chapters 2 and 3. The following sections describe specific tasks associated with each stage of the FSN data cycle and relevant new and emerging digital technologies for each task, with examples. FSN dimensions and constraints (referred to in the introduction and in Chapter 3) associated with the specific tasks are also mentioned.

DEFINE/REFINE EVIDENCE PRIORITIES AND QUESTIONS

Among the tasks associated with this stage of the data cycle is **assessing options and proposing priorities and questions.** As explained by Yoshida (2016), for example, various methods are used to set priorities in health and nutrition research. For instance, networks such as the Child Health Nutrition Research Initiative (CHNRI) and the James Lind Alliance (NIHR - National Institute for Health Research, 2021) gather information from experts (for example through the Delphi technique and through focus group discussions) and consolidate the expert opinions in order to set priorities. This approach, based on expert opinions, can be supported using digital technologies such as: Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), chatbots, crowdsourcing, machine learning, Open Data Kit (ODK)-based technologies, **Interactive Voice Response (IVR)** and other mobile applications. Such technologies may also help FSN actors contribute to and articulate priorities and weigh the different options (using machine learning, for example) thereby potentially improving clarity on priorities. Wazny *et al.* (2019), for instance, used the CHNRI method to set research priorities for maternal and child health and nutrition in India, using crowdsourcing to collect research ideas from a network of child health experts from across India. These approaches and technology may help to address the constraint pertaining to **lack of clarity on how to prioritize** (mentioned in the introduction). It is important to note that while the approach used by the CHNRI includes the collection of many research ideas from different sources (researchers, policymakers and programme managers), this process is executed in order to **define/refine evidence priorities and questions** and is therefore part of the first stage of the data cycle, rather than being part of the next stage in the data cycle of **reviewing, consolidating, collecting and curating data).**

REVIEW, CONSOLIDATE, COLLECT AND CURATE DATA

The data cycle stage concerned with reviewing, consolidating, collecting and curating data includes a number of specific tasks that can be supported by new and emerging digital technologies.

One of these tasks is **supporting the collection and production of FSN-relevant data, a task that can take many forms, including collecting FSN data** from respondents and complementing self-reported data. Digital technologies that can support the collection of FSN data from respondents include **crowdsourcing**, **crowdsensing**, **online social media**, SMS, USSD, chatbots, ODK-based technologies, IVR and other forms of mobile applications. Information collected from respondents using these technologies can include a wide variety of data relevant to any of the six FSN dimensions.

Respondents can report about incomes, expenditures, prices and the status of physical transport and communication infrastructure – information is relevant to the **FSN dimension of access.** For example, Ochieng (2019) describes a pilot study conducted in Malawi to crowdsource farm gate prices for pigeon peas and chickpeas through the Farm Radio Trust platform. Farmers reported the prices and locations at which they had sold their produce.

Respondents can also report about feeding practices, food preparation, food safety, dietary diversity and health-seeking behaviour. Such information is relevant to the **FSN dimensions of utilization**. For example, De Choudhury, Sharma and Kiciman (2016) conducted a study to estimate the quality of available foods in different geographical locations using data from 3 million food-related posts shared on social media. The study found that the foods in social media posts shared by people located in food deserts were higher in fat, cholesterol and sugar intake and lower in protein and fibre. Another effort by Shah *et al.* (2020), used natural language processing and machine learning algorithms to collect and analyse data from Twitter in order to assess Canadian's health and nutritional habits. The model classified food and non-food posts and provided information (such as caloric intake vs energy expenditure) of Twitter posts per province as well as foods and activities most tweeted about per province.

Respondents can report activities and events relevant to the **FSN dimension of sustainability,** such as those that are related to the environment and climate. For example, MIT's Climate CoLab (https://www.climatecolab.org) is an effort that taps into the collective intelligence of people from all around the globe to address societal problems, starting with climate change. Climate CoLab provides an open problem-solving platform through which thousands of people work on and assess plans to reach global climate-change goals.

Respondents (including farmers, veterinary officers and agricultural extension officers) can also report and help monitor the presence of pests and diseases which damage sources of food. For example, the Agritask agronomic platform, developed by the International Center of Insect Physiology and Ecology (ICIPE) and Tel Aviv University (TAU), provides a mobile application for field scouts and lead farmers to report pests from the field. The operations of the platform span four counties in Kenya, covering approximately 20 000 small subsistence farms.[15]

15 See https://start.agritask.com/wp-content/uploads/2020/10/Agritask-ICIPE-Case-Study-Final.pdf.

The task of collecting and producing FSN-relevant data may also involve complementing self-reporting data. Machine learning can be used for this purpose. For example, Schmidhuber *et al.* (2018) have used machine learning algorithms to extract dietary intake data from the Global Burden of Disease study and developed predictive models that estimate the consumption of each nutrient based on its national availability. Such data can inform initiatives to address nutritional needs of specific populations in the context of particular food systems.

Moreover, the task of collecting and producing FSN-relevant data may involve the automated collection of data pertaining to FSN entities such as: agricultural fields, weeds, pests, diseases, natural phenomena (such as weather) and natural food resources (e.g., wild foods, including fish). Digital technologies that can support the automated collection of data pertaining to FSN entities without involving respondents directly include: remote sensing technologies, GIS, robotics, IoT and **digital twins**. For example, WFP DataViz is a data visualization platform that provides interactive geographical and graphical information through Hunger Hub, Seasonal Explorer, Economic Explorer, Interactive Reports and Thematic Dashboards. Remote sensing data comes from the MODIS (moderate-resolution imaging spectroradiometer) instrument on board the NASA satellites Terra and Aqua. The remote sensing data are updated on a regular basis. The raster data (pixelated data where each pixel corresponds to a particular geographic location) are processed, aggregated and geo-referenced in order to present an easy-to-understand visualization (https://dataviz.vam.wfp.org/). Another example is Flybird Innovations, a social impact agricultural enterprise in India. Flybird has developed Siri, is a smart irrigation controller. Siri manages water and fertilizer application to crops and plants. Siri has **sensors** that collect data on soil moisture, temperature and humidity in order to prevent under- and over-irrigation and fertilization. Flybird also collects basic demographic information on its farmers, as well as geographic and crop data. This information enables Flybird to predict water requirements and optimal fertilization for farmers' crops (http://www.flybirdinnovations.com/).

As the examples described in this section demonstrate, many digital technologies can facilitate the task of **supporting the collection and production of FSN-relevant data.** This, in turn, can help address the constraint pertaining to **lack of available data**, which was mentioned in the introduction.

Moreover, new and emerging digital technologies can enhance the collection, storage and processing of qualitative data in the form of images, videos, audio recordings and text. Online social media, crowdsourcing and other mobile computing-based applications, for instance, can enable the collection of qualitative data. Big data and cloud computing can support the storage of qualitative data. Machine learning, through sentiment analysis for instance, enables the analysis of qualitative data. Online social media and **information visualization** enable the dissemination of qualitative data (Kanter and Gittelsohn, 2020). This can contribute to addressing the constraint pertaining to over-reliance on **quantitative data,** mentioned in the introduction.

Another task associated with the data cycle stage of reviewing, consolidating, collecting and curating data is **linking, integrating, aggregating and enriching data from different sources.** Digital technologies that can support this task include: **semantic web**, big data and digital twins. Examples of efforts in this regard include: FoodOn, CGIAR's Crop Ontology, FAO's AGROVOC, Wageningen University & Research's Digital Twin projects, BeeZon's Virtual Bee Consultant, and the CGIAR Platform for Big Data in Agriculture, which are described in Box 28. These digital technologies (in particular semantic web and big data) can contribute to improving **access to data** – mentioned in Chapter 2 as a key constraint. Semantic web can in fact support **harmonization** and interoperability of data and systems. Moreover, interoperability could also facilitate efforts around open-source tools and materials, which in turn can further contribute to data access. Open-access initiatives, open-source efforts and digital technologies (such as big data, crowdsourcing and mobile computing) can also help to alleviate constraints associated with **inadequate infrastructure and insufficient resources and capabilities** (mentioned in Chapter 3) which arise in other stages of the data cycle.

BOX 27:
EXAMPLES OF EFFORTS THAT SUPPORT DATA CONSOLIDATION

FoodOn is an ontology that describes common foods from around the world. The ontology can be used to construct statements about food, which can be entered in a database and queried or reasoned about. FoodOn focuses on foods for humans and domesticated animals. It contains animal and plant food sources, food categories and products, and other facets such as preservation processes, contact surfaces and packaging (Dooley *et al.,* 2018).

CGIAR's Crop Ontology provides descriptions of agronomic, morphological, physiological, quality and stress traits along with a standard nomenclature for composing the variables. The ontology enables digital capture, aggregation and integration of crop trait data, as well as comparisons across farmers, breeders, scientists and other communities, through surveys with citizen science tools. As of 10 November 2020, the CGIAR website reported that the ontology comprised 4 235 traits and 6 151 variables for 31 plant species (www.cropontology.org) and supported the generation of FAIR (findable, accessible, interoperable and reusable) data (https://bigdata.cgiar.org/digital-intervention/crop-ontology-2/).

FAO AGROVOC (https://www.fao.org/agrovoc/about) is a multilingual and controlled vocabulary designed to cover FSN-relevant concepts, terms, definitions and relationships. The concepts are used to support unambiguous identification of resources and standardization of indexing processes, and to make searching more efficient. Each concept also has terms used to express it in various languages. AGROVOC consists of over 39 800 concepts and over 929 000 terms in up to 41 languages.

Wageningen University & Research's Digital Twin projects, which are still under development, comprise: Virtual tomato crops; Me, my diet and I; and Digital Future Farm (https://www.wur.nl/en/newsarticle/WUR-is-working-on-Digital-Twins-for-tomatoes-food-and-farming.htm). he virtual tomato crops project is developing a digital twin of a real tomato crop in a greenhouse – a 3D simulation model that is fed in real-time with sensor information from a real greenhouse. The interactions between the specific characteristics of the tomato crop, the environmental factors and crop management measures are all simulated in the virtual crop. Since the model is linked to a real tomato crop in a greenhouse, it is possible to continually refine predictions and thus make better choices for the real crop. It is anticipated that once the model is completed, growers can use it as a decision-support tool for growing real tomato crops in a greenhouse. For example, it will allow growers to predict the effect of a crop management measure on crop harvest and financial yield and thus make a decision for the real tomato crop based on that prediction.

Virtual Bee Consultant by BeeZon (www.beezon.gr) is a digital twin solution of bee colonies involving a real-time continuous apiary monitoring system that enables beekeepers to remotely monitor their apiaries and make smart management decisions with minimal in-person interaction. The solution is based on a GPS-based tracking system and real-time data from various sensors (measuring humidity, exterior and interior temperature, brood temperature and weight). Specifically, beekeepers can remotely monitor and act upon the following aspects: timing of nectar flows; identifying the presence of diseases, pest infection, pesticide exposure and toxicity; insight into colony status, dynamics and hygiene; identification of queenless and swarming states; management of food storage reserves; antitheft mechanisms and tracking systems; and notification systems tailor-made by the user (Verdouw and Kruize, 2017).

CGIAR's Platform for Big Data in Agriculture (https://bigdata.cgiar.org/) aggregates data from various different sources. This is facilitated through the Global Agricultural Research Data and Innovation Network (GARDIAN, https://gardian.bigdata.cgiar.org/), which enables searches across all CGIAR repositories and connection to more datasets from strategic partners.

Enabling respondents to assist in cleaning up data is another task associated with the data cycle stage of reviewing, consolidating, collecting and curating data. Digital technologies that can enable respondents to assist in data clean-up include crowdsourcing, crowdsensing, online social media, other forms of mobile applications and IVR. For instance: crowdsourcing efforts similar to the ones presented by Chu *et al.* (2015) could be applied in FSN.

Furthermore, data **validation, verification, authentication, traceability and transparency** is another task associated with the data cycle stage of reviewing, consolidating, collecting and curating data. Digital technologies can support this task. For instance, ODK-based technologies support validation of user input captured through online forms and other types of user interfaces. Moreover, digital technologies, such as **blockchain technology**, machine learning, crowdsourcing, crowdsensing, online social media, mobile computing and IVR, are increasingly supporting validation, verification, authentication, traceability and transparency through more sophisticated means. Specific examples of these technologies include Barilla's blockchain system, the Blockchain Supply Chain Traceability Project, WFP Building Blocks, and AgUnity's blockchain application, as described in Box 28. Still on blockchain technology, cryptocurrencies are being experimented for adoption in FSN. One example is by AgriDigital, a technology provider for the grains industry that connects physical inventory, supply chain data and finance (www.agridigital.io/). In December 2016, AgriDigital executed the world's first sale of 23.46 tonnes of grain between farmer and buyer via blockchain. AgriDigital has so far transacted more than 1.6 million metric tonnes of grain (Sylvester, 2019). Furthermore, the Colombian delivery app Rappi, which offers on-demand deliveries of food and other goods across Latin America, launched a cryptocurrency payment pilot programme in Mexico in April 2022 (Reuters, 2022). Moreover, Burger King has been piloting transactions in cryptocurrencies in Germany, the Netherlands and Venezuela, McDonald's has been experimenting with this in El Salvador, and KFC has been piloting this in Canada (Traders of Crypto, n.d.).

BOX 28:
EXAMPLES OF THE APPLICATION OF BLOCKCHAIN TECHNOLOGY TO FSN DATA

Barilla's blockchain system: Barilla collaborated with IBM in 2018 to develop a blockchain system to add transparency and traceability to its pesto production cycle (https://cryptonews.net/en/editorial/technology/icons-of-italian-business-opt-for-blockchain/). Through the blockchain system, customers can verify the details of a product, including cultivation, treatment, harvesting, transportation, storage and quality control (Sylvester, 2019). Digital technologies are therefore relevant to the FSN dimension of utilization. Barilla's blockchain system also shows the possibility of using digital technologies to authenticate and promote transparency of FSN data. For instance, to authenticate and promote transparency of measures, indicators and scales.

The Blockchain Supply Chain Traceability Project: This project was initiated in 2018 by World Wildlife Fund (WWF) New Zealand, WWF Australia, WWF Fiji, ConsenSys, TraSeable and Sea Quest Fiji Ltd. The project uses blockchain technology to track tuna towards stamping out illegal fishing and human rights abuses in the tuna industry. Through blockchain technology, a simple scan (for instance through a smartphone using a QR code) of tuna packaging tells the story of a tuna fish, including where and when the fish was caught, by which vessel and the fishing method used) (https://www.wwf.org.nz/what_we_do/marine/blockchain_tuna_project).

Blockchain technology can therefore support the measurement of sustainability in FSN.

WFP Building Blocks: This is a blockchain solution for authenticating and registering transactions. The blockchain solution was tested as a proof-of-concept by WFP in January 2017 in Sindh Province, Pakistan. Four months later, WFP launched a pilot project covering 10 000 Syrian refugees in Azraq refugee camp. In January 2018, the pilot was extended to cover 100 000 refugees living in camps (Sylvester, 2019). The solution enables people to receive different types of assistance from multiple humanitarian organizations at once, thus reducing the complexity of accessing humanitarian support. At the same time, no sensitive information is stored anywhere on Building Blocks. Since 2017, the solution has been scaled to provide USD 325 million worth of cash transfers to 1 million refugees in Bangladesh and Jordan. It is considered the world's largest implementation of blockchain technology for humanitarian assistance (https://innovation.wfp.org/project/building-blocks). WFP Building Blocks demonstrates that blockchain technology can support the FSN dimension of access.

AgUnity's blockchain application: AgUnity has developed a smartphone application to tackle the financial and digital exclusion of remote smallholder farmers and rural communities using blockchain technology. The smartphone application helps farmers plan, sell produce, buy inputs and track everyday transactions. In a project funded by USAID, AgUnity has partnered with Virginia Tech (in the United States of America) and Egerton University (in Kenya) and customized the smartphone application to increase the flow of African indigenous vegetables to end consumers to help increase food and nutrition security in the western part of Kenya (https://www.einnews.com/pr_news/541948521/exploring-the-use-of-blockchain-technology-to-improve-food-security-in-western-kenyahttps://www.einnews.com/pr_news/541948521/exploring-the-use-of-blockchain-technology-to-improve-food-security-in-western-kenya).

As described in this subsection, digital technologies can assist in data **validation, verification, authentication, traceability and transparency** and in **enabling respondents to assist in cleaning up data.** Thus, digital technologies can contribute to **data quality.**

ANALYSE DATA USING APPROPRIATE TOOLS

One of the key tasks associated with the data cycle stage of analyzing data is **analyzing, detecting and predicting FSN-relevant aspects and**

entities, such as: food production; food supplies, food aid and food stock levels; markets; prices; dynamics of net trade; inequity factors; occurrence of adverse conditions; feeding practices; trade; pests; diseases and nutrition aspects. The task of **analyzing, detecting and predicting FSN-relevant aspects and entities** is relevant to **any FSN dimensions** depending on the FSN aspects under consideration. For instance, if the FSN aspects under consideration pertain to food production, then the task of **analyzing, detecting and predicting FSN-relevant aspects and entities** will be relevant to the **FSN dimension of availability.**

Machine learning, big data and analytics can greatly support the task of **analysing, detecting and predicting FSN-relevant aspects and entities**. For example, Talukder and Ahammed (2020) used machine-learning algorithms, specifically Random Forest (RF), Support Vector Machines (SVM) and K-Nearest Neighbor (KNN) algorithms, to process dietary patterns or nutrient and food intake data in order to predict malnutrition among children under five years of age in Bangladesh. Another machine learning algorithm, namely linear regression, was used to identify risk factors for stunting, underweight and wasting among under-five children in Bangladesh. In a similar effort (Rahman *et al.,* 2021), RF exhibited high accuracy in predicting malnutrition among under-five children in Bangladesh.

Another effort implemented by Kwon *et al.* (2020) uses a machine-learning algorithm to identify risk factors for low muscle mass based on nutritional and health-related factors among men and women. The algorithm generated five separate clusters for men and women based on age, total energy, carbohydrate ratio, protein ratio, fat ratio, smoking habits, alcohol consumption, physical activity and number of chronic diseases, yielding similar characteristics among each cluster. Another machine learning algorithm, namely logistic regression, was subsequently used to analyse the associations between each of the nine variables and low muscle-mass index, hence identifying risk factors within each cluster. A similar effort, described by Zeevi *et al.* (2015), uses a machine-learning algorithm integrating blood parameters, dietary habits, anthropometrics, physical activity and gut microbiota to predict personalized postprandial glycaemic response to real-life meals.

Yet another effort that supports the task of **analysing, detecting and predicting FSN-relevant aspects and entities** is *PlantVillage Nuru*,[16] an on-farm pest and disease identification system. Deployable as a mobile application, *PlantVillage Nuru* can help smallholders detect, identify and manage cassava diseases. The system development team annotated more than 200 000 cassava plant images, identifying and classifying diseases to train a machine-learning model. As of June 2020, the mobile application had been downloaded and used in more than 40 countries and had generated more than 18 000 reports from users.

Another task related to the data cycle stage of analysing data is **mapping and monitoring FSN aspects and entities,** such as agricultural fields, infrastructure, livestock herds, natural phenomena and natural food resources (including wild foods and fisheries resources). The collection and linking of the underlying data could be related to what was described earlier regarding review, consolidation and curation of data. Digital technologies that can support **mapping and monitoring of FSN aspects and entities** include: AI, information visualization, IoT, GIS, satellite technologies and digital twins. For example, PeskAAS, which is an open-source monitoring and analytics application that enables the collation, classification, analysis and visualization of data pertaining to small-scale fisheries catch and effort. Through the application, fishers themselves, managers and researchers can gain insights into a fisher's experience of fishing efforts, fisheries status, catch rates, economic efficiency and geographic preferences and limits that can potentially guide management and livelihood investments. The application primarily uses classification, analytics and an information visualization dashboard that was codesigned with fisheries

16 See https://bigdata.cgiar.org/divi_overlay/plantvillage-nuru/.

experts and government managers (Tilley, Lopes and Wilkinson, 2020). PeskAAS is relevant to the FSN dimension of availability, among others.

Another example is the GEOGLAM Crop Monitor for the G20 Agricultural Market Information System (AMIS) (SEE BOX 2). AMIS provides open, timely, science-driven information on crop growing conditions, status and agroclimatic factors likely to impact global production. It focuses on the major producing and trading countries for the following four primary crops: wheat, maize, rice and soybean. The information is presented as reports that include interactive visualizations (Becker-Reshef *et al.,* 2019). AMIS is relevant to the FSN dimension of stability.

Another example which supports the task of mapping and monitoring FSN aspects and entities and which is relevant to the FSN dimension of stability is the Integrated Food Security Phase Classification (IPC) Mapping Tool. The tool uses interactive and customizable maps to visualize data. Each country is colour-coded by its latest IPC classification for both acute food insecurity (AFI) and chronic food insecurity (CFI) scales (https://www.ipcinfo.org/ipc-country-analysis/ipc-mapping-tool/).

The East Africa Drought Watch is another example relevant to the task of mapping and monitoring FSN aspects and entities. It is a near-real-time platform that uses earth observation and weather data to monitor drought in East Africa. The platform has been adapted from the European Drought Observatory and customized to the East Africa region. The East Africa Drought Watch is part of the Intra-ACP (African, Caribbean, and Pacific) Climate Services Project. The platform has involved collaboration with the Drought group of the Natural Disaster Risk Unit at the Joint Research Centre of the European Commission. The platform monitors several indicators, including Standardized Precipitation Index (SPI), Soil Moisture Anomaly (SMA) and anomalies of satellite-measured FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) (See https://droughtwatch.icpac.net/ https://droughtwatch.icpac.net/).

Another example which supports the task of mapping and monitoring FSN aspects and entities is the online platform Global Forest Watch (GFW). The platform provides data and tools for monitoring forests through which users can access near-real-time information about where and how forests are changing around the world using dashboards of maps and visualizations (https://www.globalforestwatch.org). Since forests support an ecosystem that can sustain food production in the long term, through climate change mitigation, soil formation, soil erosion control and biodiversity conservation (Meybeck *et al.,* 2021), the GFW online platform is relevant to the analysis of sustainability of FSN.

TRANSLATE DATA INTO RESULTS, INSIGHTS AND CONCLUSIONS

Digital technologies can be used to support various tasks associated with translating data into results, insights and conclusions on FSN. These include **aiding the presentation of data to users by rendering it easy to understand.** Information visualization is one of the primary technologies for supporting the understandability of data in any of the six FSN dimensions. A notable example is the Food Systems Dashboard, presented in Chapter 2, which combines data from different sources to facilitate understanding, comparison and decisions on food systems (https://foodsystemsdashboard.org). Another example that uses information visualization is the ICES Marine Food Stock Assessment Database, whose marine food stock assessment information is presented using graphs and tables (https://www.ices.dk/data/assessment-tools/Pages/stock-assessment-graphs.aspx).

DISSEMINATE, SHARE, REVIEW, DISCUSS RESULTS, REFINE INSIGHTS AND CONCLUSIONS

Digital technologies can be used to support a range of specific tasks linked to the stage of the data cycle concerned with **dissemination, sharing, review, discussion of results and refinement of insights and conclusions.**

One of the tasks associated with this data cycle stage is making data accessible. New and emerging digital technologies, such as big data, machine learning, semantic web, visualization, crowdsourcing, online social media and mobile computing, can be used to make data accessible. In this way, digital technologies can contribute to addressing of the constraint associated with lack of availability and access to data. One example a relevant digital application is mKisan (https://mkisan.gov.in), a mobile application that makes agroadvisory data accessible to smallholder farmers in India. The application was one of the first examples in India of a platform through which smallholders can access agrometeorological and market price information and receive related advice on crops and livestock, thus making mKisan especially relevant to the FSN dimension of agency.

Other tasks associated with the data cycle stage of data dissemination, sharing, review, discussion of results and refinement of insights and conclusions are supporting efficient communication, wide distribution and discussion. Online social media can play a key role in supporting the foregoing task. For example, WhatsApp was used in 2016 by project implementers from the ministries of health and agriculture in selected counties of Kenya to share additional monitoring data in the form of photographs, videos and texts regarding farm status, sales, activities that the implementers carried out, etc. As a result, information delays were reduced due to collapsed reporting hierarchies, and project monitoring-related costs were reduced by 51 percent. A shared understanding on the part of different actors on the project's indicators, reporting timelines and data collection guidelines improved the quality of continuous monitoring data (Chesoli, Mutiso and Wamalwa, 2020). Digital technologies can therefore improve timeliness in the dissemination of data (and also in other stages of the data cycle). Digital technologies (such as robotics, machine learning and DSS) can enhance efficiency of specific FSN activities as well as addressing some human resource constraints (such as responsible digital automation and user- and context-adaptive digital systems).

Another task relevant to this data cycle stage is promoting transparency, traceability and accountability. Digital technologies that can support this task include crowdsourcing, crowdsensing, online social media, information visualization and blockchain technology. (This task is also related to the task of validation, verification, authentication, traceability and transparency which was mentioned earlier). An example relevant to this task is a feasibility study carried out by Global Pulse in partnership with FAO and WFP in which crowdsourcing was used to track food prices in near-real-time in Nusa Tenggara Barat, one of Indonesia's poorest provinces (https://www.unglobalpulse.org/project/feasibility-study-crowdsourcing-high-frequency-food-price-data-in-rural-indonesia/). The area comprised almost exclusively informal, cash-only markets and stalls, where availability of other data sources was limited. The study involved local *citizen reporters* who submitted food price reports via a customized mobile phone application. One of the findings was that crowdsourcing, which captures high-frequency data on local trends, is best deployed in areas where traditional data capture methods are difficult, impractical or costly due to insecurity, food price volatility and geographic dispersion. This example shows that digital technologies can contribute to enhance livelihoods and, thus, access to food.

USE RESULTS, INSIGHTS AND CONCLUSIONS TO MAKE DECISIONS

One of the tasks associated with the data cycle stage of using results, insights and conclusions to make decisions is **profiling food security and nutrition entities and using the resultant data to gain insights for decision-making.** FSN entities that can be profiled include: equipment, animals, crops, food, relevant people (for example, subjects such as farmers and consumers), natural phenomena, etc. New and emerging digital technologies that can support this task include AI, big data, information visualization and digital twins. For example, Destination Earth, (or DestinE) (see https://digital strategy.ec.europa.eu/en/library/destination-earth), an initiative of the European Commission, is developing a digital model of the earth (a digital twin) to monitor and predict natural phenomena and related human activities towards supporting sustainable development and tackling complex environmental challenges. The digital twin will be a digital replica of the earth system and will be built based on the domains of earth science. DestinE is expected to help policymakers simulate and monitor the earth's system developments (land, marine, atmosphere, biosphere) and human activities; anticipate environmental disasters and resultant socioeconomic issues in order to protect lives and avoid major economic downturns; and enable the development and testing of scenarios for guiding more sustainable development. These efforts can contribute to providing data on sustainability.

If profiling data are used to track relevant food security and nutrition indicators, they can contribute data on food utilization. For example, one of Wageningen University & Research's Digital Twin projects (mentioned earlier) is the *Me, my diet and I* project (see https://www.wur.nl/en/newsarticle/WUR-is-working-on-Digital-Twins-for-tomatoes-food-and-farming.htm). This project is bringing together human nutrition, health, AI and social science experts to build a personalised digital twin to predict the rise in blood sugar (glucose) and in blood fat (triglyceride) after a meal. The project is also expected to provide individualized nutritional advice based on personal data, such as body mass index, age, body fat distribution and blood pressure.

Digital technologies such as big data, machine learning, semantic web, visualization, crowdsourcing, online social media and mobile computing can provide users with information and resources that can guide them in making their own decisions, thereby supporting the FSN dimension of agency. For example, FoodSwitch, which is a mobile application that provides users with easy-to-understand nutrition information and support the selection of healthier choices when shopping for food. It allows users to scan the barcodes of food and drink products and instantly see whether they are high (red), medium (amber) or low (green) in fat, saturates, sugars and salt. It also searches the database for similar but healthier alternative products, facilitating the switch to healthier food choices (Dunford *et al.,* 2014). The application uses crowdsourcing to obtain nutritional information on additional food products. The application has so far been launched in Australia; China; China, Hong Kong SAR; Fiji; India; Kuwait; New Zealand; South Africa; the United Kingdom of Great Britain and Northern Ireland and the United States of America (see https://www.georgeinstitute.org/projects/foodswitch). Another example is the mobile and web platform by and for Inuit, called SIKU (https://siku.org/about). It provides tools and services for indigenous knowledge pertaining to aspects such as weather conditions, sea-ice safety, wildlife sightings and sharing information about hunting exploits. Some of the tools supported by the platform use digital technologies such as online social media and geographical mapping of sea ice using Google Street View. Another related effort is Digital Green (https://www.digitalgreen.org/), a development organization that aims to empower smallholder farmers to lift themselves out of poverty by harnessing the collective power of technology and grassroots-level partnerships using various tools, such as social media and mobile applications.

It is worth noting that mobile applications can play a key role in empowering smallholder farmers and other vulnerable FSN stakeholders, for instance, through mobile financial services. According to the Global System Mobile Association, mobile financial services can be beneficial to smallholder farmers in various ways, including time and cost savings, convenience and efficient cash management. Moreover, mobile money technology can enable agribusiness companies to lower the costs of withdrawing, transporting and securing cash; facilitate real-time payments across multiple locations and mitigate risks associated with handling cash, such as theft and fraud (Arese Lucini, Okeleke and Tricarico, 2016). Furthermore, recent studies have observed that mobile money adoption can have a positive effect on farm input use, farm output and welfare of smallholder farmers (Abdul-Rahaman and Abdulai, 2022; Peprah, Oteng and Sebu, 2020).

RISKS ASSOCIATED WITH DIGITAL TECHNOLOGIES FOR FSN AND THEIR MITIGATION

As noted in Chapter 3, some of the risks and issues inherent in data collection and analysis can be even more relevant to digital technologies, while some typologies of risks are exclusive to these technologies. This section describes various risks associated with the new and emerging digital technologies for FSN. It also proposes measures that can be taken to mitigate these risks.

ETHICS, DATA PROTECTION, TRUST, JUSTICE AND IDENTITY

There are various ethical concerns associated with digital technologies, as they can be used to undertake tasks in a manner that undermines or overrides personal judgment. While in certain specific situations (to avert disaster, for instance) undermining or overriding autonomous individual choices may be beneficial, there are scenarios where the capacity to do this may be used maliciously. For instance, AI can be used to manipulate user behaviour in a way that undermines autonomous rational choice. Users' intense interaction with AI systems enables the latter to collect a great deal of knowledge about the users. Notwithstanding the potential benefits of acquiring and using such knowledge, algorithms can be used to target users and, therefore, influence them (Narayanan *et al.*, 2020). This manipulation often uses dark patterns, whereby user interface design choices coerce, steer or deceive users into making decisions that, if fully informed and capable of opting for alternatives, they might not make. For example, through AI, social media can aggressively advertise unhealthy food to vulnerable categories of users, such as children and adolescents (Freeman *et al.*, 2014).

While digital technologies can be used to support and promote human rights and justice in FSN, there are situations where inconsiderate digital automation (such as through AI and robots) may create conflict with such norms. As Yeung (2018) notes, the use of algorithmic decision-making by AI systems can contribute to discrimination and threaten human rights in various ways, for instance when there are biases inherent in algorithmic decision-making AI systems. This can happen if the developers of the algorithm are (consciously or unconsciously) biased, if biases are built into the model upon which the systems are built or are present in the training data or in the input data (European Union Agency for Fundamental Rights, 2019), or if they are introduced when such systems are implemented in real-world settings. These biases might create or reinforce existing discrimination. While acknowledging that technology-based decision-making can enhance the accuracy, effectiveness and efficiency of law enforcement, General Recommendation No. 36 on Preventing and Combating Racial Profiling (24 November 2020) by United Nations Committee on the Elimination of Racial Discrimination, also points out that big data and AI tools may reproduce and reinforce already existing biases and lead to even more discriminatory practices (https://www.ohchr.org/en/hrbodies/cerd/pages/cerdindex.aspx). Another way through which the use of algorithmic decision-making AI systems may contribute to discrimination and threaten human rights, is when there is lack of transparency of the complex digital technology behind the systems (Yeung, 2018). The foregoing issue limits the ability of users to participate in, contest or otherwise challenge their decision-making (in terms of inputs, logic or outcomes). Consequently, there is likely to be power asymmetry, for instance, between the AI system developers, service providers or third parties, and those who interact with the AI systems. Moreover, AI systems may fail to give a comprehensible explanation of their underlying decision-making process to the affected individuals. This opacity and power asymmetry not only expand opportunities for potential exploitation, but may erode the sociotechnical foundations of justice, morality and human rights (Yeung, 2018). Some researchers, such as Baú and Calandro (2019), have recommended a human rights-based approach to digital technology. Furthermore, if the decision-making process of the digital system is hidden from the person directly affected by the outcomes, then the person may not trust the system. This is why, for instance, research for explainable AI is being conducted (see, for example, Rudin, 2019).

Currently, there are few FSN efforts aimed at increasing the interpretability and explainability of AI systems. Khan and Hoffmann (2003), for instance, propose and describe a menu construction using an incremental knowledge acquisition system (MIKAS). The diet recommendation system asks experts to provide an explanation for each of their actions, to include the explanation in the system's knowledge base. Interpretability and explainability of algorithms ought to be prioritised beyond performance and error rates (Côté and Lamarche, 2021). Algorithm developers, model builders and domain experts could provide explanations for the application's decisions for inclusion in the system's knowledge base and output. Open-source initiatives can also contribute to interpretability, transparency and explainability of systems. For instance, the details of a model can be fully described within source code. It is, however, also important to be aware that information other than the source code may be required to fully understand a model, including the nature of data, documentation, etc. (Sampson *et al.,* 2019). Digital technologies that are transparent and give users freedom of choice are desirable.

In order to mitigate the risks associated with digital technologies, it is also valuable to build the capacity of users. For instance: providing users with full information, including on risks and biases; educating users about their digital rights and responsibilities; ensuring that users are trained or supported to handle relevant technologies; creating an enabling environment for users to access the required digital infrastructure and digital resources; etc. It is important to include stakeholders in the needs analysis, design, piloting and implementation of digital technologies. When users are involved in the process, they are more likely to provide contributions to the system development process and trust and accept the realized systems (Maguire, 2001).

Another concern associated with digital technologies is who owns the FSN digital data, who has access to it, and who has control over its use and implementation. Issues of ownership, access to and control of data can lead to risks associated with inequitable data access, power asymmetry, negative exclusive property regimes over data, exclusion (wilful or not) of certain types of data, unethical tracking and targeting (for instance, through AI-powered unethical target advertising), and market dominance by organizations and bodies that control the data (SEE BOX 29). In the process, digital technologies could affect the cultural fabric and identity of FSN stakeholders (Klerkx, Jakku and Labarthe, 2019) – for instance, what it means to be a farmer (Burton, Peoples and Cooper, 2012; Carolan, 2017), and a possible change in the culture of farming from a hands-on approach to data-driven management (Butler and Holloway, 2016; Carolan, 2017). Moreover, there are cyber-security risks associated with digital technologies in FSN (for instance, for smart farming as described by Barreto and Amaral [2018]). Users and respondents in FSN may be concerned about the privacy, protection and misuse of their data. They may fear that their data may be used to exploit them, may be used against them, may end up in the wrong hands, or may put them in precarious positions in the future. Some researchers (e.g., Clapp and Ruder, 2020) have argued that digital technologies can reinforce existing systems which are considered economically, socially and ecologically unsustainable and favour specific FSN players (Rijswijk *et al.,* 2021).

BOX 29:
CHALLENGES WITH DIGITALIZING SERVICES AND ACCESS: THE CASE OF INDIA'S AADHAAR IDENTIFICATION NUMBER

India's Aadhaar (literally "the foundation" in Hindi) programme, intended to provide a unique 12-digit identification number to 1.3 billion Indian residents, was launched in 2009 as a voluntary biometric ID system to smooth delivery of public services, such as food assistance and welfare benefits, and reduce fraud. However, since 2014, the biometric ID system under Aadhaar is being made compulsory to access more and more basic services and entitlements. Failure to obtain an Aadhaar number has sometimes hindered residents' access to fundamental benefits such as rice or wheat at subsidized prices, an important source of food security for many Indians, access to pensions, school admissions for children and so on, and this is why proper functioning of the system is essential. Implementing this system presents a number of challenges that have led to shortcomings. Some of these shortcomings are caused by limited availability of the necessary IT infrastructure, including electricity, to operate the biometric ID systems, especially in rural areas. In addition, if someone is unable to go in person for biometric identification, the benefits cannot be accessed. While delegation systems exist on paper, in practice they rarely work. This disproportionately affects the elderly and the disabled, and those from remote villages. Furthermore, repeated reports of data leaks have raised concerns for the privacy of personal records, which is particularly worrying as the Aadhaar identification number is not only a condition to receive social support, but increasingly linked to private transactions, including tax payments.

The issues presented in the implementation of the Aadhaar programme should be used as a learning experience to exercise caution in the adoption of new digital technologies when these are linked to fundamental access to food and social protection, as possible technology, infrastructure and capacity constraints can deeply affect the realization of the right to food for the neediest and exacerbate inequalities.

Source: Khera, R. (2019)

In response to the risks associated with data ownership, access and control, a responsible research and innovation (RRI) approach to digital transformation has been proposed for use, for instance, in agriculture (Barrett and Rose, 2022). The RRI approach is based on four main principles: anticipation, inclusion, responsiveness and reflexivity. Similarly, Rose and Chilvers (2018) propose a more systemic approach to map innovations associated with digitalisation in agriculture; broadening of notions of inclusion in RRI to include a diversity of stakeholders; and evaluating responsible innovation frameworks in practice to determine if innovation processes can be made more socially responsible.

It is also important to formulate and enact laws, regulations and policies on ethics, consent, privacy, data protection, ownership, fair competition and copyright. Governments and regional and international organizations should involve stakeholders in defining and implementing appropriate data standards and policies in order to minimize the potentially negative consequences of data access and sharing. Ge and Bogaardt (2015) studied a number of data harvesting initiatives in agrifood chains to identify the key governance issues to be addressed. Examples of data protection and privacy laws and regulations include the European Union's General Data Protection Regulation (https://gdpr-info.eu/) and the Data Protection Act of the United Kingdom (of Great Britain and Northern Ireland) (https://www.legislation.gov.uk/ukpga/2018/12/contents/enacted). Such laws and regulations are often subject to the oversight of an independent authority to ensure compliance and protection of individual rights. At a broader level, the UN Global Pulse has developed Privacy Principles in consultation with experts from various sectors. The United Nations Secretary-General's Independent Expert Advisory Group on a Data Revolution for Sustainable Development has recommended the development of a global consensus on principles and standards concerning legal, technical, privacy, geospatial and statistical standards to, among other things, facilitate openness and information exchange and promote and protect human rights (FAO, 2017; UN, 2015) It is worth noting the UN High-Level Committee on Programmes (HLCP) is looking into a global data governance framework (https://unsceb.org/session-report-369).

It is particularly important for FSN actors to protect potentially vulnerable segments of society. For instance, Kraak *et al.* (2020) propose various actions to protect young people from irresponsible digital marketing that could negatively impact diets and lifestyle choices. Among these proposed actions are recommendations that technology firms develop policies to protect the digital privacy rights of young people; enforce standards for digital platforms that support responsible marketing to children and adolescents; and ensure that digital marketing and media policies are posted on the firms' public websites. Kraak *et al.* (2020) also propose that governments develop comprehensive national legislation, regulations and policies that protect digital privacy and restrict the use of all forms of digital marketing to children and adolescents; collaborate with international and regional bodies to develop cross-border policies to regulate transnational digital marketing and media practices; monitor and evaluate how transnational companies are using digital marketing and social media and enhance accountability for their practices. (More details on governance of FSN data are presented in Chapter 5).

It cannot be overstated that early and continuous inclusion and involvement of all relevant stakeholders is key to the acceptance and success of new technologies in the FSN sector. Stakeholders include, but are not limited to, governments, industry, consumer groups, NGOs, farmers and other smallholder producers. Although upstream and downstream sectors influence the adoption of technologies by farmers, they can also learn from farmers so that the technologies implemented take into account the requirements of the farmers (OECD, 2001). In order to ensure that everyone is in a position to benefit from new technologies and that technology-based efforts do not reinforce the digital divide, it is important to ensure that digital technology implementations are adapted to the needs, requirements and contexts of all users and stakeholders, especially vulnerable groups and those in developing countries who have less digital access (due to low internet connectivity, for example) and human capital (for instance, related to low literacy levels). Of course, support to ensure access to and utilisation of technologies should indeed be provided for all stakeholders, especially for those who are vulnerable. Furthermore, during the conceptualisation, design and implementation process of such efforts, it is also important to take into account indirect and long-term effects of the digital technologies. Moreover, it is instructive to create spaces for FSN stakeholders to reflect on how digitalization will affect existing FSN innovation systems (Bronson, 2019; Klerkx, Jakku and Labarthe, 2019) and to consider a policy-driven strategic overview of FSN needs and priorities (Regan, 2021).

Involving users and stakeholders in the design and implementation of digital applications early and throughout the process, it becomes possible to anticipate and address the associated risks and needs (Rijswijk *et al.,* 2021) and significantly increases the likelihood that they will accept, value, own, support and trust the respective technologies. Ortiz-Crespo *et al.* (2021) describe a user-centred design process that was used to develop a system called Ushauri, to provide farmers in Tanzania with agricultural advice. Furthermore, with the required capacity (such as skills, infrastructure such as open-source tools), local individuals and groups can themselves build digital technology platforms. In fact, Carolan (2022) argues that participation or inclusivity extends beyond simply making sure that voices are heard and that, inclusivity includes empowering individuals to build their own digital platforms – in contrast to exclusive intellectual property regimes.

If experts, users and stakeholders are not involved in the design, development and implementation of digital technologies, other risks may arise, for instance in data collection, analysis and interpretation. For example, in the case of automated analysis or if there is a lack of analytical expertise, without the participation of experts and/or local stakeholders there is a risk of misinterpretation or overgeneralization. (This risk arises, for example, when the computational models/algorithms used in the technologies do not take into account the social, economic, cultural and natural complexities of the target people or country). Although machine learning can help to improve prediction in nutrition-related research (for instance in cardiovascular risk prediction [Rigdon and Basu, 2019]), procedures for model validation in nutrition research are often not sound or not well reported (Christodoulou *et al.*, 2019), hampering an objective model comparison in real world case studies. Methodologies for model development and validation should therefore be more carefully designed and reported (Christodoulou *et al.*, 2019); or improved upon (Espel-Huynh *et al.*, 2021). In this regard, experts can play a key role in identifying algorithms that have optimal performance and are appropriate for specific prediction problems. When designing, developing, implementing and researching digital technologies, therefore, it is important to involve relevant experts to give inputs for or during the various data cycle stages (including data collection, building the underlying models and performing analysis).

Digital technologies should offer FSN services and FSN content that are based on and adapted from trusted sources, and that take into consideration local contexts in order to meet the unique needs and preferences of different user groups (FAO, 2013b). For equity and inclusivity, the global community and international organizations should actively and continually engage and support the sustainability of indigenous knowledge, innovations and capacity from the grassroots and local levels, and vulnerable groups, thus contributing to empower local communities.

On a final note, it is interesting to note that some of the new digital technologies, when made accessible, can be used to support and enhance stakeholder engagement, promote inclusion, and support coordination in FSN efforts. These facilitative technologies include crowdsourcing, crowdsensing, online social media and mobile computing.

QUALITY OF DATA

Data quality entails elements such as accuracy, completeness, timeliness, validity and consistency. While digital technologies can enhance data quality (for instance, by validating accuracy and ensuring timeliness), there is also potential for digital technologies to affect data quality negatively. Data collection from users or respondents through technologies such as online social media, crowdsourcing and other mobile computing-based applications is relatively subjective and, therefore, subject to factors such as deception and carelessness. It has also been reported that data collected from **citizen science** efforts tends to be noisy, that is unreadable by analysis programmes (Kelling *et al.*, 2015). It may be useful to complement such user-focused digital technologies with other digital technologies or methods that are more objective.

It is worth noting, however, that over-reliance on numeric data (on the false presumption that such data is more objective) may lead to a scenario where data or information remain largely incomplete. In many cases, qualitative data captures key information about local contexts where FSN interventions are or will be undertaken in ways that cannot be represented by numbers. As was noted in Section 4.1.2, some of the new and emerging digital technologies support the processing of qualitative data in the form of images, videos, audio recordings and text. Such technologies can be used for data collection (e.g. online social media, crowdsourcing and other mobile computing-based applications), data storage (e.g. cloud computing, big data), data analysis (e.g. machine learning via sentiment analysis) and data dissemination (e.g. information visualization, online social media). However, a number of digital technologies still only collect or process numeric data, given that qualitative data collection, processing, codification and storage may involve complex processes and be highly demanding in terms of time and resources. Still, it is important to consider that over-reliance on digital technologies that collect, or process only numeric data may downplay important nuances that can be gleaned from qualitative data, and therefore, it is useful to also use digital technologies that can effectively manage qualitative data.

Moreover, another potential source of inaccurate data can derive from distractions in the respondents' uncontrolled settings, which can affect the quality of data collected. IoT and sensors can give false or misleading readings (for instance due to environmental complexities), which can translate into potentially detrimental agricultural and nutritional decisions and actions by farmers and policy-makers. However, research (such as Hariri, Fredericks and Bowers, 2019), is in progress to overcome these limitations, making big "poor-quality" data more valuable than small "high-quality" data. As such, digital technologies used in real-world settings should be constantly monitored, tested, calibrated and enhanced and, in some cases, a combination of digital technologies or methods should be used to ensure data quality.

INTEROPERABILITY OF DATA

Interoperability makes it possible for different systems to share, exchange and understand data. This is critical when efforts are being made to integrate different systems, which, in turn, is key to making digital technologies and systems widely useful. Interoperability may be necessary at any stage in the data cycle. For instance: users may want their respective digital applications to be able to fetch and analyse FSN data from diverse big data or **cloud computing** sources.

Interoperability initiatives often involve tasks such as developing standards and specifications (such as using ontologies to provide global term identifiers and frameworks to define and categorize FSN-relevant terms); building mappings for many different sets of standards and specifications; curating multiple domains of vocabulary; and harmonizing existing vocabularies or curating new terms in them. It is important to note that initiatives, such as FAO's AGROVOC,[17] FoodOn (Dooley *et al.,* 2018) and CGIAR's Crop Ontology,[18] (described earlier), are efforts that contribute to interoperability.

CAPACITY, EQUITY, SCALABILITY AND SUSTAINABILITY

Digital technologies involve relatively high investment costs, and are expensive for some organizations, for farmers with lower socioeconomic status, and for other vulnerable FSN stakeholders. Some organizations that carry out data collection and analysis are finding the cost of requisite technological infrastructure prohibitive (Sivarajah *et al.,* 2017), in addition to lacking sufficient personnel with skills in core data competencies (for example, in data analysis, information visualization, interpretation and decision making). Vulnerable FSN stakeholders might also not have the capacity to use the technologies or interpret data results, or may lack altogether access to internet connection and digital devices. The use of digital technologies in such scenarios may lead to or reinforce existing inequalities, such as the digital divide, and to the unequal distribution of the benefits of new digital technologies, favouring those who can already afford them. Furthermore, if technologies are implemented without the inputs of vulnerable FSN stakeholders, they may become even more disconnected from and further marginalised.

It is therefore important to invest in the necessary technology, infrastructure and research necessary to improve data interoperability and data quality, as well as access to and affordability

17 For further information, see https://www.fao.org/agrovoc/about.

18 For further information, see https://bigdata.cgiar.org/digital-intervention/crop-ontology-2/.

of technology. It is also important to build and enhance human capacity. For instance, by training in core data competencies (e.g., data collection, data analysis, information visualization, interpretation and decision making). Several institutions are supporting this training in the FSN domain. For example, FAO is offering training in such areas through the FAO eLearning Academy (Remotely Sensed Information for Crop Monitoring and Food Security - Techniques and methods for arid and semi-arid areas (https://elearning.fao.org/course/view.php?id=155). Other means for building and enhancing human capacity include educating users to support the data lifecycle process; enhancing user- and indigenous-capacity to improve data quality; and educating data owners and data producers about privacy, consent, data usage, data ownership and the rights they have. All stakeholders – data owners, producers and respondents – should be informed about the purpose of collecting, processing and using data and whether the data will be shared with other parties. Collaboration can also be useful in addressing some capacity concerns. The potential benefits of collaboration include: ensuring interoperability of technology standards and architectures; defining appropriate data standards and policies on data access and data sharing; pooling digital resources and infrastructure; implementing shared services in a synergic manner; sharing best practices and mutually beneficial information; developing context-relevant and user-relevant technological interventions; and limiting the potential for technology to be a disincentive to meaningful production. In addition, efforts on interoperability of data and systems can lead to the realisation of open-source tools and materials which, in turn, can reduce some capacity costs. Responsible automation, as described earlier, can also help to alleviate some of the capacity challenges.

Furthermore, almost all digital agriculture initiatives have to contend with the challenges of scaling (how to include locations, users, etc.) and sustainability (how the initiatives can extend beyond the current funding, etc.) (Florey, Hellin and Balié, 2020; Kos and Kloppenburg, 2019). Some of the recommendations to overcome these challenges include: demonstration of the benefits of using digital technologies and tools to support decision-making, adoption of interdisciplinary approaches and interconnectedness, recognizing the need for learning, feedback, partnerships, and joint action in multi-stakeholder settings within the context of FSN innovation systems (Florey, Hellin and Balié, 2020 p.135; Schut *et al.,* 2016; Shepherd *et al.,* 2020).

Chapter 5

INSTITUTIONS AND GOVERNANCE FOR FSN DATA COLLECTION, ANALYSIS, AND USE

Italy, 15 October 2018, FAO Headquarters – CFS annual Plenary.
©IFAD/Daniele Bianchi

Previous chapters in the report have made the case for the importance of using data to inform decisions; discussed the type of data needed at various levels in the wide ecosystem that determines food security and nutrition; commented on their current availability and the most important gaps; presented examples of valuable initiatives that contribute at each step of the cycle; presented an overview of the major constraints and bottlenecks that still affect FSN data systems worldwide; and introduced the enormous potential that resides in new and emerging digital technologies.

One theme that emerges from this discussion is the increased complexity of modern data systems, with many actors involved. Nowadays, in every practical context – including FSN policymaking at global, national or local levels – the collection, processing and use of data to reach effective, evidence-informed decisions involves a distributed (and often fragmented) process, with responsibilities held by different individuals and institutions, at different levels. Ensuring the proper coordination and collaboration among the various actors involved throughout the data cycle is fundamental to the success of any solution. This presents significant challenges for the design of an effective data governance system and creates an opportunity to take a systems approach not only to describe what is meant by food security and nutrition (Clapp *et al.*, 2021; HLPE, 2020), but also when addressing the roles that data collection, dissemination and analysis play in ensuring food security and adequate nutrition for all.

The multiplicity of actors involved in generating and using data for public good, together with the special nature of data in the digital era, creates complex challenges for data governance. This is a very active area of investigation, and a consolidated view of which the most appropriate governance mechanisms are and which institutions should lead and coordinate them is still far from being crystallized. In fact, there is not even an agreed-upon of data governance. The DAMA Guide to The Data Management Body of Knowledge defines it as, "The exercise of authority and control (planning, monitoring, and enforcement) over the management of data assets." (DAMA International, 2009, p.37). Abraham, Schneider and vom Brocke define it as "a cross-functional framework for managing data as a strategic enterprise asset", highlighting its broad scope to include the specification of "decision rights and accountabilities for an organization's decision-making about its data" and the formalization of "data policies, standards, and procedures" (Abraham, Schneider and vom Brocke, 2019, p.425-26). These definitions refer to data as an asset owned by a specific firm, company or organization (reflected implicitly in the expression "decision-making about *its* data"), that has clearly established, full authority and control over the data. We find these definitions too narrow to be applied to

FSN data, which encompasses a wide range of types of data, including data "owned" by governments, data "owned" by private entities and, quite importantly, data apparently owned by no one, which is potentially available to anyone who has the skills to access it from the internet. The evolving data landscape that is taking shape as the digital revolution continues, especially following recent global events such as the COVID-19 pandemic, introduces new challenges for data governance, highlighting the need for it to transcend boundaries – of firms, organizations and even national governments. As noted by the Center for Strategic and International Studies (CSIS), in the publication "Data Governance Principles for the Global Digital Economy":

> ***The architecture of global data governance is comprised of an interlinked set of laws, conventions, protocols, and standards at the international, regional, national, and local levels. Gaps in this architecture have resulted in a lack of clarity that is undermining confidence in and adoption of new technologies and limiting the tools available to address harmful uses of data (CSIS, 2019, p. 1).***

As such, the governance of data intended to inform FSN policy action today must be addressed from a global perspective. Given the relevance of food security and nutrition for development, and the pervasiveness of food insecurity and malnutrition throughout the world, there are legitimate reasons to treat FSN data as a global public good, as has been long advocated for in research (Knottnerus, 2016) and as is now being proposed for the health sector (WHO, 2021).

The 2021 World Development Report (World Bank, 2021) devotes an entire chapter to the discussion of institutions for data governance. It is beyond the scope of this report to duplicate the informative, comprehensive treatment of data governance issues set forth in the World Development Report that apply to FSN data. Nevertheless, this chapter discusses some of the salient aspects that should be considered in designing effective governance mechanisms for FSN data.

ISSUES OF RELEVANCE FOR DATA GOVERNANCE

In this section, we discuss two key issues that continue to permeate discussions on data governance: questions around the concept of data ownership, and how to protect the right to privacy when dealing with personal data. These issues pertain to all types of data, but become particularly relevant in the context of FSN data when viewed from the perspective of the conceptual framework introduced in Chapter 1, which stresses the importance of the dimension of agency for food security and nutrition.

THE DEBATE ON THE NATURE OF DATA AND THE ROLE OF DATA MARKETS

Decades ago, the Nobel laureate Joseph Stiglitz (1999) presented the argument that information should be treated as a public good. According to the traditional economic definition, public goods (Reiss, 2021) are goods and services that are *not excludable* (meaning that once the good or service is available, fruition by anyone cannot be prevented, unless by enforcement mechanisms), and *not rival* in nature (meaning that "consumption" by one user does not reduce the availability or usefulness of the good or service for anyone else). The public nature of goods or services is one of the conditions leading to market failures, that is a suboptimal outcome if transactions or decisions are left to market forces alone (Bator, 1958; Stiglitz, 1989). In the case of public goods, in fact, efficiency arguments suggest that an unfettered, market-based mechanism would lead to their insufficient supply. Moreover, even if private agents engage in the production of a public good or service, the actual cost of making it available would be increased by the need to put in place special mechanisms to limit access to those who pay for it and avoid "free-riders".[19]

19 Even if in some cases – as, for example, with public health, education, and transportation – the government (or any other institution created to represent and protect the collective interest) might want to act as the private owner of the good and regulate access by requiring the payment of a fee, this is only justified when there is a concrete risk of overcrowding. This is very different from making those goods and services private. Although it is technically doable, privatization of essentially public goods and services is not necessarily desirable (Anderson, 1995).

We strongly support the arguments made by Stiglitz, and extend it here to data, even in cases where one might want to distinguish between *data* and *information* (though, see Chapter 1). The main argument to support extending the notion of public good to data is that, especially now in the era of the internet and digitalisation, data have become the ultimate example of nonrivalry: millions of people may have access to the same data repeatedly, even simultaneously, without affecting the availability of the data to others. Moreover, now that virtually all data are available in digital form and stored in databases that can be accessed via the internet, the marginal cost needed to add one additional user is zero. This means that anything short of full, open access to data that has already been generated by someone and is stored in digital form, must be justified by arguments other economic efficiency (Badiee *et al.,* 2021).

Market-like mechanisms through which business and research institutions obtain useful data have existed even before the digital era, but the argument here is that such markets should be recognized for what they are, namely, markets for *data collection services*, not for the data themselves. Indeed, there are good reasons why the development of competitive, efficient markets for data collection services should be promoted, fully exploiting the recent advances in information and communication technology that have made data collection much easier than before. It is the data collection service that possesses the characteristics of exclusivity, which supports the usefulness of a private transaction between a seller and a buyer, who is the consumer of the service. Treating the data itself as the object of the exchange presents numerous problems, beginning with the fact that – especially when data are produced and stored in digital form – exclusion is difficult (in addition to being morally questionable). Typically, treating data as the object of the exchange has been made possible by creating legal frameworks that extend provisions (created long ago and in very different contexts),[20] such as copyright, to various types of digitally stored data. Enforcement is then carried out via the introduction of firewalls and other technical barriers that limit or prevent access to the repository that contains the data, thus effectively limiting the possibility and extent of data re-utilization.

In addition, exclusive reliance on private arrangements for data generation has long been considered inadequate. Traditionally, NSOs or similar agencies have been created in most countries to generate the data needed by governments to inform policies. Designed as autonomous public institutions, independent even of current executives, let alone of possible private interests — NSOs are still typically tasked with the responsibility of compiling and maintaining national accounts and generating other official statistics which are useful to guide policy. In the early operation of the NSOs, although relevant data was also generated by academic institutions and by private firms, the bulk of the data used to guide policymaking remained *official* and *public*.

The situation, however, is changing dramatically with the advent of the digital revolution and big data. Today, an incredibly large and increasing amount of new data and information, potentially relevant for policymaking, is generated outside the domains of official data and statistics, and therefore of NSOs. Many useful datasets covering agriculture and FSN are now available and can be openly and easily queried via the internet,[21] thanks to alternative arrangements promoting open access, such as CopyLeft,[22] Creative Commons[23] and Open Source Initiative.[24] These open-access datasets seem to be much better suited than copyright and fees-based licensing, to recognize and deal with the extant ethical problems related to data sharing. Furthermore, a global open-science movement is actively supporting the transition towards full, open access to scientific publications (Siew, 2017), and the principle by which data should be "as open as possible, as closed as necessary" (European Commission, 2016, p. 4) is what inspires accessibility among the Findable, Accessible, Interoperable and Reusable (FAIR) principles

20 See https://en.wikipedia.org/wiki/Copyright. Not surprisingly, the debate regarding whether copyright (as originally intended to protect the rights of the authors of literary and artistic productions) applies to digital resources, including what we have defined as data, is still very much open.

(Landi *et al.*, 2020). Despite this, many datasets are still "owned" by private entities who profit from an active market for data, which *de facto* promotes the view that data can be considered private, like any other private asset. Of special relevance is the fact that such datasets contain information that can be tremendously useful to inform development actions (including promoting FSN) and humanitarian interventions. It is in this new context that "[i]nternational development and humanitarian organizations are increasingly calling for digital data to be treated as a public good because of its value in supplementing scarce national statistics and informing intervention" (Taylor, 2016, p. 1) The situation becomes particularly delicate when datasets contain information of a personal nature, raising important questions regarding who should claim ownership of such data (something we turn to next). With the rapid diffusion of smartphones and internet-based personal services, incredibly large amounts of data, including personal data, are currently owned by relatively few large private companies in the information industry. This has led to the emergence of commercial data-access services and to various proposals intended to favour a broader circulation of data, including through *data philanthropy* (Lapucci and Cattuto, 2021), an approach that does not question the legal ownership of the data by the private companies that collect and store them.

THE QUESTIONS OF DATA OWNERSHIP AND THE SOCIAL VALUE OF DATA

Taylor's (2016) article, from which the quote in the previous section is taken, is entitled "The ethics of big data as a public good: which public? Whose good?", making it very clear that, in order to support the vision of data as a public good, we must answering these two fundamental questions – Which public? and Whose good? The questions are particularly relevant for what is considered *personal data*, that is, data that reflect personal attributes of individuals and for which full open access — which would appear to be the obvious choice for public data—would risk violating the rights to privacy of the concerned individuals.

On one hand, there is likely ample consensus that personal data should belong to the individuals to whom they refer, who should be able to decide what use can or cannot be made of such data. On the other hand, personal data may have a tremendous importance in many areas for which they need to be accessed and actively used by people and institutions other than the individual to whom they refer. Access to personal data can

21 To provide the following table contains the number of "hits" produced by queries run on 25 May 2022, on various web-based data repositories, using specific keywords:

repository	website	No of datasets	keyword			
			agriculture	food	food security	nutrition
Harvard dataverse	https://dataverse.harvard.edu/	156,062	6,404	8,334	910	1,864
International Household Survey Network (IHSN)	http://catalog.ihsn.org/	9,188	2,876	2,139	805	706
World Bank microdata catalogue	https://microdata.worldbank.org/	3,820	634	891	1,345	408
The Australian Data Archive	https://dataverse.ada.edu.au/	1,616	14	104	6	70
DataverseNL	https://dataverse.nl/	5,963	46	51	1	6
DataverseNO	https://dataverse.no/	1,228	12	47	0	6

22 For more information, see https://en.wikipedia.org/wiki/Copyleft.

23 For more information, see https://en.wikipedia.org/wiki/Creative_Commons_license.

24 For more information, see https://en.wikipedia.org/wiki/Open_Source_Initiative.

be important, for example, for health, security or administrative reasons, or to enable the provision of personal services. In the context of FSN, as set forth in this report, individual data collected via surveys has great importance for FSN planning and action, and broader access to such data allows for better understanding of issues such as the determinants of people's access food and the most effective means to properly address various forms of malnutrition.

The tension between the personal right to privacy and the value of broad data use has led legislators throughout the world to take steps intended to keep data open (thus allowing the use of personal data for research, development and humanitarian intervention) while subjecting it to personal data protection norms designed to protect the individuals' right to privacy (SEE BOX 30).[25]

25 Having the legislation for personal data protection in place, however, is only the first necessary step towards effective protection. Effective protection requires that an independent and active data protection authority exists to support the individuals' ability to enforce their rights under the law. A recent report (World Bank, UNSD and Paris21, 2022) shows however that a big gap exists between low- and high-income countries with respect to data protection authorities, as they have been established in only 24 percent of low-income countries, compared to 81 percent of high-income countries, by 2021.

BOX 30:
PERSONAL DATA PROTECTION AND THE RIGHT TO PRIVACY

Personal data protection guarantees are foreseen in most legislations throughout the world and in the UN System.

For example, the Charter of the Fundamental Rights of the **European Union**, under Article 8, states that:

1. Everyone has the right to the protection of personal data concerning him or her.

2. Such data must be processed fairly for specified purposes and on the basis of the consent of the person concerned or some other legitimate basis laid down by law. Everyone has the right of access to data which has been collected concerning him or her, and the right to have it rectified.

3. Compliance with these rules shall be subject to control by an independent authority. (Office Journal of the European Union, 2016., p. 7).

The European Union's legal protection framework is implemented through a specific regulation, commonly referred to as the General Data Protection Regulation (GDPR).

In the **United States of America**, although there is no all-encompassing federal legislation that ensures the privacy and protection of personal data similar to the European Union's GDPR, a combination of legislation at the federal and state levels, administrative regulations, and industry-specific self-regulation guidelines provides protection that – some authors argue – is even greater than that of the European Union (Boyne, 2018).

In **China**, the Personal Information Protection Law of the People's Republic of China (Chairman's Order No. 91) (the PIPL) was adopted by the 30th session of the Standing Committee of the 13th National People's Congress of the People's Republic of China on 20 August 2021 and implemented as of 1 November 2021. As a fundamental law equivalent to the European Union's GDPR, the PIPL has gained much attention since its first draft was released in October 2020.

In dealing with personal data, organizations within the **UN System** are encouraged to follow a series of principles intended to:

(i) harmonize standards for the protection of personal data across the United Nations System Organizations;

(ii) facilitate the accountable processing of personal data for the purposes of implementing the mandates of the United Nations System Organizations; and

(iii) ensure respect for the human rights and fundamental freedoms of individuals, in particular the right to privacy (UNSCEB, n.d.).

(For more information, see https://unsceb.org/principles-personal-data-protection-and-privacy-listing).

Such data protection norms include avoid assigning explicit property rights on personal data to anyone[26] and rely on the principle of informed consent to grant the right to use the collected information, including the possibility that the data may be shared with others (for example, for research purposes) as the mechanism to ensure the protection of individuals' right to privacy. Thus far, this has been considered a reasonable compromise between the two competing needs of ensuring protection while allowing adequate circulation of data. It is useful to note, however, that informed consent implies that access to personal data is only granted for the specific purposes stated in the signed informed consent form. At least in theory, this should not be configured as a *sale* of the data itself (that is, a transfer of ownership), which would have required the assignment of legally binding private property rights on the data to the individual to start with.

The continued evolution of information and communication technology, however, has presented new challenges regarding privacy, control and dissemination of personal data. When personal data was collected mostly via face-to-face interviews by entities such as NSOs, subject to strict control of the public authority, informed consent was relatively easy to obtain and generally sufficiently safe to protect privacy. With the spread of internet and mobile phone-based services, however, collecting personal data has become both much easier and much more pervasive, but also, potentially, much more dangerous.

First, the scope of what can be considered personal data has broadened. Even in surveys, in addition to information that is willingly and directly provided, the use of these new technologies may involve the collection of personal information in a way that is not immediately transparent to the survey participant, as metadata are automatically gathered from the device used. For example, when using an online survey provider or a phone-based interview, the Internet Protocol (IP) address used by the survey participant's device, or the location of her or his mobile phone device may be automatically passed to the data collection service provider. To the extent that such metadata may be used in combination with other information to identify the respondent (individually or as member of a specific group), they also must be considered personal data.[27] Second, a growing amount of personal data are collected by private companies in the information and communication industry when offering services such as subscriptions to cellular phone services, social networks, software licensing, etc. In agriculture, there is also the case of data generated by devices mounted on agricultural machines (tractors, harvesters, milking machines, etc.), which are often automatically sent to the machine manufacturers (justified by the need for information to customize or develop new services for farmers), but these may reveal elements of farmers' activities which may also be considered private. The way consent is elicited in these cases raises doubts as to whether people are fully aware of what they are consenting to, especially when being presented with an all-or-nothing option to click either "accept" or "refuse" to enable the needed service (see the discussion in Purtova, 2013). Further, it has been argued that the way in which consent is requested with electronic devices may even lead to people releasing more personal information – and hence increasing the risk of privacy violation – than if their consent was not requested, in what has been termed the *control paradox* (Brandimarte, Acquisti and Loewenstein, 2013). Moreover, issues of equity may arise when the full utilization of existing data for relevant public objectives is impeded by the need for proprietary licenses or by technological barriers

26 On the other hand, see Purtova (2013, 2018), according to whom considering personal data as no one's property is nothing but an illusion as, in practice, effective (if not legal) property right on personal data gets appropriated in any case by companies in the information industry, rather than by the individuals to whom the data should belong.

27 Purtova (2018) goes further, proposing that "in the age of the Internet of Things, datafication, advanced data analytics and data-driven decision-making, any information relates to a person in the sense of European data protection law" (emphasis added) and therefore is subject to the practice of informed consent (Purtova, 2018, p. 42).

that effectively prevent some population groups from even accessing data that may significantly affect them.

Second, caution should be raised against commercial arrangements that are framed in ways that imply that the service provider has the right to sell data collected via surveys or acquired otherwise (such as through audio recording devices or video cameras) (Kitchin, 2014a). This is certainly not the case for personal data (as opposed to anonymous data) but the question of who owns personal data applies also to data that refer, for example, to the state of the environment or to the extent of nature's exploitation. In this respect, the rapid evolution of new data-generating technologies raises an entirely new – and largely unexplored – area of ethical considerations. The generation of data obtained by gathering, codifying and storing information cannot be assumed to automatically assign full property rights to the data generator, even when the information has been freely provided by individuals who have signed an informed consent.

The reflections above are intended to highlight the complexity of the aspects involved in designing data governance institutions, and to explain why this is an area of active scientific and philosophical inquiry, with several questions that remain unanswered regarding both data science (Blum, Hopcroft and Kannan, 2017) and its ethics (Floridi and Taddeo, 2016).[28] Our position is that, morally, **personal data can be considered in the same light as blood: something that individuals might decide to give,** when necessary, in order to obtain a personal service (for example, when own blood is given for testing for medical reasons), but also that people should be **encouraged to donate,** when there is a clear indication that its use may contribute to a greater good (such as saving someone else's life). What should be crystal clear is that **any resale of such data should be deemed immoral and even prosecuted as illegal.**

28 See also the entire collection of articles included in The ethical impact of data science, volume 374 of the *Philosophical Transactions of the Royal Society* A, available at: https://royalsocietypublishing.org/toc/rsta/2016/374/2083.

PRIORITY OBJECTIVES FOR FSN DATA-GOVERNANCE INITIATIVES

With the above considerations in mind, let us discuss some of the main priorities that effective data governance should tackle, with specific reference to FSN data.

ACHIEVING ADHERENCE TO GLOBAL STANDARDS AND HARMONIZATION OF DATA

One of the key findings of Chapter 2 in this report is that, though there are still a few notable gaps, there is already a large amount of available FSN data. However, these data are often fragmented across different public and private institutions, or may be collected or managed using different protocols, making them difficult to use it. Therefore, it is a priority for effective governance of FSN data, to strengthen international coordination efforts to define, promote and enforce the adoption of global data (and associated metadata) standards, including of harmonized indicators, which are essential for comparison and to obtain the full potential of data.

Within the public sectors in many countries NSOs play a key role in governing FSN data, and many of them already follow international standards. The United Nations Statistics Division (UNSD) has a long history guiding the advancement of global statistics. The UN (2014) Fundamental Principles of Official Statistics (UN Resolution 2014 A/RES/68/261) stresses the need to harmonize concepts and methods, to use professional criteria (including scientific methods and ethics) to collect and use data, to develop transparent rules and governance mechanisms and to enhance coordination among statistical agencies. One of the key areas of work in the UNSD mandate is to develop harmonized statistical classifications.[29] In a survey conducted in 2020, 136 countries reported that they have national statistical legislation that complies with the Fundamental

29 See https://unstats.un.org/unsd/classifications/.

Principles of Official Statistics (UNSD, 2021). In a similar vein, the Inter Agency and Expert Group on SDG indicators, created by the UN Statistical Commission, has spent considerable effort promoting the adoption by all countries of a harmonised set of official SDG indicators when reporting on progress towards SDG targets.

These efforts, however, are still largely insufficient, particularly for FSN data. As an example, global reporting rates for the 21 indicators of the SDGs under FAO custodianship vary greatly. Only 4 of these indicators have been reported by more than 70 percent of the countries in the period 2015-2019, and some indicators, such as the average income of small-scale producers, have been reported by less than 10 percent of the countries (FAO, 2020b).The lack of agreement on standard definitions makes it difficult to exploit the full potential of data already available. For example, food data in household surveys is still routinely collected by different agencies using very different survey approaches, modules and definitions, making the analysis of those data to derive food security indicators particularly difficult (FAO and The World Bank, 2018). Another very important example is data on food security assessments. Often, various indicators are used to report on food security, but the indicators used may differ in reports from different countries or from different institutions. Moreover, indicators are aggregated in different ways, leading to effectively different measures. Definitions of concepts is another problematic issue. Sometimes the same expressions are used in different contexts, but with very different meanings, generating confusion and giving way to misinterpretation of important indicators. For example, in the Consolidated Approach for Report Indicators of food security (CARI), used by the WFP in assessments intended to inform their operational responses (WFP), 2021), severity levels labelled *moderate* and *severe* are different (more severe) than those used in the definition of the official SDG indicator 2.1.2, Prevalence of moderate and severe food insecurity based on the Food Insecurity Experience Scale (FIES) (Cafiero, Viviani and Nord, 2018). Governance frameworks should establish an agreed-upon set of indicators for measuring food security to facilitate informed decision-making.

PROMOTING BROADER, QUICKER AND MORE EFFECTIVE CIRCULATION OF DATA NEEDED TO INFORM FSN POLICY AND ACTIONS

Given the system view that we promote, FSN data should be seen as a *global* public good and the global governance system should be such that no single entity should have the power to subtract relevant FSN data from the public domain, unless justified by security reasons or to protect specific rights. Moreover, there should be no doubts regarding the potential benefits associated with more timely and broader sharing of data (especially data that adhere to global standards as discussed above), which would allow more analyses and fuller utilization of the information content in data. Hence, the second priority for a global FSN data governance system is to address factors that currently impede broader data sharing.

Typically, for data generated by public institutions such as NSOs, such factors refer to the presence of real or perceived risks of negative consequences for the data producer/owner resulting from sharing the data. Apart from the fear that sharing data containing personal information might lead to infringement of personal data protection agreements, data are not shared more broadly for fear that further analysis might reveal issues of data quality, thus affecting the reputation of the NSO. While there is a clear tendency towards open data in the public sector, as recently expressed by the United Nations Statistical Commission, in endorsing the Report of the Working Group on Open Data which establishes the principle of Open Data by Default (UNSD, 2022), making it a reality remains challenging, especially for statistical systems in less developed regions with limited capacity. As highlighted in the key messages derived from the analysis of the results of a recent survey on The implementation of the Cape Town Global Action Plan on Sustainable Development Data (World Bank, UNSD and Paris21, 2022):

> *"[…] most NSOs identified strengthening the compilation and dissemination of metadata, as well as the development of an organization-wide open data strategy as top priorities, highlighting the need for enhanced capacity*

around data visualization, communication, and dissemination platforms and tools. ❞

Moreover,

❝ *[…] almost all NSOs in low- and lower-middle-income countries expressed the need for partners' support in enhancing their capacity to capitalize on new technologies, methods, and data sources to effectively establish new multistakeholder partnerships. In addition, more than two-thirds of them consider that data management, processing, and analysis are high-priority areas for training. (ibid.).* ❞

Almost as a paradox, there are also cases where data generated by international organizations are prevented from broader dissemination, even though such organizations have been created, in part, to contribute to data and information. FAO, for example, has been created with the explicit mandate to "collect, analyse, interpret and disseminate information relating to nutrition, food and agriculture" (FAO, 2017, page 3. However, according to the Fundamental Principles of Official Statistics (UN General Assembly, 2014) data and statistics produced by FAO are still not recognized as equivalent to *official* statistics in the context, for example, of the SDG monitoring framework. Though examples exist of the use of non-official sources in international statistics (CCSA, 2016) the mechanism in place to facilitate data exchanges (Gennari and Navarro, 2019) is still insufficient to guarantee, for example, the publication of the values of SDG indicator 2.1.2 and the release of anonymized **microdata** collected by FAO even when no equivalent national official source of data exists.

In case of data generated and owed by private institutions, usually the reason for limited sharing is related to power control along the data cycle, which strongly conditions the sharing of benefits derived from data use, another important aspect that data governance is meant to address. As discussed at the beginning of this chapter, managing data as an economic asset naturally leads to selection of users by design, in order to maximize profits, and to less than optimal sharing. Moreover, the relationship between contributors, collectors, processors and users of data is asymmetric, also because data collectors and processors have the processing and sharing facilities to manage data and gain the control over the datasets. This is the case also in agriculture: Wolfert *et al.* (2017, p. 1), for example, discussing the role of big data for smart farming, propose that research priority be given to "organizational issues concerning governance issues and suitable business models for data sharing in different supply chain scenarios." As a way to contribute towards better sharing of the benefits derived from new digital data.

❝ *The FAO and ITU have produced a toolkit specific to E-Agriculture Strategy and Policy which examines a context across leadership and governance; strategy and investment; services and applications; infrastructure; standards and interoperability; content, knowledge management, and sharing; legislation, policy, and compliance; and workforce and capacity development (Florey, Hellin and Balié, 2020; with reference to FAO and ITU, 2016).* ❞

Transnational data-governance initiatives are emerging to reduce inequities currently experienced by data contributors and users (Arner, Castellano and Selga, 2021). These initiatives include private codes of conduct, international agreements on the protection of intellectual property rights, and initiatives by international organizations like FAO and the World Bank aimed at promoting more data sharing, in the context of what has been labelled a *responsible data movement* (Alemanno, 2021). However, as noted by Alemanno, "in the absence of a common multi-stakeholder platform for data governance, this movement lacks institutionalisation and emerges as a result largely fragmented" (Alemanno, 2021 p.72) and "despite their potentially life-saving nature, these collaborations are entirely left to the good-will of the private actors involved" (ibid., p.73).

ENSURING ADEQUATE MECHANISMS ARE IN PLACE TO PROTECT INDIVIDUAL AND COLLECTIVE RIGHTS

Data-governance mechanisms, including institutional mechanisms, must recognise the contributions of all stakeholders – those who provide, collect, process, share and use data – and regulate their rights, while fostering cooperation between them. Such mechanisms must uphold privacy rights, protect personal information and intellectual property, and establish codes of conduct. Attention must be devoted to the institutional arrangement and the tools and the technologies used for generating, recording, storing and transmitting data, which should include appropriate protection measures, for example, to mask sensitive personal information that might be extracted from the data.

In the context of FSN, privacy rights must be defined and upheld in order to provide stronger protection and control to data contributors over the use of personal data. It is widely recognized, for example, that more effort is needed to generate information on nutrition and health effects of diets and to monitor progress in nutrition indicators, which calls for broader use and analysis of microdata from surveys (Mozaffarian *et al.,* 2018), but one of the challenges to this is that sensitive data (such as health data or business data) requires a high level of protection.

A data-governance framework with mechanisms to protect sensitive data at all stages of the data cycle is a pre-condition for a safe environment in which data can be used to promote FSN. One of the mechanisms commonly used to preserve privacy when using survey data is anonymization. However, since anonymization techniques do not fully guarantee anonymity, particularly in a digital data context, privacy rules often follow the principle of informed consent, meaning that contributors must give consent before collectors can gather information. How effective the mechanism of informed consent is to protect rights, while allowing for broader data use, continues to be debated (see the discussion in Section 5.1.2.). Nevertheless, governance rules that establish restrictions on the collection and use of personal data based on informed consent are becoming the prevailing standard, as in the case of the GDPR of the European Union, which inspired similar legal frameworks in other regions (SEE ALSO BOX 29).

Open science initiatives aimed at enhancing access to research, articles, data and software, despite their great benefits, have raised concerns about finding the proper balance between protecting the rights of particular groups (including Indigenous Peoples, farmers and consumers), and promoting open access to data in a global research environment.

With regard to Indigenous Peoples' knowledge and rights in particular, as the world engages with open data and open science, and FSN data are increasingly used for making decisions, concerns arise about the need to integrate Indigenous Peoples' knowledge, while establishing governance mechanisms that enable Indigenous Peoples to have control over their data. The CARE Principles for Indigenous Data Governance (which are: collective benefit, authority to control, responsibility and ethics) are an attempt to define collective rights as part of openness. These principles complement the FAIR Principles and can promote more equitable participation of data contributors in the data cycle (Carroll *et al.,* 2020).

As the underlying problem with regard to protecting individual and collective rights in data collection and use appears to be a lack of sufficient trust in the way data and information are collected, maintained and shared, an interesting avenue to explore is for the CFS to take the lead in establishing *data trusts* (Hardinges, 2018, 2020) for FSN.

As defined by the Open Data Initiative, a data trust is:

> *[…] a legal structure that provides independent stewardship of some data for the benefit of a group of organisations or people. That benefit might be to create new businesses, help research a medical disease, or empower a community of workers, consumers or citizens. In a data trust, the trustors may include individuals and organisations that hold data. The trustors grant some of the rights they have to control the data to a set of trustees, who then make decisions about the data – such as who has access to it and for what purposes. The beneficiaries of the data trust include those who are provided with access to the data (such as*

researchers and developers) and the people who benefit from what they create from the data. The trustees take on a legally binding duty to make decisions about the data in the best interests of the beneficiaries. This is sometimes referred to as a fiduciary duty. Proponents of data trusts suggest this duty would help to increase the trust that individuals and organisations have in the way data is used." (Open Data Initiative, 2018). ”

Spearheaded in the context of personal data protection (see, for example, https://datatrusts.uk/) similar initiatives to data trusts might be extended to food security and nutrition data. This might be an effective way to promote the establishment of viable data collaboratives among public and private entities involved in the generation, storage, and dissemination of FSN-relevant data.

RELEVANT RECENT INITIATIVES ON DATA GOVERNANCE FOR FSN

This section reviews recent international initiatives concerning FSN data that address data governance and transparency.

WORLD BANK OPEN DATA

The World Bank data portal (https://data.worldbank.org/) provides access to FSN datasets and disseminates anonymised microdata from sample surveys, censuses and administrative systems under its open data policy (http://microdata.worldbank.org). Datasets are generated by the World Bank or by third parties, including member states, international organizations, and regional agencies. The World Development Report 2021 is dedicated to data issues, with many insights and recommendations that concern directly FSN (World Bank 2021).

OPEN SCIENCE INITIATIVES AND THE FAIR AND CARE DATA PRINCIPLES

Open science initiatives are developing rapidly in all research areas, including FSN and are considered very promising. They are based on international collaboration and contribute to the deployment of cloud-based services and other collaborative tools that facilitate data access, sharing, interoperability and reuse (see, for example the REDCap example in Box 12). The openness of data and research output facilitates timely and universal access to information on food system developments. Open access standards can promote the use of official statistics in research by balancing the usability and confidentiality of primary data (microdata).

The FAIR (findable, accessible, interoperable, reusable) data principles (SEE TABLE 1) provide international guidelines for organising research outputs, so that they can be easily found, accessed, understood and integrated in other applications or different settings (Wilkinson *et al.*, 2016). Major research funding bodies, including the European Commission, are adopting the FAIR data principles to optimise the integrity and impact of research outputs.

TABLE 1: FAIR DATA PRINCIPLES

FAIR PRINCIPLES	COMPLIANCE INDICATORS
Findable Metadata and data should be easy to find for both humans and computers.	F1. (meta)data are assigned a globally unique and persistent identifier F2. data are described with rich metadata (defined by R1 below) F3. metadata clearly and explicitly include the identifier of the data they describe F4. (meta)data are registered or indexed in a searchable resource
Accessible The exact conditions under which the data are accessible should be provided in such a way that humans and machines can understand them.	A1. (meta)data are retrievable by their identifier, using a standardized communications protocol A1.1 the protocol is open, free and universally implementable A1.2 the protocol allows for an authentication and authorization procedure, where necessary A2. metadata are accessible, even when the data are no longer available
Interoperable The (meta)data should be based on standardized vocabularies, ontologies, thesauri etc. so that they integrate with existing applications or workflows.	I1. (meta)data use a formal, accessible, shared and broadly applicable language for knowledge representation I2. (meta)data use vocabularies that follow FAIR principles I3. (meta)data include qualified references to other (meta)data
Reusable Metadata and data should be well-described so that they can be replicated or combined in different settings.	R1. meta(data) are richly described with a plurality of accurate and relevant attributes R1.1. (meta)data are released with a clear and accessible data usage license R1.2. (meta)data are associated with detailed provenance R1.3. (meta)data meet domain-relevant community standards

SOURCE: AUTHOR'S OWN ELABORATION BASED ON WILKINSON *ET AL.* (2016)

The FAIR principles are often applied in conjunction with the CARE (collective benefit, authority to control, responsibility and ethics) principles, which are more people-oriented and reflect the importance of **data sovereignty** in advancing Indigenous innovation and self-determination (Research Data Alliance International Indigenous Data Sovereignty Interest Group, 2019).

One good example of making data open access comes from the International Food Policy Research Institute (IFPRI), which views the products of its research, including research datasets, as global public goods, and is committed to enabling their widespread distribution and use. They do so by depositing their data at Harvard Dataverse,[30] an open-access repository for research data, keeping with the IFPRI Research Data Management and Open Access (RDMOA) Policy[31] and the CGIAR Open Access and Data Management Policy.[32]

Another example is SIAgroBD, a collaborative initiative to inform food security and agrobiodiversity conservation policies in Mexico. SIAgroBD focuses on integrating data on native crops of global importance, food composition and nutritional data, qualitative and quantitative agronomic data and qualitative assessments of local agrobiodiversity, among other data. These

30 Visit the Dataverse at: https://dataverse.harvard.edu/.

31 The access policy is available at: https://www.ifpri.org/cdmref/p15738coll2/id/133308/filename/133517.pdf.

32 For more information, see: https://cgspace.cgiar.org/bitstream/handle/10947/4488/Open%20Access%20Data%20Management%20Policy.pdf.

data are often collected in collaboration with local communities (https://siagro.conabio.gob.mx/).

SIAgroBD implements a workflow for open and FAIR data, including the adoption of digital field data collection tools, vocabulary standards, reproducible practices, open data training for participants, and the development of a custom data integration platform. Hence, SIAgroBD contributes to enhancing capacities with respect to data generation, access, analysis and use by different actors.

GLOBAL STRATEGY TO IMPROVE AGRICULTURAL AND RURAL STATISTICS

The Global Strategy to Improve Agricultural and Rural Statistics[33] (GSARS) of the FAO is a coordinated, long-term initiative to address the decline in the agricultural statistical systems of developing countries. The strategy contributes to harmonizing national and international agricultural statistics systems.

Significant results were achieved during its first phase of implementation (2012–2018): i) agricultural statistical methods were completely upgraded and endorsed by FAO, ii) Strategic Plans for Agricultural and Rural Statistics (SPARS) were prepared in almost 40 countries, iii) a fast-track model of technical assistance was successfully implemented, and iv) tangible progress was made in countries' overall statistics capacity through regional training programmes (FAO, 2019b).

The second phase of the GSARS (2020–2025) focuses on the application and use of existing methodologies and approaches developed in the framework of the first phase. GSARS contributes to strengthening the statistical capacities of countries through the provision of training and technical assistance at national, regional and global levels (UN Statistical Commission, 2019). The activities of the GSARS are interlinked with the activities of the 50x2030 Initiative to close the agricultural data gap, aimed at collecting data in 50 low-income and lower middle-income countries by 2030.

INITIATIVES IN STAKEHOLDER COLLABORATION

As mentioned earlier in this report, data collection and analyses of food insecurity and malnutrition has been impeded by a lack of collective effort and shared commitment across institutions, resulting in expensive, redundant, incomplete and inefficient processes. On the other hand, collaboration among stakeholders of the data chain results in generation of timely, relevant and good-quality data for decision-makers, enhanced digitalization efforts and better use of available information. Thus, inclusive and multi-stakeholder approaches can enhance trust, support data governance, information sharing, leading to better utilisation of data. This can also result in higher success when seeking funding for FSN data-collection efforts. With respect to FSN, collaboration among stakeholders of sustainable **food supply chain** management including farmers, policymaking organisations and research institutions based on data-sharing activities, trust, commitment, coordination, stability and joint efforts, facilitates achievement of food security, business and environmental outcomes (Dania, Xing and Amer, 2018). Given its organization and mandate, FAO may play a vital role in improving engagement of relevant stakeholders through its liaison offices while extending country level support.

Exemplars in achieving success in international collaborations are characterised by the commitment to engaging stakeholders, creating of a shared vision amongst them (as with the EAF-Nansen programme, SEE BOX 31) and coordination among all the participating organisations (for example, in Nepal's nutrition sensitive livestock introduction programme, SEE BOX 32).

33 http://gsars.org/en/

BOX 31:
THE EAF-NANSEN PROGRAMME

The EAF-Nansen Programme is a partnership between the Food and Agriculture Organization of the United Nations (FAO), the Norwegian Agency for Development Cooperation (Norad), and the Institute of Marine Research (IMR), Bergen, Norway, for sustainable management of the fisheries of partner countries (FAO n.d.a). The long-term objective is that "Sustainable fisheries improve food and nutrition security for people in partner countries" (FAO, n.d.). Since 1974, the programme has provided an opportunity for coastal low- and middle-income countries to assess and manage their fisheries resources, and in 2017 the theme "nutrition and food safety" was implemented in the science plan (Moxness Reksten *et al.,* 2020). Fishes are sampled on the research vessel Dr Fridtjof Nansen, and most of the samples are analysed at the accredited laboratories at IMR. As part of the capacity building embedded in the programme, local scientists and students can get funds to pursue a master's degree or PhD and take part in mentoring programmes. The results may assist national food authorities to evaluate the beneficial effects of nutrients against any potentially negative effects of contaminants or biohazards and guide officials tasked with regulating aquatic foods for both local consumption and exportation.

BOX 32:
NEPAL'S NUTRITION-SENSITIVE LIVESTOCK INTRODUCTION PROGRAMME

A four-year longitudinal investigation in rural Nepal demonstrated that an intervention that promoted livestock introduction and related training for community development and poverty alleviation was associated with significantly improved child anthropometry and child health. The project involved various non-governmental organisations (NGOs) that independently collected data on the effectiveness of government-driven implementation of the programme. The activities represent a viable 'nutrition sensitive' intervention, but these impacts take time to manifest and be sustained. The programmes' collective outputs, monitoring and evaluation efforts and knowledge generation were made possible through well-planned methodology, intervention delivery and data collection through an effective collaboration between the participating organisations and the stakeholders. (Miller *et al.,* 2017).

Another example of a successful collaborative partnership is the Integrated Food Security Phase Classification (IPC), an initiative that is funded by international collaborators but still enables national ownership (SEE BOX 13).

Other initiatives focusing at sustainable food systems include components to enable data collection for monitoring and evaluation (SEE FOR EXAMPLE, BOX 33).

BOX 33:
THE GLOBAL AGRICULTURE AND FOOD SECURITY PROGRAM (GAFSP)

As an example of coordination and institutional arrangement for monitoring and evaluation, the GAFSP provides funding and technical assistance to support implementation of country-led initiatives, giving priority to those with evidence of stakeholder participation, including producer organizations (PO) and relevant civil society organizations (CSOs), from project design to implementation (GAFSP, n.d.).

More recently, not-for-profit social enterprises such as Statistics for Sustainable Development (Stats4SD) have ventured into research, statistical support and capacity building for monitoring and evaluation (M&E) of development interventions with the aim to promote the better use of statistics for decision-making. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is an independent intergovernmental body that aims to strengthen the science-policy interface for biodiversity and ecosystem services for long-term human well-being and sustainable development. IPBES, whose membership is open to all UN-member countries, has specific objectives on strengthening knowledge, facilitating data sharing and catalysing the generation of new knowledge. Specific attention is paid to indigenous and local knowledge systems.

GREATER ATTENTION TO DATA QUALITY ISSUES

Financial and institutional support from policymakers to collect good-quality data, adhering to the four foundational principles of findability, accessibility, interoperability, and reusability (FAIR), could be forthcoming if the benefits of collecting good quality data, as well as the cost of insufficient data quality, is internalized and well-communicated. This requires champions, in each institution involved, who will provide sufficient drive and traction for the initiation and sustenance of such data collection efforts.

Enforceable regulatory frameworks also provide guidance to facilitate better coordination between agencies and the involvement of stakeholders. This may also provide an incentive for governments to generate, analyse and utilise timely and relevant data and support open access in line with FAIR principles. The establishment of adequate legal and regulatory frameworks will facilitate international and cross-border collaboration as data collection is subject to local laws and regulations and may subtly vary between countries or even regions. In the absence of regulatory frameworks that codify the need for specific data, successful collaborations such as the EAF-Nansen Programme are also limited in their reach. The use of new methods such as machine learning could be associated with black box models where the algorithms may not be transparent or easily understandable. Appropriate regulatory frameworks will establish the requirement for documentation and transparency of these efforts to adequately understand and interpret the results generated, ensuring power balance and equality in the process.

A forum to build mutual understanding on FSN data and statistics, governance issues and a consensus on the principles and norms that should guide resource allocation among the stakeholders could be proposed as a step in facilitating standardisation and harmonisation efforts.

CHALLENGES TO DATA GOVERNANCE FROM DATA-DRIVEN TECHNOLOGIES

Technological innovation opens the door to new data sources and increased data volume but may also divert attention from strengthening data collection procedures, as well as from identifying data governance capabilities and gaps. According to a recent study, "this underscores the need to better exploit complementarities between traditional and alternative data sources and methods, which will require both technical solutions as well as creative institutional arrangements that foster collaboration and value addition" (Carletto, 2021 p. 721).

Data-driven technologies may facilitate data collection, processing and sharing, as they may facilitate more effective collaboration in data and statistics. Digital technologies can also favour timeliness in data availability and can facilitate the performance of quality checks (World Bank, 2021). However, these technologies may lead to higher asymmetries in data access, for example, when data are transferred from data contributors to data processing companies that control further access and use of these data (World Bank, 2021). In some cases, data collected in one country are processed in cloud-based facilities operated by other countries or private companies, creating dependencies and risks for data privacy and data access (World Bank, 2021).

Finally, while open data can facilitate access to data, it is not synonymous with universal data access. The ability to access open data is limited to those with access to digital infrastructures and digital technologies, and who possess the required technical skills.

SOLUTIONS TO ENHANCE FSN DATA GOVERNANCE

STREAMLINING TRANSNATIONAL AND NATIONAL DATA GOVERNANCE FOR FSN

The development of improved knowledge systems to inform more effective policy action in FSN requires special attention to governance issues. Furthermore, effective collaboration both at country and international levels is essential to address data governance challenges.

International standards for FSN data governance and data sharing should be further developed. Enhanced coordination of country efforts can lead to a more efficient way of collecting FSN data, avoiding fragmentation and duplication of data initiatives. There are international institutions already well-positioned to lead such initiatives and provide country-support. FAO can play an important role in facilitating the integration of datasets and support data sharing and data governance. Digital technologies create opportunities to establish data platforms that connect data providers and data users, while international organizations are essential to ensure that data generation meets quality standards and builds data trust.

Some global initiatives to develop international standards and enhance coordination are ongoing, but implementation at the country level is slow. New institutional arrangements are being promoted in some countries to facilitate the effective integration, sharing and reuse of FSN data. In the framework of transnational data standards and protocols, governments should develop data strategies including regulations for data protection, sharing and use as well as mechanisms to enhance collaboration on FSN data at national and subnational levels.

INCLUSIVE APPROACH TO DATA GOVERNANCE

Inclusive and multi-stakeholder approaches are critical for data governance and sharing. Governance mechanisms established through dialogue between stakeholders (data contributors, collectors, processors, providers and users), whether state or non-state, increase trust, which is a precondition for effective collaboration and, therefore, for implementing feasible governance solutions.

INCREASING TRANSPARENCY AND GOVERNANCE OF OFFICIAL STATISTICS FOR FSN

National statistical agencies generating datasets on FSN should pay special attention to:

- harmonization of concepts and indicators;
- coordination both with international and other national institutions producing data (e.g., national and international sources of food prices and markets) to ensure comparability of data;

- governance mechanisms to enhance data sharing and usability, while respecting the confidentiality of personal and sensitive data.

Although there are initiatives to coordinate data collection and governance, greater internal and international coordination is needed to avoid the proliferation of disconnected data initiatives that can lead to data gaps and duplication. Improved coordination may reduce the burden of collecting data by focusing on the essential datasets needed to promote FSN and integrating across data sources to overcome the limitations of individual data sources. Therefore, setting priorities and adopting agreed data protocols will help to further develop and maintain FSN data systems.

The FAIR and CARE data principles have the potential to address some of the governance challenges. The adoption of these principles should be promoted across the global research community.

However, more effort is needed in research areas that are currently under-covered. Funding agencies should prioritise research on optimal dietary targets and cost-effective policies to achieve them; monitoring and evaluation of health indicators and policy outcomes; engagement with communities and active public-private partnerships, and ensure coordination on these under-covered areas at the national and international levels.

PARTNERSHIP AGREEMENTS TO MANAGE AND SHARE DIGITAL DATA

The development and adoption of data-driven technologies have the potential to increase data availability and reduce data gaps, but governance mechanisms must be in place to protect the rights of data contributors and data users.

The spread of new data sources (satellite data, data from sensors, citizen-generated data, social media data) contributes to impressive improvements in data availability and timeliness and will likely have important implications for FSN (Weersink *et al.,* 2018). For example, the higher amount of nutrition-related data available to consumers can help them to make better decisions. However, more FSN data does not translate automatically in improved data systems and there are risks involved in the operation of new data sources and technologies. For instance, the transfer of consumer data to the private corporations that provide digital technologies raises concerns about data ownership, data protection and consumers agency. Thus, data governance frameworks must account for the new challenges posed by data-driven technologies to balance their positive and negative impacts on FSN and on all stakeholders (Deichmann, Goyal and Mishra, 2016).

Digital data and data technologies entail complex governance challenges. Digital data can be in multiple places at the same time, making control over data very complex. Governance mechanisms implemented in some countries have shown limited effectiveness because data providers can easily relocate to countries with more flexible regulation (World Bank, 2021). Therefore, global agreements are necessary to effectively govern digital data.

Chapter 6

FINAL REFLECTIONS AND RECOMMENDATIONS

Italy, 15 October 2018, FAO Headquarters – CFS annual Plenary.
©IFAD/Daniele Bianchi

One overarching conclusion from all the discussion in the report is that **we live in a world where data and information are generated and flow with unprecedented volume and speed.** Much more data and information potentially relevant for FSN is being generated today **outside the traditional, official domains of data and statistics.** As such, **the number of actors who play an important role in this has increased substantially.** Use of data and information to reach effective, evidence-informed decisions, involves a distributed process, including **both public actors** (such as national governments and international multilateral organizations in the UN System) and **private actors** (from large multinational corporations to small farmers and other actors in food value chains, to NGOs and representatives of consumers and citizens throughout the world).

The recommendations set forth in this report constitute a call to action on the part of all these actors, which, if followed, may prove useful in moving towards more effective, evidence-informed decisions that will make food systems more sustainable and ensure food security and better nutrition for all, particularly for the billions of people throughout the world who still experience hunger and various forms of malnutrition.

Many of the messages in this report will not be new. The importance of data and evidence-based decision-making to transform food systems has been widely published and reviewed (World Bank, 2021). The 2014 Global Nutrition Report (GNR) called for a Nutrition Data Revolution (International Food Policy Research Institute [IFPRI], 2014), and many subsequent efforts have drawn attention to both the challenges and the emerging efforts to address them (see, for example, Piwoz et al., 2019). Indeed, several of the challenges across the data cycle were effectively highlighted, and solutions proposed, in the 2021 United Nations World Data Forum.[34] Ample literature has also stressed the essential role of sustained investment in the financial and human capacity needed to accompany the data revolution.[35]

Despite this recognition and prior efforts, the generation and use of data for advancing FSN remains woefully inadequate. For example, while the effects of the COVID-19 pandemic

34 For more information, see https://unstats.un.org/unsd/undataforum/blog/promoting-data-use-a-key-challenge-for-statisticians/.

35 See for example this initiative from the Strategy for Agricultural Transformation in Africa 2016-2025: Invest in country level systems and data to support Climate-Smart Agriculture practices and agriculture sector resilience; develop the acquisition, application and management of big data for resilience decision tools and services; invest in country-level infrastructure and training for meeting CSA targets, monitoring GHG emissions and supporting innovation; support the design and development of agriculture climate risk tools and products. (African Development Bank, 2016, p. 20).

have been modelled (FAO *et al.,* 2017; Headey *et al.*, 2020), we do not know its true impact on the affordability of food or on FSN outcomes due to the lack of up-to-date data. The continued effects on FSN of COVID-19 and of ongoing conflicts will also go insufficiently quantified and understood. These data gaps impede the development of effective policy and programmatic responses to address increasing hunger and malnutrition. Indeed, in the face of the failure of food systems and with less than a decade to go until 2030, the achievement of most of the SDGs is dependent on a radical and urgent transformation of food systems (HLPE, 2020). But resources and time are scarce, and there are many competing priorities and trade-offs to be considered. In light of these considerations, *data must be at the centre to diagnose and inform the food system transformations so urgently needed for FSN and for the planet.*

True progress towards enhanced data utilization for FSN will require bold, concerted action and the achievement of these five fundamental shifts in the way in which data and information are used:

CREATE GREATER DEMAND FOR DATA FOR DECISION-MAKING AMONG GOVERNMENTS, POLICY MAKERS AND DONORS

Demand for data for decision-making is a prerequisite for achieving more and better investments and more effective data utilization. But many political, economic and other considerations are brought to bear on policy and programmatic decisions, so that data may not always be a high priority. Data transparency and clear national data strategies[36] are vital to ensure that actionable data are available to policymakers when they need them, and in forms that facilitate their utilization. Another way to enhance data utilization is to illustrate the potential economic implications of not using data. Surprisingly however, few studies have quantified the economic cost to countries of policy and program measures that were not adequately informed by data. This must change.

Supporting demand for data can be facilitated by a framework for aligning and coordinating assistance from international organizations and donors.

To this effect, we recommend that:

- the UN System provide guidance that lays out **good practices for priority setting** guided by frameworks for data decision-making; and develop practical guidelines on data-informed ex-ante and ex-post policy evaluation in the FSN domain for national-level policymakers and administration;
- organizations in the UN System and national and international academic institutions develop and promote the use of **e-learning and continuing education courses in data prioritization and utilization** for policymakers;
- donors, supported by international organizations and academia, develop and use costing and cost-benefit analysis to assist policymakers to **estimate the cost trade-offs of decision-making using data** from varying sources;
    — the World Bank, in its efforts to estimate the cost of nutrition-specific and nutrition-sensitive actions to achieve the SDG2 targets, also estimate the costs of decisions and actions that are not informed by up-to-date, accurate data on the FSN situation in countries, and estimate the savings that may be accrued by acting on better data;
- governments (via their ministries and agencies, including statistics offices) as well as private sector agents, international organizations and research institutions, **complete a data-informed decision-making process matrix for FSN each time they are requested to address a specific challenge;**

36 See Section 5.5.3 of the report.

- for all FSN-related legislation and policy proposals, the responsible government authority include a **detailed data annex**, presenting available data sources and the analytic tools intended to be used for their treatment;

- governments encourage empirical analysis of existing FSN microdata in administration, statistics institutes, agencies and universities; promote the hiring of statisticians, data scientists and experts in the analysis of qualitative FSN data; and **create an annual forum for data-informed discussion on national FSN policies.**

OPTIMIZE AND, IF NEEDED, REPURPOSE CURRENT DATA-RELATED INVESTMENTS, WHILE INCREASING COLLABORATION BETWEEN INTERNATIONAL ORGANIZATIONS, GOVERNMENTS, CIVIL SOCIETY, ACADEMIA AND THE PRIVATE SECTOR, TO HARMONIZE AND MAXIMIZE THE SHARING OF EXISTING FSN DATA

While additional investment in generating data is certainly needed, much can be accomplished through better use of existing data-related resources and by reinforcing the role of international organizations as producers of official FSN data as public goods.

The cost of surveys and all data collection efforts can be substantially reduced by being selective in what data to collect. It is therefore crucial to plan how data will be used *from the outset* to avoid collection of data whose purpose and utilization is unclear. Optimizing the data cycle for FSN is a key priority to reduce costs and enhance data-informed policy responses. The time from data collection to utilization can be decreased by developing analytical plans. Digital technologies and remote sensing hold enormous promise to reduce data collection costs, as does streamlined sampling. Finally, we must be open to change in technologies and processes for data collection, analysis and dissemination. As technologies advance, long-standing data collection systems must be adapted quickly and efficiently. In this respect, it is critical to harmonize data models and ontologies.

Although some initiatives are already in place to coordinate existing data collection activities and their governance, greater internal and international coordination is needed to avoid the proliferation of disconnected data initiatives, which can lead to costly duplication of efforts and contribute to sending conflicting signals. To the extent possible, initiatives should promote the use of data, including qualitative data, generated by the private sector, civil society and academia, in addition to official statistics, but these sources should never be intended to substitute national data systems. The main call should not be for more data, but, rather, for actions that will ensure that data generated are relevant, timely and useful.

To support the achievement of the SDGs, the United Nations Statistics Division (UNSD) is intensifying efforts to develop indicators and integrate geospatial and statistical data. However, not all countries have the same capability to establish food-data systems capable of collecting detailed, disaggregated data over time. Therefore, for these initiatives to succeed, efforts to modernize national statistics systems must be accompanied by assistance to countries with limited capabilities.

To this effect, we recommend that:

- organizations in the UN System develop **minimum standards that set clear criteria for optimizing the use of existing data** in the area covered in their respective mandate, streamlining the processes to be followed when using data for decision-making in FSN;

and prioritize all types of remote and digital data and the development of appropriate data-management plans;

• governments, using such standards, **review existing national data-collection systems relevant for FSN**, with the aim of identifying opportunities to streamline and modernize them, and enhance their efficiency and relevance;

• academic institutions throughout the world **coordinate to consolidate existing FSN data** and respond to the need for continued innovation in the areas of data science and survey-based research to address FSN questions;

• efforts to **modernize national statistics** systems in order to establish comprehensive, coordinated FSN data systems and to sustain the collection of the disaggregated and detailed data needed over time, be **accompanied by technical and financial assistance to countries with limited capabilities;**

• UN System organizations and donors establish a **Global Food Security and Nutrition Data Trust Fund,** to which governments of eligible countries and other stakeholders interested in generating and benefiting from data (including, for example, communities and organizations of Indigenous People) can apply, in order to obtain the necessary financial resources to establish FSN data plans; conduct FSN assessment surveys for specific communities; and create and own data dissemination platforms;

• international organizations that produce key FSN data form a **joint commission to harmonize and coordinate the release of datasets,** avoiding the publication of competing datasets on important FSN domains (such as food commodity balances, food prices and market prospects, food security assessments, etc.);

• all these initiatives devote priority and specific attention to the **transfer of ownership of the used data and methodologies to the countries involved,** promoting the institutionalization of such data systems in national platforms.

INCREASE AND SUSTAIN INVESTMENT IN THE COLLECTION OF ESSENTIAL DATA FOR FSN

This report illustrates the multiple types of data essential to diagnosing and informing FSN actions. Data are woefully lacking in most countries for agriculture, food environments, household-level food access and dietary intake and nutrition outcomes . Often, most data exist only in the form of national-level statistics and indicators, providing few insights into subnational differences, inequalities across population groups, and other variations that may hold relevance for FSN. Increased and sustained investment in sufficiently disaggregated data collection is therefore urgently needed to fill these gaps, accompanied by clear standards to enhance the granularity of data and ensure that those most likely to be affected by inequalities are appropriately represented. Such investments must be accompanied by concurrent investment in capacity, structures and institutions to ensure effective data-related activities from prioritization through utilization.

To this effect, we make a strong plea to donors and governments for increased and sustained financial investment for the collection and consolidation of essential FSN data. Likewise, and recognizing the challenges in increasing investments, we recommend that:

• governments, especially those of low- and middle-income countries where FSN data gaps are particularly large, elaborate national plans to define priorities for FSN data collection and analysis and to improve and optimize existing national data systems for FSN. Countries that require support should be supported both technically and financially by international organizations and donors, and should follow international standards, while preserving country ownership;

• UN system agencies, in their respective areas of competence, develop specific guidance for governments and national statistics offices to streamline data collection in order to prioritize the collection of actionable data;

- donors; private entities in the information, communication and industrial technology sectors; civil society groups; and academic research institutions invest in further refinement, validation and application of resource-saving data collection approaches, such as remote sensing, natural resource scanning by drones and digital data collection tools;

- tools and technology that streamline and simplify data collection (such as REDCap) be used and promoted at all levels;

- international organizations and academic research institutions improve existing analytic models and develop new ones to be employed in various areas of relevance for FSN decision-making, especially model-based approaches, in order to forecast future values of FSN determinants and outcomes, ensuring that such models are transparent and flexibly implemented so that they can generate predictions under clear, alternative scenarios (avoiding the use of black-box modelling).

INVEST IN HUMAN CAPITAL AND IN THE NEEDED INFRASTRUCTURES TO ENSURE THE SUSTAINABILITY OF DATA PROCESSING AND ANALYTIC CAPACITY

Investments specifically aimed at developing the human capital to collect, manage and analyse quality data, but also to synthesize and translate data into actionable insights for decision-making are urgently needed. Among other capacity gaps, we must address the differential between high- and low-income countries, and between the private and public sectors, in terms of ability to exploit the enormous potential that resides in existing data, accessible through the internet via increasingly affordable technology.

Adequate data literacy is needed, especially among policymakers who rely on the results of sophisticated models for data analysis to make policy or investment decisions.

Promoting data literacy for the general population would also be a potent way to promote agency on the part of those whose FSN is at stake. Specific attention should be devoted to promoting sufficient minimum understanding of modern statistics and data science at all levels, for instance, by including these topics in school and academic curricula.

To this effect, we recommend that:

- targeted scholarship programmes be created by national governments – and adequately funded by donors – to allow young people from low-income countries, especially girls, to study science, technology, engineering and mathematics (STEM) disciplines;

- governments take action to expand primary and secondary education curricula to include statistics and data science early in public education programmes;

- national statistics offices offer training opportunities to all staff, of all ages, to enhance their competences in using open-source software for data analysis, and reward demonstrated achievement;

- UN System organizations and international research institutions contribute to eliminating language barriers, by expanding the set of languages in which relevant e-learning platforms are offered;

- international organizations, in collaboration with academic institutions, establish criteria for the quality of e-learning materials for data science and create a framework providing objective quality assessment and ranking of existing, open-access on-line learning opportunities, to identify the best, up-to-date courses and draw attention where quality improvement is needed;

- international organizations avoid crowding out local capacity, by making all efforts to work closely with young professionals from national public institutions whenever the need exists to analyse FSN data at national and subnational levels.

IMPROVE DATA GOVERNANCE AT ALL LEVELS, PROMOTING INCLUSIVENESS TO RECOGNIZE AND ENHANCE AGENCY AMONG DATA USERS AND DATA GENERATORS

Agency refers to the ability to identify one's own data needs and to generate and use data to guide individual and collective decision-making in a two-way flow of data between the immediate and the distal levels. The inclusion of agency as one of the dimensions of FSN has important repercussions in the collection, analysis and use of data for FSN. It highlights, for example, how effective use of existing and new data will greatly benefit from concerted efforts to promote institutional and governance arrangements that favour data sharing at all levels and across all sectors involved in FSN, thus enhancing the agency of all those involved. We strongly subscribe to and support the call made by the 2021 World Development Report to work towards "a new social contract for data – one built on trust to produce value from data that are equitably distributed" (World Bank, 2021 p. 17). Thus, it is fundamental to enhance the role of data collection, analysis and utilization in giving voice to the people most affected by FSN policies, that is, to farmers and other food producers, to Indigenous Peoples, women, youth and vulnerable groups. A human-rights-based approach to FSN and to the realization of the right to food call for greater attention to citizens as right-holders and to their demand of accountability from the state as duty bearer in the realization of this right. Data can be an instrument of empowerment as it enables checks on the accountability of government actors and, as relevant, of the private sector.

Recognizing the importance of agency for data users and generators and enhancing agency require a conducive policy environment and capacity development. Enhancing agency in data generation and access (especially through digital technologies) can help address ethical concerns linked to power imbalances in data ownership and control, and can contribute to reducing inequalities.

To this effect, we recommend that:

- governments, international organizations, civil society, private companies and research institutions, both public and private, **comply with existing open-access principles for data and analysis tools**, ensuring access to and reproducibility of relevant research results, and continually adapt to enhance data access, as open-access principles and guidance evolve;
- all **government data that refer to agriculture and FSN be treated as "open by default"** as recently endorsed by the UN statistical commission;
- governments and multilateral organizations in the UN System work to improve **legal frameworks that protect sensitive data and privacy,** developing accountability systems for their implementation;
- FAO and other UN System organizations that have a mandate for agriculture, food and nutrition, develop a **code of conduct for data generation and use, based on FAIR and CARE principles,** that addresses the diversity of FSN data-governance-related issues – including power imbalances, inclusiveness, the operationalization of open access and transparency principles – for all types of actions in data generation, consolidation and utilization; and that FAO become a FAIR and CARE certifier for agriculture, food and nutrition datasets;
- CFS explore the possibility of establishing **one or more data trusts for food security and nutrition,** where a subgroup of CFS members can act as trustees, receiving the legal right to make decisions – such as who has access to specific data and for what purposes – on behalf of the data owners; and that such a data trust

may constitute the legal basis to support the sharing of data collected with funds obtained through the global FSN data trust fund;

- CFS convene a **workshop to assess the state of private data sharing in agriculture, food security and nutrition** and consider exploring the possibility of piloting the aforementioned data trust for food security and nutrition;

- appropriate **collaborative data initiatives** between governments, international organizations, civil society and private companies in the information and communication industry should be put in place to guarantee access to all relevant, non-personal, food security and nutrition data generated and stored by private agents;

- upon justified request, personal data collected and stored by private agents be mandatorily made **accessible to governmental and intergovernmental organizations for research and policy-guidance purposes,** in a way that protects against misuse and violation of privacy and other individual rights;

- when relevant, private and public sectors, together with all the previously mentioned actors, engage in analytical processes that incorporate the science–policy interface, through, for example, foresight analyses (e.g., Foresight4Food), DELPHI processes, or approaches that incorporate multiple analytical approaches to engage **diverse stakeholders and policymakers (e.g. the INFORMAS approach for the study of food environments).**

REFERENCES

Abdul-Rahaman, A. & Abdulai, A. 2022. Mobile money adoption, input use, and farm output among smallholder rice farmers in Ghana. *Agribusiness*, 38(1): 236–255. https://doi.org/10.1002/agr.21721

Abraham, R., Schneider, J. & vom Brocke, J. 2019. Data governance: A conceptual framework, structured review, and research agenda. *International Journal of Information Management*, 49: 424–438. https://doi.org/10.1016/j.ijinfomgt.2019.07.008

Alemanno, A. 2021. Data for Good: Unlocking Privately-Held Data to the Benefit of the Many. In: M. Lapucci & C. Cattuto, eds. *Data Science for Social Good: Philanthropy and Social Impact in a Complex World.* pp.69–78. Cham, Springer International Publishing. https://doi.org/10.1007/978-3-030-78985-5_6

Anderson, E. 1995. *Value in Ethics and Economics.* Harvard University Press.

Arese Lucini, B., Okeleke, K. & Tricarico, D. 2016. *Market size and opportunity in digitising payments in agricultural value chains.* GSMA intelligence report. GSMA Intelligence. https://data.gsmaintelligence.com/research/research/research-2016/market-size-and-opportunity-in-digitising-payments-in-agricultural-value-chains

Arner, D.W., Castellano, G.G. & Selga, E. 2021. *The Transnational Data Governance Problem.* SSRN Scholarly Paper. ID 3912487. Rochester, NY, Social Science Research Network. https://doi.org/10.2139/ssrn.3912487

Asian Development Bank. 2013. *Food Security in Asia and the Pacific.* Asian Development Bank. http://hdl.handle.net/11540/1435

Aweke, C.S., Hassen, J.Y., Wordofa, M.G., Moges, D.K., Endris, G.S. & Rorisa, D.T. 2021. Impact assessment of agricultural technologies on household food consumption and dietary diversity in eastern Ethiopia. *Journal of Agriculture and Food Research,* 4: 100141. https://doi.org/10.1016/j.jafr.2021.100141

Backiny-Yetna, P., Steele, D. & Yacoubou Djima, I. 2017. The impact of household food consumption data collection methods on poverty and inequality measures in Niger. *Food Policy*, 72: 7–19. https://doi.org/10.1016/j.foodpol.2017.08.008

Badiee, S., Crowell, J., Noe, L., Pittman, A., Rudow, C. & Swanson, E. 2021. Open data for official statistics: History, principles, and implementation. *Statistical Journal of the IAOS,* 37(1): 139–159. https://doi.org/10.3233/SJI-200761

Banik, D. 2016. The Hungry Nation: Food Policy and Food Politics in India. *Food Ethics,* 1(1): 29–45. https://doi.org/10.1007/s41055-016-0001-1

Barreto, L. & Amaral, A. 2018. Smart Farming: Cyber Security Challenges. 2018 *International Conference on Intelligent Systems* (IS): 870–876.

Barrett, H. & Rose, D.C. 2022. Perceptions of the Fourth Agricultural Revolution: What's In, What's Out, and What Consequences are Anticipated? *Sociologia Ruralis*, 62(2): 162–189. https://doi.org/10.1111/soru.12324

Bator, F.M. 1958. The Anatomy of Market Failure. *The Quarterly Journal of Economics*, 72(3): 351–379. https://doi.org/10.2307/1882231

Baú, V. & Calandro, E. 2019. Digital Media and Information Rights. In: *The International Encyclopedia of Media Literacy.* pp.1–13. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118978238.ieml0234

Beal, T., Herforth, A., Sundberg, S., Hess, S.Y. & Neufeld, L.M. 2021. Differences in modelled estimates of global dietary intake. *The Lancet,* 397(10286): 1708–1709. https://doi.org/10.1016/S0140-6736(21)00714-5

Becker-Reshef, I., Barker, B., Humber, M., Puricelli, E., Sanchez, A., Sahajpal, R., McGaughey, K. *et al.* 2019. The GEOGLAM crop monitor for AMIS: Assessing crop conditions in the context of global markets. *Global Food Security,* 23: 173–181. https://doi.org/10.1016/j.gfs.2019.04.010

Bell, W., Colaiezzi, B.A., Prata, C.S. & Coates, J.C. 2017. Scaling up Dietary Data for Decision-Making in Low-Income Countries: New Technological Frontiers. *Advances in Nutrition (Bethesda, Md.),* 8(6): 916–932. https://doi.org/10.3945/an.116.014308

Black, M.M., Lutter, C.K. & Trude, A.C.B. 2020. All children surviving and thriving: re-envisioning UNICEF's conceptual framework of malnutrition. *The Lancet Global Health,* 8(6): e766–e767. https://doi.org/10.1016/S2214-109X(20)30122-4

Blum, A., Hopcroft, J. & Kannan, R. 2017. *Foundations of Data Science.* https://www.microsoft.com/en-us/research/publication/foundations-of-data-science-2/

Bond, T.G., Yan, Z. & Heene, M. 2020. *Applying the Rasch Model: Fundamental Measurement in the Human Sciences.* Fourth edition. New York, Routledge. https://doi.org/10.4324/9780429030499

Boyne, S.M. 2018. Data Protection in the United States. *The American Journal of Comparative Law,* 66(suppl_1): 299–343. https://doi.org/10.1093/ajcl/avy016

Brandimarte, L., Acquisti, A. & Loewenstein, G. 2013. Misplaced Confidences: Privacy and the Control Paradox. *Social Psychological and Personality Science,* 4(3): 340–347. https://doi.org/10.1177/1948550612455931

Bronfenbrenner, U. 1979. *The Ecology of Human Development: Experiments by Nature and Design by U Bronfenbrenner.* Harvard University Press.

Bronson, K. 2019. Looking through a responsible innovation lens at uneven engagements with digital farming. *NJAS: Wageningen Journal of Life Sciences,* 90–91(1): 1–6. https://doi.org/10.1016/j.njas.2019.03.001

Burrell, J. 2016. How the machine 'thinks': Understanding opacity in machine learning algorithms. *Big Data & Society,* 3(1): 2053951715622512. https://doi.org/10.1177/2053951715622512

Burton, R.J.F., Peoples, S. & Cooper, M.H. 2012. Building 'cowshed cultures': A cultural perspective on the promotion of stockmanship and animal welfare on dairy farms. *Rural Realities in the Post-Socialist Space,* 28(2): 174–187. https://doi.org/10.1016/j.jrurstud.2011.12.003

Butler, D. & Holloway, L. 2016. Technology and Restructuring the Social Field of Dairy Farming: Hybrid Capitals, 'Stockmanship' and Automatic Milking Systems. *Sociologia Ruralis,* 56(4): 513–530. https://doi.org/10.1111/soru.12103

Cafiero, C. 2020. Measuring Food Insecurity. In: S.L. Hendriks, ed. *Food security policy, evaluation and impact assessment.* pp.169–205. London and New York, Routledge.

Cafiero, C., Melgar-Quiñonez, H.R., Ballard, T.J. & Kepple, A.W. 2014. Validity and reliability of food security measures. *Annals of the New York Academy of Sciences,* 1331(1): 230–248. https://doi.org/10.1111/nyas.12594

Cafiero, C., Viviani, S. & Nord, M. 2018. Food security measurement in a global context: The food insecurity experience scale. *Measurement,* 116: 146–152. https://doi.org/10.1016/j.measurement.2017.10.065

Carletto, C. 2021. Better data, higher impact: improving agricultural data systems for societal change. *European Review of Agricultural Economics,* 48(4): 719–740. https://doi.org/10.1093/erae/jbab030

Carolan, M. 2017. Publicising Food: Big Data, Precision Agriculture, and Co-Experimental Techniques of Addition. *Sociologia Ruralis,* 57(2): 135–154. https://doi.org/10.1111/soru.12120

Carolan, M. 2022. Digitization as politics: Smart farming through the lens of weak and strong data. *Journal of Rural Studies,* 91: 208–216. https://doi.org/10.1016/j.jrurstud.2020.10.040

Carroll, S.R., Garba, I., Figueroa-Rodríguez, O.L., Holbrook, J., Lovett, R., Materechera, S., Parsons, M. *et al.* 2020. The CARE Principles for Indigenous Data Governance. *Data Science Journal*, 19(1): 43. https://doi.org/10.5334/dsj-2020-043

Cave, J. 2016. The ethics of data and of data science: an economist's perspective. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 374(2083): 20160117. https://doi.org/10.1098/rsta.2016.0117

CCSA. 2016. *Case studies: using non-official sources in international statistics.* Committee for the Coordination of Statistical Activities (CCSA). https://unstats.un.org/unsd/ccsa/documents/E-publication.pdf

Center For Strategic & International Studies (CSIS). 2019. Data Governance Principles for the Global Digital Economy. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/190604_handout_v2.pdf

Charrondiere, U.R. 2017. Food composition challenges. In: *INternational Network of Food Data Systems (INFOODS).* Cited 16 December 2021. https://www.fao.org/infoods/infoods/food-composition-challenges/en/

Chesoli, R.N., Mutiso, J.M. & Wamalwa, M. 2020. Monitoring with social media: Experiences from "integrating" WhatsApp in the M&E system under sweet potato value chain. *Open Agriculture,* 5(1): 395–403. https://doi.org/10.1515/opag-2020-0045

Christodoulou, E., Ma, J., Collins, G.S., Steyerberg, E.W., Verbakel, J.Y. & Van Calster, B. 2019. A systematic review shows no performance benefit of machine learning over logistic regression for clinical prediction models. *Journal of Clinical Epidemiology*, 110: 12–22. https://doi.org/10.1016/j.jclinepi.2019.02.004

Chu, X., Morcos, J., Ilyas, I.F., Ouzzani, M., Papotti, P., Tang, N. & Ye, Y. 2015. KATARA: reliable data cleaning with knowledge bases and crowdsourcing. *Proceedings of the VLDB Endowment,* 8(12): 1952–1955. https://doi.org/10.14778/2824032.2824109

Clapp, J., Moseley, W.G., Burlingame, B. & Termine, P. 2021. Viewpoint: The case for a six-dimensional food security framework. *Food Policy:* 102164. https://doi.org/10.1016/j.foodpol.2021.102164

Clapp, J. & Ruder, S.-L. 2020. Precision Technologies for Agriculture: Digital Farming, Gene-Edited Crops, and the Politics of Sustainability. *Global Environmental Politics*, 20(3): 49–69. https://doi.org/10.1162/glep_a_00566

Colston, J.M., Ahmed, T., Mahopo, C., Kang, G., Kosek, M., de Sousa Junior, F., Shrestha, P.S. *et al.* 2018. Evaluating meteorological data from weather stations, and from satellites and global models for a multi-site epidemiological study. *Environmental Research*, 165: 91–109. https://doi.org/10.1016/j.envres.2018.02.027

Committee on World Food Security. 2021. *Closing data gaps and promoting evidence-informed decision-making for food security and nutrition.* Cited 16 December 2021. https://www.youtube.com/watch?v=x4dynfVd75s

Côté, M. & Lamarche, B. 2021. Artificial intelligence in nutrition research: perspectives on current and future applications. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition Et Metabolisme:* 1–8. https://doi.org/10.1139/apnm-2021-0448

DAMA International. 2009. *The DAMA Guide to the Data Management Body of Knowledge - DAMA-DMBOK.* Denville, NJ, USA, Technics Publications, LLC.

Dania, W.A.P., Xing, K. & Amer, Y. 2018. Collaboration behavioural factors for sustainable agri-food supply chains: A systematic review. *Journal of Cleaner Production,* 186: 851–864. https://doi.org/10.1016/j.jclepro.2018.03.148

Datadent. n.d. https://datadent.org/ Cited on 3 August 2022.

De Choudhury, M., Sharma, S. & Kiciman, E. 2016. *Characterizing Dietary Choices, Nutrition, and Language in Food Deserts via Social Media. In: Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing.* CSCW '16. New York, NY, USA, Association for Computing Machinery, 27 February 2016. https://doi.org/10.1145/2818048.2819956

Deconinck, K., Giner, C., Jackson, L.A. & Toyama, L. 2021. *Overcoming evidence gaps on food systems.* Paris, OECD. https://doi.org/10.1787/44ba7574-en

Deichmann, U., Goyal, A. & Mishra, D. 2016. Will digital technologies transform agriculture in developing countries? *Agricultural Economics,* 47(S1): 21–33. https://doi.org/10.1111/agec.12300

DesJardins, J.R. 2015. Biocentrism. Cited 27 June 2022. https://www.britannica.com/topic/biocentrism

DFID. 1999. *Sustainable livelihoods guidance sheets.* DfID. https://www.livelihoodscentre.org/documents/114097690/114438878/Sustainable+livelihoods+guidance+sheets.pdf/594e5ea6-99a9-2a4e-f288-cbb4ae4bea8b?t=1569512091877

Dooley, D.M., Griffiths, E.J., Gosal, G.S., Buttigieg, P.L., Hoehndorf, R., Lange, M.C., Schriml, L.M., Brinkman, F.S.L. & Hsiao, W.W.L. 2018. FoodOn: a harmonized food ontology to increase global food traceability, quality control and data integration. *npj Science of Food,* 2(1): 23. https://doi.org/10.1038/s41538-018-0032-6

Drew, C. 2016. Data science ethics in government. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 374(2083): 20160119. https://doi.org/10.1098/rsta.2016.0119

Dunford, E., Trevena, H., Goodsell, C., Ng, K.H., Webster, J., Millis, A., Goldstein, S., Hugueniot, O. & Neal, B. 2014. FoodSwitch: A Mobile Phone App to Enable Consumers to Make Healthier Food Choices and Crowdsourcing of National Food Composition Data. *JMIR mHealth and uHealth,* 2(3): e37. https://doi.org/10.2196/mhealth.3230

Enenkel, M., See, L., Karner, M., Álvarez, M., Rogenhofer, E., Baraldès-Vallverdú, C., Lanusse, C. & Salse, N. 2015. Food Security Monitoring via Mobile Data Collection and Remote Sensing: Results from the Central African Republic. *PLOS ONE,* 10(11): e0142030. https://doi.org/10.1371/journal.pone.0142030

Espel-Huynh, H., Zhang, F., Thomas, J.G., Boswell, J.F., Thompson-Brenner, H., Juarascio, A.S. & Lowe, M.R. 2021. Prediction of eating disorder treatment response trajectories via machine learning does not improve performance versus a simpler regression approach. *International Journal of Eating Disorders,* 54(7): 1250–1259. https://doi.org/10.1002/eat.23510

European Commission. 2016. H2020 Programme Guidelines on FAIR Data Management in Horizon 2020. https://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-data-mgt_en.pdf

European Food Safety Authority (EFSA), Nikolic, M. & Ioannidou, S. 2021. FoodEx2 maintenance 2020. EFSA *Supporting Publications,* 18(3): 6507E. https://doi.org/10.2903/sp.efsa.2021.EN-6507

European Union Agency for Fundamental Rights. 2019. Data quality and artificial intelligence – mitigating bias and error to protect fundamental rights. Cited 15 March 2022. https://fra.europa.eu/en/publication/2019/data-quality-and-artificial-intelligence-mitigating-bias-and-error-protect

Fabi, C., Cachia, F., Conforti, P., English, A. & Rosero Moncayo, J. 2021. Improving data on food losses and waste: From theory to practice. *Food Policy,* 98: 101934. https://doi.org/10.1016/j.foodpol.2020.101934

Fanzo, J., Haddad, L., Schneider, K.R., Béné, C., Covic, N.M., Guarin, A., Herforth, A.W. *et al.* 2021. Viewpoint: Rigorous monitoring is necessary to guide food system transformation in the countdown to the 2030 global goals. Food Policy, 104: 102163. https://doi.org/10.1016/j.foodpol.2021.102163

FAO. 1996. Rome Declaration and Plan of Action of the 1996 World Food Summit. Cited 19 December 2021. https://www.fao.org/3/w3613e/w3613e00.htm

FAO. 2006. Food Security Concept Note. Rome. https://www.fao.org/fileadmin/templates/faoitaly/documents/pdf/pdf_Food_Security_Cocept_Note.pdf

FAO. 2013a. Towards food security and improved nutrition: increasing the contribution of forests and trees. FAO.

FAO. 2013b. 10-Year WSIS Action Line Facilitator's Report on the Implementation of WSIS Outcomes. WSIS Action Line - C7: E-Agriculture. Executive Summary. ITU. Cited 17 December 2021. https://www.itu.int/net/wsis/review/inc/docs/ralfreports/WSIS10_ALF_Reporting-C7_E-Agriculture.Summary.pdf

FAO. 2015. INFORMATION SYSTEMS FOR FOOD SECURITY AND NUTRITION.

FAO. 2017a. Information and Communication Technology (ICT) in Agriculture.

FAO. 2017b. Basic texts of the Food and Agriculture Organization of the United Nations. https://www.fao.org/3/mp046e/mp046e.pdf

FAO. 2018. Sustainable food systems: Concept and framework. Rome. https://www.fao.org/3/ca2079en/CA2079EN.pdf

FAO. 2019a. *The State of Food and Agriculture* 2019. Rome, Italy, Food and Agriculture Organization of the United Nations. https://www.fao.org/publications/sofa/2019/en/

FAO. 2019b. *Evaluation of the Global Strategy to Improve Agricultural and Rural Statistics (GSARS): Main report.* Project Evaluation. Rome, Italy, FAO. https://www.fao.org/documents/card/en/c/CA4159EN/

FAO. 2020a. *FAO Statistical Programme of Work 2020–2021.* Rome, Italy, FAO. https://doi.org/10.4060/ca9734en

FAO. 2020b. *Factsheets on the 21 SDG indicators under FAO custodianship: A highlight of the main indicators with the greatest gaps in country reporting.* FAO. https://doi.org/10.4060/ca8958en

FAO. 2020c. Evaluation of FAO's Statistical Work. Cited 17 December 2021. https://www.fao.org/3/nc854en/nc854en.pdf

FAO. 2022. *Mapping of territorial markets: Methodology and guidelines for participatory data collection.* Rome, Italy, FAO. https://doi.org/10.4060/cb9484en

FAO. n.d.a. EAF-Nansen Programme. https://www.fao.org/in-action/eaf-nansen/background/objectives/en/

FAO. n.d.b CFS: Making a difference in food security and nutrition. In: FAO. Rome. http://www.fao.org/cfs

FAO. n.d.c Sustainable Development Goals. In: FAO. Rome. https://www.fao.org/sustainable-development-goals/indicators/212/en/

FAO, A. of B.I. and C. 2021. *Indigenous Peoples' food systems: Insights on sustainability and resilience from the front line of climate change.* Rome, Italy, FAO, Alliance of Bioversity International, and CIAT. https://doi.org/10.4060/cb5131en

FAO and Intake-Center for dietary assessment. 2022. *Global report on the state of dietary data*. Rome, Italy, FAO. https://doi.org/10.4060/cb8679en

FAO and ITU. 2016. *E-Agriculture Strategy Guide. Piloted in Asia-Pacific countries.* Policy Support and Governance. Bangkok, Thailand, Food and Agriculture Organization of the United Nations. https://www.fao.org/policy-support/tools-and-publications/resources-details/es/c/471020/

FAO and The World Bank. 2018. *Food Data Collection in Household Consumption and Expenditure Surveys: Guidelines for Low- and Middle-Income Countries.* The World Bank Group. https://openknowledge.worldbank.org/bitstream/handle/10986/32503/ca1561en.pdf

FAO, IFAD, UNICEF, WHO, & WFP. 2017. *The State of Food Security and Nutrition in the World 2017: Building resilience for peace and food security.* The State of Food Security and Nutrition in the World (SOFI) 2017. Rome, Italy, FAO. https://www.fao.org/3/a-I7695e.pdf

FAO, IFAD, UNICEF, WHO, & WFP. 2018. *The State of Food Security and Nutrition in the World 2018: Building climate resilience for food security and nutrition.* The State of Food Security and Nutrition in the World (SOFI) 2018. Rome, Italy, FAO. https://www.fao.org/3/I9553EN/i9553en.pdf

FAO, IFAD, UNICEF, WHO, & WFP. 2019. *The State of Food Security and Nutrition in the World 2019: Safeguarding against economic slowdowns and downturns.* The State of Food Security and Nutrition in the World (SOFI) 2019. Rome, Italy, FAO. https://doi.org/10.4060/cb4474en

FAO, IFAD, UNICEF, WHO, & WFP. 2022. *The State of Food Security and Nutrition in the World 2022: Repurposing food and agricultural policies to make healthy diets more affordable.* The State of Food Security and Nutrition in the World (SOFI) 2022. Rome, Italy, FAO.

FAO & Ministry of Social Development and Family of Chile. 2021. *Promoting fruit and vegetable consumption.* Santiago, Chile, FAO,. https://doi.org/10.4060/cb7956en

Filter, M., Nauta, M., Pires, S.M., Guillier, L. & Buschhardt, T. 2022. Towards efficient use of data, models and tools in food microbiology. *Current Opinion in Food Science,* 46: 100834. https://doi.org/10.1016/j.cofs.2022.100834

Florey, C., Hellin, J. & Balié, J. 2020. Digital agriculture and pathways out of poverty: the need for appropriate design, targeting, and scaling. *Enterprise Development & Microfinance,* 31(2): 126–140. https://doi.org/10.3362/1755-1986.20-00007

Floridi, L. 2016. Faultless responsibility: on the nature and allocation of moral responsibility for distributed moral actions. *Philosophical Transactions of the Royal Society A,* 374: 20160112.

Floridi, L. & Taddeo, M. 2016. What is data ethics? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 374(2083): 20160360. https://doi.org/10.1098/rsta.2016.0360

Fote, F.N., Roukh, A., Mahmoudi, S., Mahmoudi, S.A. & Debauche, O. 2020. Toward a Big Data Knowledge-Base Management System for Precision Livestock Farming. *Procedia Computer Science*, 177: 136–142. https://doi.org/10.1016/j.procs.2020.10.021

Freeman, B., Kelly, B., Baur, L., Chapman, K., Chapman, S., Gill, T. & King, L. 2014. Digital Junk: Food and Beverage Marketing on Facebook. *American Journal of Public Health,* 104(12): e56–e64. https://doi.org/10.2105/AJPH.2014.302167

Gallacher, J. 2016. What's the good of a science platform? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 374(2083): 20160127. https://doi.org/10.1098/rsta.2016.0127

Ganti, R.K., Ye, F. & Lei, H. 2011. Mobile crowdsensing: current state and future challenges | IEEE Journals & Magazine | IEEE Xplore. *IEEE Communications magazine*, 49(11): 32–39. https://ieeexplore.ieee.org/document/6069707

Gartner. 2022. Big Data. In: *Gartner*. https://www.gartner.com/en/information-technology/glossary/big-data#:~:text=Big%20data%20is%20high%2Dvolume,decision%20making%2C%20and%20process%20automation

Ge, L. & Bogaardt, M.-J. 2015. *Bites into the Bits: Governance of Data Harvesting Initiatives in Agrifood Chains.* 148th Seminar, November 30-December 1, 2015, The Hague, The Netherlands 229261. European Association of Agricultural Economists. https://ideas.repec.org/p/ags/eaa148/229261.html

Gemmill-Herren, B. 2020. Closing the circle: an agroecological response to covid-19. *Agriculture and Human Values:* 1–2. https://doi.org/10.1007/s10460-020-10097-7

Gennari, P Navarro, D.K. 2019. Validation of methods and data for SDG indicators. *Statistical Journal of the IAOS,* 35(4): 735–741. https://doi.org/10.3233/SJI-190519

Global Agriculture & Food Security Program - GAFSP. n.d. What We Do. https://www.gafspfund.org/our-work

Research Data Alliance International Indigenous Data Sovereignty Interest Group. 2019. CARE Principles for Indigenous Data Governance. The Global Indigenous Data Alliance. GIDA-global.org https://static1.squarespace.com/static/5d3799de845604000199cd24/t/5da9f4479ecab221ce848fb2/1571419335217/CARE+Principles_One+Pagers+FINAL_Oct_17_2019.pdf

Grilli, G., Curtis, J. & Hynes, S. 2021. Using angling logbook data to inform fishery management decisions. *Journal for Nature Conservation*, 61: 125987. https://doi.org/10.1016/j.jnc.2021.125987

Grindrod, P. 2016. Beyond privacy and exposure: ethical issues within citizen-facing analytics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160132. https://doi.org/10.1098/rsta.2016.0132

Hardinges, J. 2018. Defining a 'data trust'. In: *Open Data Institute. Knowledge & Opinion.* Cited 6 June 2022. https://theodi.org/article/defining-a-data-trust/

Hardinges, J. 2020. Data trusts in 2020. In: *Open Data Institute. Knowledge & Opinion.* Cited 6 June 2022. https://theodi.org/article/data-trusts-in-2020/

Hariri, R.H., Fredericks, E.M. & Bowers, K.M. 2019. Uncertainty in big data analytics: survey, opportunities, and challenges. *Journal of Big Data*, 6(1): 44. https://doi.org/10.1186/s40537-019-0206-3

Headey, D., Heidkamp, R., Osendarp, S., Ruel, M., Scott, N., Black, R., Shekar, M. *et al.* 2020. Impacts of COVID-19 on childhood malnutrition and nutrition-related mortality. *The Lancet*, 396(10250): 519–521. https://doi.org/10.1016/S0140-6736(20)31647-0

Headey, D.D. & Ecker, O. 2012. *Improving the Measurement of Food Security.* SSRN Scholarly Paper. ID 2185038. Rochester, NY, Social Science Research Network. https://doi.org/10.2139/ssrn.2185038

Hicks, C.C., Cohen, P.J., Graham, N.A.J., Nash, K.L., Allison, E.H., D'Lima, C., Mills, D.J. *et al.* 2019. Harnessing global fisheries to tackle micronutrient deficiencies. *Nature*, 574(7776): 95–98. https://doi.org/10.1038/s41586-019-1592-6

HLPE. 2014. Food losses and waste in the context of sustainable food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome. https://www.fao.org/3/i3901e/i3901e.pdf

HLPE. 2017. *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.* Rome. https://www.fao.org/3/i7846e/i7846e.pdf

HLPE. 2020. Food security and nutrition: building a global narrative towards 2030. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. https://www.fao.org/3/ca9731en/ca9731en.pdf

Humphrey, J. 2017. *Food safety, trade, standards and the integration of smallholders into value chains.* IFAD Research Series 11. Rome, Italy, International Fund for Agricultural Development. https://www.ifad.org/en/web/knowledge/-/publication/research-series-issue-11-food-safety-trade-standards-and-the-integration-of-smallholders-into-value-chains

Hund, L. & Pagano, M. 2014. Extending cluster lot quality assurance sampling designs for surveillance programs. *Statistics in Medicine,* 33(16): 2746–2757. https://doi.org/10.1002/sim.6145

ILO, I.L.O. 2016. N*ew technologies: A jobless future or golden age of job creation?*. Working paper. http://www.ilo.org/global/research/publications/working-papers/WCMS_544189/lang--en/index.htm

ILO, I.L.O. 2020. Digital skills and the future of work: Challenges and opportunities in a post COVID-19 environment (WISIS Session 216, 29 July 2020). Cited 31 March 2022. http://www.ilo.org/emppolicy/pubs/WCMS_766085/lang--en/index.htm

International Food Policy Research Institute - IFPRI. 2014. *Global Nutrition Report.* Washington, DC, International Food Policy Research Institute. https://doi.org/10.2499/9780896295643

IPC Global Partners. 2021. *Integrated Food Security Phase Classification Technical Manual Version 3.1. Evidence and Standards for Better Food Security and Nutrition Decisions.* Rome, The Integrated Food Security Phase Classification (IPC) Global Partners.

Johari, A. 2021. A new app is failing India's fight against child malnutrition. In: *Scroll.in.* Cited 17 December 2021. https://scroll.in/article/1007521/a-new-app-is-failing-india-s-fight-against-child-malnutrition

Jones, J.W., Antle, J.M., Basso, B., Boote, K.J., Conant, R.T., Foster, I., Godfray, H.C.J. *et al.* 2017. Toward a new generation of agricultural system data, models, and knowledge products: State of agricultural systems science. *Agricultural Systems,* 155: 269–288. https://doi.org/10.1016/j.agsy.2016.09.021

Jones, S.K., Estrada-Carmona, N., Juventia, S.D., Dulloo, M.E., Laporte, M.-A., Villani, C. & Remans, R. 2021. Agrobiodiversity Index scores show agrobiodiversity is underutilized in national food systems. *Nature Food,* 2(9): 712–723. https://doi.org/10.1038/s43016-021-00344-3

Kalibata, A. & Mohamedou, E.I. 2021. A lack of basic agricultural data holds African countries back — *Quartz Africa.* In: Quartz Africa. Cited 16 December 2021. https://qz.com/africa/2001970/a-lack-of-basic-agricultural-data-holds-african-countries-back/

Kanter, R. & Gittelsohn, J. 2020. Measuring Food Culture: a Tool for Public Health Practice. *Current Obesity Reports,* 9(4): 480–492. https://doi.org/10.1007/s13679-020-00414-w

Kanter, R., Walls, H.L., Tak, M., Roberts, F. & Waage, J. 2015. A conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health. *Food Security,* 7(4): 767–777.

Kelling, S., Fink, D., La Sorte, F.A., Johnston, A., Bruns, N.E. & Hochachka, W.M. 2015. Taking a 'Big Data' approach to data quality in a citizen science project. *Ambio*, 44(4): 601–611. https://doi.org/10.1007/s13280-015-0710-4

Khan, A.S. & Hoffmann, A. 2003. Building a case-based diet recommendation system without a knowledge engineer. *Artificial Intelligence in Medicine*, 27(2): 155–179. https://doi.org/10.1016/s0933-3657(02)00113-6

Khera, R. 2019. Dissent on Aadhaar, Big Data Meets Big Brother. New Delhi India, Orient BlackSwan https://orientblackswan.com/details?id=9789352875429

Kitchin, R. 2014a. The Data Revolution: *Big Data, Open Data, Data Infrastructures & Their Consequences.* 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom, SAGE Publications Ltd. https://doi.org/10.4135/9781473909472

Kitchin, R. 2014b. Big Data, new epistemologies and paradigm shifts. *Big Data & Society,* 1(1): 2053951714528481. https://doi.org/10.1177/2053951714528481

Kitchin, R. 2016. The ethics of smart cities and urban science. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160115. https://doi.org/10.1098/rsta.2016.0115

Kitchin, R. 2021. *The Data Revolution: A Critical Analysis of Big Data, Open Data and Data Infrastructures.* Second edition edition. Thousand Oaks, SAGE Publications Ltd.

Klerkx, L., Jakku, E. & Labarthe, P. 2019. A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS: Wageningen Journal of Life Sciences*, 90–91(1): 1–16. https://doi.org/10.1016/j.njas.2019.100315

Knottnerus, J.A. 2016. Research data as a global public good. *Journal of Clinical Epidemiology*, 70: 270–271. https://doi.org/10.1016/j.jclinepi.2015.05.034

Kos, D. & Kloppenburg, S. 2019. Digital technologies, hyper-transparency and smallholder farmer inclusion in global value chains. *Current Opinion in Environmental Sustainability*, 41: 56–63. https://doi.org/10.1016/j.cosust.2019.10.011

Kraak, V., Zhou, M. & Rincón-Gallardo Patiño, S. 2020. Digital marketing to young people: Consequences for the health and diets of future generations. https://vtechworks.lib.vt.edu/handle/10919/101673

Krosnick, J.A., Presser, S. & Husbands, K.G. 2015. *The Future of Survey Research: Challenges and Opportunities.*

Kwon, Y.-J., Kim, H.S., Jung, D.-H. & Kim, J.-K. 2020. Cluster analysis of nutritional factors associated with low muscle mass index in middle-aged and older adults. *Clinical Nutrition*, 39(11): 3369–3376. https://doi.org/10.1016/j.clnu.2020.02.024

Landi, A., Thompson, M., Giannuzzi, V., Bonifazi, F., Labastida, I., da Silva Santos, L.O.B. & Roos, M. 2020. The "A" of FAIR – As Open as Possible, as Closed as Necessary. *Data Intelligence*, 2(1–2): 47–55. https://doi.org/10.1162/dint_a_00027

Lapucci, M. & Cattuto, C., eds. 2021. *Data Science for Social Good. Philanthropy and Social Impact in a Complex World.* Springer Brief in Complexity. Springer Cham. https://doi.org/10.1007/978-3-030-78985-5

LeFevre, A., Chamberlain, S., Singh, N.S., Scott, K., Menon, P., Barron, P., Ved, R.R. & George, A. 2021. Avoiding the Road to Nowhere: Policy Insights on Scaling up and Sustaining Digital Health. *Global Policy*, 12(S6): 110–114. https://doi.org/10.1111/1758-5899.12909

Leonelli, S. 2016. Locating ethics in data science: responsibility and accountability in global and distributed knowledge production systems. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160122. https://doi.org/10.1098/rsta.2016.0122

Lezoche, M., Hernandez, J.E., Alemany Díaz, M. del M.E., Panetto, H. & Kacprzyk, J. 2020. Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture. *Computers in Industry*, 117: 103187. https://doi.org/10.1016/j.compind.2020.103187

Lishan Adam & Michael Minges. 2018. *ICTs, LDCs and the SDGs. Achieving universal and affordable Internet in the least developed countries.* ITU.

Lowder, S.K., Skoet, J. & Raney, T. 2016. The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. *World Development*, 87: 16–29. https://doi.org/10.1016/j.worlddev.2015.10.041

Maguire, M. 2001. Methods to support human-centred design. *International Journal of Human-Computer Studies*, 55(4): 587–634. https://doi.org/10.1006/ijhc.2001.0503

Mahanty, S. & McDermott, C.L. 2013. How does 'Free, Prior and Informed Consent' (FPIC) impact social equity? Lessons from mining and forestry and their implications for REDD+. *Land Use Policy*, 35: 406–416. https://doi.org/10.1016/j.landusepol.2013.06.014

Malabo Montpellier Panel. 2017. *Nourished: How Africa can build a future free from hunger and malnutrition.* Dakar, Senegal, International Food Policy Research Institute (IFPRI); Malabo Montpellier Panel. https://ebrary.ifpri.org/digital/collection/p15738coll2/id/131407

Malapit, H., Quisumbing, A., Meinzen-Dick, R., Seymour, G., Martinez, E.M., Heckert, J., Rubin, D., Vaz, A. & Yount, K.M. 2019. Development of the project-level Women's Empowerment in Agriculture Index (pro-WEAI). *World Development*, 122: 675–692. https://doi.org/10.1016/j.worlddev.2019.06.018

Manning, L. & Soon, J.M. 2016. Food Safety, Food Fraud, and Food Defense: A Fast Evolving Literature. *Journal of Food Science,* 81(4): R823-834. https://doi.org/10.1111/1750-3841.13256

Mari, L., Maul, A., Torres Irribarra, D. & Wilson, M. 2017. Quantities, Quantification, and the Necessary and Sufficient Conditions for Measurement. *Measurement*, 100: 115–121. https://doi.org/10.1016/j.measurement.2016.12.050

Mason, M.A., Fanelli Kuczmarski, M., Allegro, D., Zonderman, A.B. & Evans, M.K. 2015. The impact of conventional dietary intake data coding methods on foods typically consumed by low-income African-American and White urban populations. *Public Health Nutrition*, 18(11): 1922–1931. https://doi.org/10.1017/S1368980014002687

Meybeck, A., Licona Manzur, C., Gitz, V., Dawson, I.K., Martius, C., Kindt, R., Louman, B. *et al.* 2021. FTA Highlight No.12 – Adaptation to Climate Change with Forests, Trees and Agroforestry. In: *CIFOR*. Cited 31 May 2022. https://www.cifor.org/knowledge/publication/8222/

Micha, R., Coates, J., Leclercq, C., Charrondiere, U.R. & Mozaffarian, D. 2018. Global Dietary Surveillance: Data Gaps and Challenges. *Food and Nutrition Bulletin,* 39(2): 175–205. https://doi.org/10.1177/0379572117752986

Miller, L.C., Joshi, N., Lohani, M., Rogers, B., Kershaw, M., Houser, R., Ghosh, S. *et al.* 2017. Duration of programme exposure is associated with improved outcomes in nutrition and health: the case for longer project cycles from intervention experience in rural Nepal. *Journal of Development Effectiveness,* 9(1): 101–119. https://doi.org/10.1080/19439342.2016.1231706

Moxness Reksten, A., Bøkevoll, A., Frantzen, S., Lundebye, A.-K., Kögel, T., Kolås, K., Aakre, I. & Kjellevold, M. 2020. Sampling protocol for the determination of nutrients and contaminants in fish and other seafood – The EAF-Nansen Programme. *MethodsX*, 7: 101063. https://doi.org/10.1016/j.mex.2020.101063

Mozaffarian, D., Angell, S.Y., Lang, T. & Rivera, J.A. 2018. Role of government policy in nutrition—barriers to and opportunities for healthier eating. *BMJ,* 361: k2426. https://doi.org/10.1136/bmj.k2426

Mulligan, D.K., Koopman, C. & Doty, N. 2016. Privacy is an essentially contested concept: a multi-dimensional analytic for mapping privacy. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160118. https://doi.org/10.1098/rsta.2016.0118

Narayanan, A., Mathur, A., Chetty, M. & Kshirsagar, M. 2020. Dark patterns: past, present, and future. *Communications of the ACM,* 63(9): 42–47. https://doi.org/10.1145/3397884

Neema, S. & Chandrashekar, L. 2021. Research Funding—Why, When, and How? *Indian Dermatology Online Journal,* 12(1): 134–138. https://doi.org/10.4103/idoj.IDOJ_684_20

NIHR - National Institute for Health Research. 2021. The James Lind Alliance Guidebook - Version 10. National Institute for Health Research. https://www.jla.nihr.ac.uk/jla-guidebook/

Ochieng, D.O. 2019. Report on a pilot study to crowdsource farmgate prices for legumes in southern Malawi. Cited 15 March 2022. https://ebrary.ifpri.org/digital/collection/p15738coll2/id/133569

OECD. 2001. *Adoption of Technologies for Sustainable Farming Systems: Wageningen Workshop Proceedings.* Paris, France, Organisation for Economic Co-operation and Development. https://www.oecd.org/greengrowth/sustainable-agriculture/2739771.pdf

OECD. 2019. *Statistical Capacity Development Outlook 2019.* https://paris21.org/flagship/2019

Office Journal of the European Union. 2016. Charter of Fundamental Rights of the European Union. Page 7. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12016P/TXT&rid=3

Okello, D., Owuor, G., Larochelle, C., Gathungu, E. & Mshenga, P. 2021. Determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya. *Journal of Agriculture and Food Research*, 6: 100213. https://doi.org/10.1016/j.jafr.2021.100213

Oliver, N. 2021. When Philanthropy Meets Data Science: A Framework for Governance to Achieve *Data-Driven Decision-Making for Public Good.* In: Data Science for Social Good. pp.55–68. Springer.

Open Data Initiative. 2018. https://theodi.org/article/defining-a-data-trust/

Open Definition. (n.d.). Open Definition: Defining Open in Open Data, Open Content and Open Knowledge. In: Open Definition. Cited 3 August 2022. http://opendefinition.org/od/2.1/en/

Ortiz-Crespo, B., Steinke, J., Quirós, C.F., van de Gevel, J., Daudi, H., Gaspar Mgimiloko, M. & van Etten, J. 2021. User-centred design of a digital advisory service: enhancing public agricultural extension for sustainable intensification in Tanzania. *International Journal of Agricultural Sustainability,* 19(5–6): 566–582. https://doi.org/10.1080/14735903.2020.1720474

Peprah, J.A., Oteng, C. & Sebu, J. 2020. Mobile Money, Output and Welfare Among Smallholder Farmers in Ghana. SAGE Open, 10(2): 2158244020931114. https://doi.org/10.1177/2158244020931114

Piwoz, E., Rawat, R., fracassi, P Kim, D. 2019. Strengthening the Nutrition Data Value Chain for Accountability and Action. Progress, gaps and next steps. *Sight and Life*, 2019(1): 38–43. https://doi.org/10.52439/HDXT8911

Porsdam Mann, S., Savulescu, J. & Sahakian, B.J. 2016. Facilitating the ethical use of health data for the benefit of society: electronic health records, consent and the duty of easy rescue. Philosophical Transactions of the Royal Society A: Mathematical, *Physical and Engineering Sciences,* 374(2083): 20160130. https://doi.org/10.1098/rsta.2016.0130

Purtova, N. 2013. *Illusion of Personal Data as No One's Property.* SSRN Scholarly Paper. 2346693. Rochester, NY, Social Science Research Network. https://papers.ssrn.com/abstract=2346693

Purtova, N. 2018. The law of everything. Broad concept of personal data and future of EU data protection law. *Law, Innovation and Technology,* 10(1): 40–81. https://doi.org/10.1080/17579961.2018.1452176

Rahman, S.M.J., Ahmed, N.A.M.F., Abedin, M.M., Ahammed, B., Ali, M., Rahman, M.J. & Maniruzzaman, M. 2021. Investigate the risk factors of stunting, wasting, and underweight among under-five Bangladeshi children and its prediction based on machine learning approach. PloS One, 16(6): e0253172. https://doi.org/10.1371/journal.pone.0253172

Regan, Á. 2021. Exploring the readiness of publicly funded researchers to practice responsible research and innovation in digital agriculture. *Journal of Responsible Innovation,* 8(1): 28–47. https://doi.org/10.1080/23299460.2021.1904755

Reiss, J. 2021. Public Goods. In: E.N. Zalta, ed. *The Stanford Encyclopedia of Philosophy.* Fall 2021 edition, p.Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/fall2021/entries/public-goods/

Reuters. 2022. Delivery app Rappi begins accepting cryptocurrency in Mexico. *Reuters.* https://www.reuters.com/technology/delivery-app-rappi-begins-accepting-cryptocurrency-mexico-2022-04-11/

Rigdon, J. & Basu, S. 2019. Machine learning with sparse nutrition data to improve cardiovascular mortality risk prediction in the USA using nationally randomly sampled data. *BMJ open*, 9(11): e032703. https://doi.org/10.1136/bmjopen-2019-032703

Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I. & Brunori, G. 2021. Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation. *Journal of Rural Studies*, 85: 79–90. https://doi.org/10.1016/j.jrurstud.2021.05.003

Robertson, S.E. & Valadez, J.J. 2006. Global review of health care surveys using lot quality assurance sampling (LQAS), 1984–2004. *Social Science & Medicine*, 63(6): 1648–1660. https://doi.org/10.1016/j.socscimed.2006.04.011

Roe, M. a., Bell, S., Oseredczuk, M., Christensen, T., Westenbrink, S., Pakkala, H., Presser, K. & Finglas, P.m. 2013. Updated food composition database for nutrient intake. *EFSA Supporting Publications*, 10(6): 355E. https://doi.org/10.2903/sp.efsa.2013.EN-355

Rose, D.C. & Chilvers, J. 2018. Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming. *Frontiers in Sustainable Food Systems*, 2. https://doi.org/10.3389/fsufs.2018.00087

Rudin, C. 2019. Stop explaining black box machine learning models for high stakes decisions and use interpretable models instead. *Nature Machine Intelligence*, 1(5): 206–215. https://doi.org/10.1038/s42256-019-0048-x

Sampson, C.J., Arnold, R., Bryan, S., Clarke, P., Ekins, S., Hatswell, A., Hawkins, N. *et al.* 2019. Transparency in Decision Modelling: What, Why, Who and How? *PharmacoEconomics*, 37(11): 1355–1369. https://doi.org/10.1007/s40273-019-00819-z

Santos Valle, S. & Kienzle, J. 2020. Agriculture 4.0 – Agricultural robotics and automated equipment for sustainable crop production (Policy Support and Governance) Food and Agriculture Organization of the United Nations. *Integrated Crop Management*, 24. https://www.fao.org/3/cb2186en/CB2186EN.pdf

Sauermann, H., Vohland, K., Antoniou, V., Balázs, B., Göbel, C., Karatzas, K., Mooney, P. *et al.* 2020. Citizen science and sustainability transitions. Research Policy, 49(5):103978.

Schafer, B. 2016. Compelling truth: legal protection of the infosphere against big data spills. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160114. https://doi.org/10.1098/rsta.2016.0114

Schmidhuber, J., Sur, P., Fay, K., Huntley, B., Salama, J., Lee, A., Cornaby, L. *et al.* 2018. The Global Nutrient Database: availability of macronutrients and micronutrients in 195 countries from 1980 to 2013. *The Lancet Planetary Health*, 2(8): e353–e368. https://doi.org/10.1016/S2542-5196(18)30170-0

Schut, M., Klerkx, L., Sartas, M., Lamers, D., Campbell, M.M., Ogbonna, I., Kaushik, P., Atta-Krah, K. & Leeuwis, C. 2016. INNOVATION PLATFORMS: EXPERIENCES WITH THEIR INSTITUTIONAL EMBEDDING IN AGRICULTURAL RESEARCH FOR DEVELOPMENT. *Experimental Agriculture*, 52(4): 537–561. https://doi.org/10.1017/S001447971500023X

Shah, N., Srivastava, G., Savage, D.W. & Mago, V. 2020. Assessing Canadians Health Activity and Nutritional Habits Through Social Media. *Frontiers in Public Health*, 7. https://www.frontiersin.org/article/10.3389/fpubh.2019.00400

Shepherd, M., Turner, J.A., Small, B. & Wheeler, D. 2020. Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture' revolution. *Journal of the Science of Food and Agriculture*, 100(14): 5083–5092. https://doi.org/10.1002/jsfa.9346

Siew, K. 2017. The open science movement. Revolution is underway. *Physiology News*(107): 24–29.

Sivarajah, U., Kamal, M.M., Irani, Z. & Weerakkody, V. 2017. Critical analysis of Big Data challenges and analytical methods. *Journal of Business Research*, 70: 263–286. https://doi.org/10.1016/j.jbusres.2016.08.001

Stiglitz, J.E. 1989. Markets, Market Failures, and Development. *The American Economic Review,* 79(2): 197–203.

Stiglitz, J.E. 1999. Knowledge as a Global Public Good. In: *Global Public Goods.* New York, Oxford University Press. https://doi.org/10.1093/0195130529.003.0015

Swaminathan, M. & Swaminathan, M.S. 2018. ICT and agriculture. *CSI Transactions on ICT,* 6(3): 227–229. https://doi.org/10.1007/s40012-018-0209-9

Sylvester, G. 2019. *E-agriculture in action: Blockchain for agriculture: Challenges and opportunities.* Bangkok, Thailand, FAO. https://www.fao.org/documents/card/en/c/CA2906EN/

Taddeo, M. 2016. Data philanthropy and the design of the infraethics for information societies. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160113. https://doi.org/10.1098/rsta.2016.0113

Talukder, A. & Ahammed, B. 2020. Machine learning algorithms for predicting malnutrition among under-five children in Bangladesh. *Nutrition*, 78: 110861. https://doi.org/10.1016/j.nut.2020.110861

Taylor, L. 2016. The ethics of big data as a public good: which public? Whose good? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 374(2083): 20160126. https://doi.org/10.1098/rsta.2016.0126

Thow, A.M., Greenberg, S., Hara, M., Friel, S., duToit, A. & Sanders, D. 2018. Improving policy coherence for food security and nutrition in South Africa: a qualitative policy analysis. *Food Security,* 10(4): 1105–1130. https://doi.org/10.1007/s12571-018-0813-4

Tilley, A., Lopes, J.D.R. & Wilkinson, S.P. 2020. PeskAAS: A near-real-time, open-source monitoring and analytics system for small-scale fisheries. *PLOS ONE*, 15(11): e0234760. https://doi.org/10.1371/journal.pone.0234760

Tinsley, R. 2010. Financially Stalled Governments. In: *Smallholder Agriculture.* Cited 16 December 2021. https://agsci.colostate.edu/smallholderagriculture/financially-stalled-governments/

Traders of Crypto. n.d. *The Crypto Adoption Report.* https://tradersofcrypto.com/crypto_adoption/

Turner, C., Kalamatianou, S., Drewnowski, A., Kulkarni, B., Kinra, S. & Kadiyala, S. 2020. Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. *Advances in Nutrition*, 11(2): 387–397. https://doi.org/10.1093/advances/nmz031

United Nations (UN). 2014. Fundamental Principles of Official Statistics. https://unstats.un.org/unsd/dnss/gp/fundprinciples.aspx

UN. 2015. A World That Counts: Mobilizing the Data Revolution for Sustainable Development - Report of the Secretary-General'S Independent Expert Advisory Group on the Data Revolution for Sustainable Development. UN. Cited 17 December 2021. https://digitallibrary.un.org/record/3882725

UN General Assembly. 2014. Fundamental Principles of Official Statistics. https://unstats.un.org/unsd/dnss/gp/FP-New-E.pdf

UNSD (United Nations Statistics Division). 2022. Report of the Working Group on Open Data, E/CN.3/2022/27. https://unstats.un.org/unsd/statcom/53rd-session/documents/2022-27-OpenData-E.pdf

UN Statistical Commission. 2019. Report of the Food and Agriculture Organization of the United Nations on recent developments in agricultural and rural statistics. https://undocs.org/en/E/CN.3/2020/30

UN System Chief Executive's Board for Coordination - UNSCEB. n.d. Principles on Personal Data Protection and Privacy. https://unsceb.org/principles-personal-data-protection-and-privacy-listing

UNICEF. 1990. Strategy for improved nutrition of children and women in developing countries. UNICEF,. Cited 13 December 2021. https://digitallibrary.un.org/record/227230

UNICEF. 2021. UNICEF Conceptual Framework on Maternal and Child Nutrition. United Nations Childrens' Fund (UNICEF).

United Nations. 2007. United Nations Declaration on the Rights of Indigenous Peoples | United Nations For Indigenous Peoples. Cited 13 May 2022. https://www.un.org/development/desa/indigenouspeoples/declaration-on-the-rights-of-indigenous-peoples.html

Vaitla, B., Collar, D., Smith, M.R., Myers, S.S., Rice, B.L. & Golden, C.D. 2018. Predicting nutrient content of ray-finned fishes using phylogenetic information. *Nature Communications*, 9(1): 3742. https://doi.org/10.1038/s41467-018-06199-w

Varley-Winter, O. & Shah, H. 2016. The opportunities and ethics of big data: practical priorities for a national Council of Data Ethics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160116. https://doi.org/10.1098/rsta.2016.0116

Vayena, E. & Tasioulas, J. 2016. The dynamics of big data and human rights: the case of scientific research. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2083): 20160129. https://doi.org/10.1098/rsta.2016.0129

Veillard, J., Garcia-Armesto, S., Kadandale, S. & Klazinga, N. 2010. International health system comparisons: from measurement challenge to management tool. In: P.C. Smith, E. Mossialos, I. Papanicolas & S. Leatherman, eds. *Performance Measurement for Health System Improvement: Experiences, Challenges and Prospects*. pp.641–672. Health Economics, Policy and Management. Cambridge University Press. https://doi.org/10.1017/CBO9780511711800.023

Verdouw, C.N. & Kruize, J.W. 2017. *Digital twins in farm management : illustrations from the FIWARE accelerators SmartAgriFood and Fractals.* https://scholar.google.com/scholar_lookup?title=Digital+twins+in+farm+management+%3A+illustrations+from+the+FIWARE+accelerators+SmartAgriFood+and+Fractals&author=Verdouw%2C+C.N.&publication_year=2017

Vosti, S.A., Kagin, J., Engle-Stone, R. & Brown, K.H. 2015. An Economic Optimization Model for Improving the Efficiency of Vitamin A Interventions: An Application to Young Children in Cameroon. *Food and Nutrition Bulletin*, 36(3_suppl): S193–S207. https://doi.org/10.1177/0379572115595889

Wan, G. & Zhou, Z.-Y., eds. 2017. *Food Insecurity in Asia: Why Institutions Matter.* Asian Development Bank. https://www.adb.org/publications/food-insecurity-asia-why-institutions-matter

Wazny, K., Arora, N.K., Mohapatra, A., Gopalan, H.S., Das, M.K., Nair, M., Bavdekar, S. *et al.* 2019. Setting priorities in child health research in India for 2016-2025: a CHNRI exercise undertaken by the Indian Council for Medical Research and INCLEN Trust. *Journal of Global Health*, 9(2): 020701. https://doi.org/10.7189/jogh.09.020701

Weersink, A., Fraser, E., Pannell, D., Duncan, E. & Rotz, S. 2018. Opportunities and Challenges for Big Data in Agricultural and Environmental Analysis. *Annual Review of Resource Economics*, 10(1): 19–37. https://doi.org/10.1146/annurev-resource-100516-053654

WHO. 2013. Social determinants of health: Key concepts. In: *World Health Organization*. https://www.who.int/news-room/questions-and-answers/item/social-determinants-of-health-key-concepts

WHO & UNICEF. 2020. *Use of nutrition data in decision making: a review paper.* https://www.who.int/publications/m/item/use-of-nutrition-data-in-decision-making-a-review-paper

Wilkinson, M.D., Dumontier, M., Aalbersberg, Ij.J., Appleton, G., Axton, M., Baak, A., Blomberg, N. *et al.* 2016. The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, 3(1): 160018. https://doi.org/10.1038/sdata.2016.18

Wolfert, J., Ge, L., Verdouw, C. & Bogaardt, M.J. 2017. Big Data in Smart Farming – A review. *Agricultural Systems*, 153: 69–80. https://doi.org/10.1016/j.agsy.2017.01.023

World Bank. 2018. Blockchain & Distributed Ledger Technology (DLT). In: *World Bank*. https://www.worldbank.org/en/topic/financialsector/brief/blockchain-dlt

World Bank. 2021. *World Development Report 2021: Data for Better Lives.* https://www.worldbank.org/en/publication/wdr2021

World Bank, UNSD, & Paris21. 2022. S*urvey on the Implementation of the Cape Town Global Action Plan for Sustainable Development Data.* Text/HTML. Washington, DC, World Bank Group. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/826351643712794722/Survey-on-the-Implementation-of-the-Cape-Town-Global-Action-Plan-for-Sustainable-Development-Data

World Food Program (WFP). 2021. Technical guidance for WFP's consolidated Approach for Reporting Indicators of Food security (CARI). https://docs.wfp.org/api/documents/WFP-0000134704/download/

Wright, B. 1999. Common Sense for Measurement. *Rasch Measurement Transactions,* 13(3): 704.

Yeung, K. 2018. *A Study of the Implications of Advanced Digital Technologies (Including AI Systems) for the Concept of Responsibility Within a Human Rights Framework.* SSRN Scholarly Paper. ID 3286027. Rochester, NY, Social Science Research Network. https://papers.ssrn.com/abstract=3286027

Yoshida, S. 2016. Approaches, tools and methods used for setting priorities in health research in the 21st century. *Journal of Global Health,* 6(1). https://www.jogh.org/documents/issue201601/jogh-06-010507.pdf

Zeevi, D., Korem, T., Zmora, N., Israeli, D., Rothschild, D., Weinberger, A., Ben-Yacov, O. *et al*. 2015. Personalized Nutrition by Prediction of Glycemic Responses. *Cell*, 163(5): 1079–1094. https://doi.org/10.1016/j.cell.2015.11.001

Zins, C. 2007. Conceptual approaches for defining data, information, and knowledge. *Journal of the American Society for Information Science and Technology,* 58(4): 479–493. https://doi.org/10.1002/asi.20508

GLOSSARY

Access (as a dimension of food security) Having personal or household financial means to acquire food for an adequate diet at a level to ensure that satisfaction of other basic needs are not threatened or compromised; and that adequate food is accessible to everyone, including vulnerable individuals and groups (FAO, 2006).

Agency (as a dimension of food security) Individuals or groups having the capacity to act independently to make choices about what they eat, the foods they produce, how that food is produced, processed and distributed, and to engage in policy processes that shape food systems (HLPE, 2020). The protection of agency requires sociopolitical systems that uphold governance structures that enable the achievement of FSN for all (HLPE, 2020).

Artificial Intelligence (AI) The theory and development of computer systems to enable them to carry out tasks commonly associated with human intelligence. AI includes specific fields such as machine learning, perception, robotics and natural language processing. Computer vision and deep learning can be used to support visual perception.

Availability (as a dimension of food security) Having a quantity and quality of food sufficient to satisfy the dietary needs of individuals, free from adverse substances, and acceptable within a given culture, supplied through domestic production or imports (FAO, 2006).

Big data High-volume, high-velocity, high-variety and/or high-veracity information assets that demand cost-effective, innovative forms of information processing for enhanced insight, decision-making, and process automation (Gartner, n.d.).

Blockchain technology (or Distributed Ledger Technology) A decentralized, distributed ledger such that the data units are broken up into shared blocks that are chained together with unique identifiers in the form of cryptographic hashes (World Bank, 2018).

Citizen science Scientific research that actively involves the public in the collection of information to help advance scientific knowledge and address the gap between science and society at large (Sauermann *et al.,* 2020).

Cloud computing Cloud computing centralizes resources and services remotely and facilitates their use by multiple users without the need for the users to store the resources or install the services on their individual hard drives.

Committee on World Food Security (CFS) The Committee on World Food Security (CFS) is the foremost inclusive international and intergovernmental platform for all stakeholders to work together to ensure food security and nutrition for all. The Committee reports to the UN General Assembly through the Economic and Social Council (ECOSOC) and to the FAO Conference (FAO, n.db).

Crowdsensing (or community sensing) Paradigm in which a community leverages devices with sensing and computing capabilities to collectively share data and extract information to measure and map phenomena of common interest (Kraft et al., 2020). Crowdsensing differs from the paradigm of personal sensing, where, in the latter, the phenomena that are monitored belong to an individual user. Crowdsensing is considered to apply to scenarios where the phenomena of interest cannot be easily measured by a single user or device (Ganti, Ye and Lei, 2011).

Crowdsourcing Practice of engaging a group of people (i.e., a "crowd"), usually via the internet, to assist in collecting information, ideas, opinions, or other resource for a common goal, such as problem solving, innovation, etc.

Data Any set of codified symbols representing units of information regarding specific aspects of the world that can be captured or generated, recorded, stored and transmitted in analogue or digital form.

Data analysis tool A set of formal rules used to guide the processing of available data, aimed at obtaining analytic results for a specific purpose or research question.

Data curation Active and ongoing management of data to provide an increased number of data sources, to facilitate data discovery and maintain quality for reutilization over time.

Data ecosystem An environment in which several actors and entities interact to provide, produce, exchange and consume data. Data ecosystems offer a setting to facilitate the creation, management and sustainability of data sharing initiatives, among others.

Data governance Cross-functional framework for managing data as a strategic enterprise asset. In doing so, data governance specifies decision rights and accountabilities for an organization's decision-making about its data. Furthermore, data governance formalizes data policies, standards and procedures and monitors compliance.

Data sovereignty Notion to describe data management that considers the local laws, practices and customs in which the data is based.

Decision-support system (DSS) Software-based system that gathers and analyses data from a variety of sources in order to facilitate the decision-making process for management, operations, planning, or optimal solution path recommendation.

Digital twin Virtual representation that serves as the real-time digital counterpart of a physical object or system and that helps in decision-making.

Food Insecurity Experience Scale (FIES) The food insecurity measurement system used as the basis to compute SDG Indicator 2.1.2, The prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES). FIES is an innovative, experience-based tool aiming to measure access to food at the level of individuals or households. It focuses on self-reported, food-related behaviours and experiences associated with increasing difficulties in accessing food due to resource constraints (FAO, n.dc).

Food security "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2001).

Food supply chain An important component of food systems, including all the stages and actors (including private sector businesses), from production, to trade and processing, to retail and consumption, including waste disposal (HLPE, 2017; HLPE, 2020).

Food systems All the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the output of these activities, including socio-economic and environmental outcomes" (HLPE, 2014). The three constituent elements of food systems are: food supply chains, food environments and consumer behaviour (HLPE, 2017).

Geographic Information System (GIS) System with software tools for capturing, storing, analysing and visualizing location-relevant data.

Information visualization Process of transforming otherwise abstract data into an interactive, visual form that enables or triggers users to use their mental and visual capabilities, thereby gaining insight and understanding of that data.

Interactive Voice Response (IVR) Technology that allows humans to interact with a computer-operated phone system using voice and a dual-tone multi-frequency (DTMF) user interface, allowing them to provide and access information.

Internet of Things (IoT) Network of physical objects, which have sensors, software and other technologies to connect and exchange data with other devices and systems over the internet. IoT is often used together with other technologies such as machine learning, analytics, computer vision and robotics.

Machine learning Type of artificial intelligence in which computer automation is used to study complex problems through automating solutions.

Metadata Data that provides information about other data, intended to help users find relevant information and discover resources. To be effective, metadata should be compiled and published according to appropriate metadata standards, which exist for different disciplines.

Microdata Data on the characteristics of members of a population, such as individuals, households or establishments, collected by a census, survey or experiment.

Online social media User-generated information, opinions, video, audio and multimedia that are shared and discussed over digital networks.

Open data (open-access data) Data that can be freely used, modified and shared by anyone for any purpose. It requires that data fulfil the following four characteristics (Open Definition, n.d.).

- **Open license or status:** The data must be in the public domain or provided under an open license;
- **Access:** The data must be provided as a whole and at no more than a reasonable one-time reproduction cost and should be downloadable via the internet without charge.
- **Machine readability:** The data must be provided in a form readily processable by a computer and where the individual elements of the work can be easily accessed and modified.
- **Open format:** The data must be provided in an open format. An open format is one which places no restrictions, monetary or otherwise, upon its use and can be fully processed with at least one free/libre/open-source software tool.

Primary data Data that is collected firsthand; through research, experiments, self-administered surveys, interviews, field observations, etc.

Right to food The right of every individual, alone or in community with others, to have physical and economic access at all times to sufficient, adequate and culturally acceptable food that is produced and consumed sustainably, preserving access to food for future generations (de Schutter, 2014).

Semantic web Semantic web technologies enable the creation of web-based data stores, the construction of vocabularies and ontologies, and the writing of rules to process the data. At the top of the Semantic web stack is inference, which is reasoning about data-use rules.

Sensors A sensor is a device that measures a physical or chemical feature. Sensors include but are not limited to: standard sensors (such as for soil moisture or for tracking animals), weather stations and remote sensing (e.g., via satellite technology). Digital images or video (RGB or hyperspectral) are increasingly used to capture reality. These sensors can be fixed or mobile (on tractors, robots, drones, etc). The development of nano-computers (e.g. Raspberry) and microcontrollers (e.g. Arduino) has facilitated and popularised the use of these sensors, making them accessible to a wide population. Sensors are commonly used in IoT applications.

Social gradient A phenomenon that describes a link between health and socioeconomic status in which health outcomes decline as socioeconomic status declines (WHO, 2013). Whereby individuals in lower socioeconomic positions have worse health, and often a lower life expectancy, compared to those in higher socioeconomic positions (WHO, 2013).

Stability (as a dimension of food security) Having the ability to ensure food security in the event of sudden shocks (e.g. an economic, health, conflict or climate crisis) or cyclical events (e.g. seasonal food insecurity) (FAO, 2006).

Sustainability (as a dimension of food security)	Food system practices that contribute to long-term regeneration of natural, social and economic systems, ensuring the food needs of the present generations are met without compromising the food needs of future generations (FAO, 2018).
System integration and aggregation	Different systems can be brought together so that they connect or link to each other, share and exchange data or information (for instance, through Application Programming Interfaces, or APIs). Consequently, it is possible that systems can gather data from other systems (i.e., other data sources) and perform various operations on these data from multiple data sources, such as data fusion, analysis, summarizing, etc.
Ubiquitous computing	Concept where computing is made to appear or occur anytime and everywhere. Ubiquitous computing has become widespread, especially through mobile computing, where end-users carry their devices (such as mobile phones, including smartphones) and use it them in everyday activities and contexts. Mobile computing applications can be based on SMS, USSD (Unstructured Supplementary Service Data), chatbots, Computer-Assisted Telephone Interviewing (CATI), and other forms of applications (for instance ODK-based technologies such as CommCare, TaroWorks, etc).
Utilization (as a dimension of food security)	Having an adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met (FAO, 2006).
Virtual reality and augmented reality	Computer-generated simulated environment with objects and scenes that seem real, making the user feel immersed in their surroundings. Augmented reality (AR) is an interactive experience of a real-world environment where the objects in the real world are enhanced by computer-generated information and features.

ANNEXES

ANNEX TABLE 1.
EXAMPLES OF EXISTING FSN DATA-RELATED INITIATIVES (INCLUDING DATABASES, REPOSITORIES, DATA SYSTEMS AND ANALYSIS TOOLS), ORGANIZED BY DIMENSION OF FOOD SECURITY AND NUTRITION

Level in the conceptual framework	Dimensions of food security and nutrition					
	Availability	Stability	Sustainability	Access	Utilization	Agency
Distal	**Natural resource base** (FAOSTAT – Land use and land cover; FAOSTAT – Soil; FAOSTAT - Pesticides; FAOSTAT - Fertilizers; also here; AQUASTAT; FISHSTAT) Earth Observation Google Earth SEPAL **International food commodity stocks and trade** (FAOSTAT – Trade)	**Global/ regional food commodity stocks and reserves** (e.g., AMIS)	Weather and other risk trends and predictions (Global Climate Risk Index; Temperature changes (FAOSTAT – climate) Greenhouse gas emissions (FAOSTAT – Emissions; also here and here)	**International food commodity prices** (FAO Food Price Index, AMIS;)	**Food composition data** (INFOODS) **Food safety** data (CODEX)	
Meso	**Domestic food availability** FAOSTAT – FBS/ SUA FAOSTAT – Food & Diets FAOSTAT - Trade FAOSTAT - Production	**National food stocks and reserves** (FAOSTAT - FBS)		**National food price indices** (ILOSTAT, Premise)	**Water and sanitation** (UNICEF-WASH)	Data on market concentration (for agricultural inputs, retail, etc.) at national and global levels
Immediate	**Local food systems** (Agricultural censuses and surveys 50x2030, AGRISurvey 50x2030, LSMS-ISA	**Early warning information systems** (FAO – GIEWS; FEWSNET) **Integrated food security phase classification analyses** (IPC Analyses)		**Local food prices** (WFP Data Viz, FPMA) **Household incomes and consumption patterns** (HIES, LSMS) (FIES)**Food insecurity experience scale (FIES)**	**Household living conditions** (LSMS, MICS, DHS) **Household water access**	**Food insecurity assessment surveys** (FIES, CFSVA, etc.) Women's Index in Agriculture (WEAI) (CGIAR), and other women's empowerment indices; **Rural Livelihoods Information Systems** (RuLIS)
Individual (Outcomes)	**Dietary intake/diet quality; malnutrition prevalence and related health outcomes** (MICS; DHS; National health and nutrition surveys, etc.)					

Abbreviations: MICS=Multiple Indicator Cluster Survey; DHS= Demographic and Health Surveys; AMIS= Agricultural Market Information System: HIES=Household Income and Expenditure Surveys
N.A.=Not Applicable

ANNEX TABLE 2.
SUMMARY OF RISKS, ASSOCIATED DIGITAL TECHNOLOGIES, KEY STAKEHOLDERS AND RISK MITIGATION MEASURES

Risk	Description of risk	Digital technologies associated with the risk	Key stakeholders (Affected and actors)	Data cycle stage(s)	Risk mitigation measure(s)
Ethical, data protection, trust, justice, identity theft and other violation of privacy issues	Inconsiderate digitalization may create conflict with human rights and justice in FSN	AI, robotics, etc	Users of digital automation solutions for FSN Farmers, FSN customers, FSN consumers affected by the digital automation (whether they are users of the digital automation solutions or not FSN service providers and businesses (that design, implement or provide digital automation) Government and policy makers (e.g., appropriate regulation) Civil society organisations Special interest group associations (e.g., farmers' associations, consumers' associations)	All stages	Formulation and enactment of appropriate laws, regulations and policies (e.g., ethics, consent, privacy, data protection, ownership, fair competition, and copyright) Inclusion of the stakeholders in the needs analysis, design, piloting and implementation of digital automation Adoption of digital solutions that are transparent and give users freedom of choice. For machine learning applications, algorithm developers, model builders and domain experts can provide explanations (for the application's decisions) so that they can be included in the application's knowledge base and output Building the capacity of users. For instance: providing users with information; educating users about their digital rights and responsibilities; ensuring that users are trained or supported to handle relevant technologies; creating an enabling environment for users to access the required digital infrastructure and digital resources; etc
	Power asymmetry, inequitable access to data, negative exclusive intellectual property regimes, unethical tracking and targeting, and market dominance attributable to FSN data "ownership", data privacy and control	Big data, AI, cloud computing, etc	Users of digital applications that collect or process data for FSN Farmers, FSN customers, FSN consumers from or about whom data are collected or processed (whether they are users of the digital applications or not) FSN service providers and businesses (that design, implement or provide digital applications for data collection or processing, big data, cloud computing, etc.) Government and policy makers (e.g., appropriate regulation) Civil organizations Special interest group associations (e.g., farmers' associations, consumers' associations)	All stages	Formulation and enactment of appropriate laws, regulations and policies (e.g., ethics, consent, privacy, data protection, ownership, fair competition, and copyright) Adopting responsible approaches to research and innovation Protection of potentially vulnerable segments of FSN stakeholders in the society Inclusion of the stakeholders in the needs analysis, design, piloting and implementation of digital technologies Considering a policy-driven strategic overview of the needs and priorities of FSN Anticipating and addressing the concerns and needs associated with FSN data "ownership", data privacy and control Taking into account indirect and long-term effects of the digital technologies Creating spaces for FSN stakeholders to reflect on how digitalization will affect existing FSN innovation systems

Risk	Description of risk	Digital technologies associated with the risk	Key stakeholders (Affected and actors)	Data cycle stage(s)	Risk mitigation measure(s)
Quality of data	Subjectivity during data collection	Online social media, crowdsourcing, mobile computing, etc	FSN data analysts and researchers FSN service providers and businesses (that design, implement or provide FSN applications based on online social media, crowdsourcing, mobile computing, etc.) Users of FSN applications based on online social media, crowdsourcing, mobile computing, etc Farmers, FSN customers, FSN consumers from or about whom data are collected or processed (whether they are users of FSN applications based on online social media, crowdsourcing, mobile computing, etc. or not)	Collect, retrieve and manage data	Complementing with other digital technologies or methods that are more objective
	Real-world setting challenges (distraction, weather, etc.)	IoT, sensors, robotics, crowdsourcing, mobile computing, etc	FSN data analysts and researchers FSN service providers and businesses (that design, implement or provide FSN applications based on IoT, sensors, robots, crowdsourcing, mobile computing, etc.) Users of FSN applications based on IoT, sensors, robots, crowdsourcing, mobile computing, etc Farmers, FSN customers, FSN consumers from or about whom data are collected or processed (whether they are users of FSN applications based on IoT, sensors, robots, crowdsourcing, mobile computing, etc. or not)	Collect, retrieve and manage data	Constant monitoring, testing, calibration and enhancement of digital technologies deployed in real-world settings Additionally using other digital technologies or methods to complement FSN data obtained from, or tasks undertaken by digital technologies deployed in real-world settings

Risk	Description of risk	Digital technologies associated with the risk	Key stakeholders (Affected and actors)	Data cycle stage(s)	Risk mitigation measure(s)
Quality of data	Over-reliance on digital technologies that collect or process only numeric data may downplay important nuances that can be gleaned from qualitative data	Some mobile phone-based data collection applications	FSN data analysts and researchers FSN service providers and businesses (that design, implement or provide digital technologies for FSN that collect or process only numeric data) Users of digital technologies for FSN that collect or process only numeric data Farmers, FSN customers, FSN consumers from or about whom data are collected or processed (whether they are users of digital technologies for FSN that collect/process only numeric data or not)	All stages	Additionally using complementary digital technologies or methods that can capture or process qualitative data
Poor (and in some instances lack of) interoperability of disparate sets of food security and nutrition data		Big data, cloud computing, IoT	FSN data analysts, researchers (and users of FSN applications that collect, store, curate or process data) FSN service providers and businesses (that design, implement or provide FSN applications that collect, store, curate or process data) Government and policy makers Communities of practice Civil society organisations	All stages	Supporting efforts on standards and interoperability (such as through the use of ontologies)

Risk	Description of risk	Digital technologies associated with the risk	Key stakeholders (Affected and actors)	Data cycle stage(s)	Risk mitigation measure(s)
Capacity, equity, scal-ability and sustainabili-ty issues	Digital technologies involve relatively high infrastructural and human capacity costs	All new and emerging digital applications for FSN	Potential and active users of new and emerging digital applications for FSN FSN service providers and businesses (that design, implement or provide new and emerging digital applications for FSN) FSN data analysts and researchers Government and policy makers Funding organizations Special interest group associations (e.g., farmers' associations, consumers' associations) and communities of practice Civil society organisations	All stages	Tapping into collaborations Supporting efforts for: improving access to and affordability of technology; ensuring interoperability of data and systems; and developing and implementing open source tools Building and enhancing human capacity. For instance: training in core data competencies (e.g., data analysis, information visualization, interpretation and decision making); educating users to support the data cycle process; etc Educate data owners and data producers about privacy, consent, data usage, data ownership and the rights they have Responsible digitalisation
	Scalability and sustainability issues	All new and emerging digital applications for FSN	Potential and active users of new and emerging digital applications for FSN FSN service providers and businesses (that design, implement or provide new and emerging digital applications for FSN) FSN data analysts and researchers Government and policy makers Funding organizations Special interest group associations (e.g., farmers' associations, consumers' associations) and communities of practice Civil society organisations	All stages	Continually providing demonstrations of the benefits or positive results of using the digital technologies Adoption of interdisciplinary approaches and interconnectedness. Recognizing the need for learning, feedback, partnerships, and joint action in multi-stakeholder settings

ANNEX TABLE 3:
LIST OF COUNTRIES GROUPED BY DATE OF LAST AGRICULTURAL CENSUS ON RECORD

No agricultural census conducted in the last 10 years (2012-2022)	No agricultural census conducted in the last 20 years (2002-2022)	No agricultural census on record
Afghanistan	Algeria	Andorra
Algeria	Andorra	Cuba
Andorra	Bahamas	Faroe Islands
Antigua and Barbuda	Bahrain	Monaco
Bahamas	Barbados	San Marino
Bahrain	Bosnia and Herzegovina	South Sudan
Barbados	Brunei Darussalam	Tokelau
Bosnia and Herzegovina	Burundi	Turkmenistan
Brunei Darussalam	Cameroon	Ukraine
Burundi	Central African Republic	Maldives
Cameroon	Chad	
Central African Republic	Cuba	
Chad	Democratic People's Republic of Korea	
Cuba	Democratic Republic of the Congo	
Democratic People's Republic of Korea	Djibouti	
Democratic Republic of the Congo	Dominica	
Djibouti	Dominican Republic	
Dominica	Ecuador	
Dominican Republic	Eritrea	
Ecuador	Faroe Islands	
El Salvador	Guyana	
Eritrea	Honduras	
Ethiopia	Iraq	
Faroe Islands	Kenya	
Guatemala	Kuwait	
Guyana	Liberia	
Haiti	Libya	
Honduras	Mauritania	
Iraq	Monaco	
Jamaica	Nigeria	
Kazakhstan	Papua New Guinea	

Kenya	Rwanda
Kuwait	Saint Vincent and the Grenadines
Kyrgyzstan	San Marino
Lebanon	Sao Tome and Principe
Liberia	Sierra Leone
Libya	Singapore
Malawi	Solomon Islands
Malaysia	Somalia
Mali	South Sudan
Mauritania	Sudan
Monaco	Tokelau
Mongolia	Türkiye
Montenegro	Turkmenistan
Mozambique	Ukraine
Myanmar	Uzbekistan
Nicaragua	Zambia
Niger	Zimbabwe
Nigeria	Maldives
North Macedonia	**Angola***
Pakistan	**Benin***
Panama	**Guinea-Bissau***
Papua New Guinea	**Marshall Islands#**
Paraguay	**Qatar***
Republic of Moldova	**Saint Kitts and Nevis***
Rwanda	
Saint Lucia	
Saint Vincent and the Grenadines	
San Marino	
Sao Tome and Principe	
Seychelles	
Sierra Leone	
Singapore	
Solomon Islands	
Somalia	
South Sudan	
Sudan	

Suriname		
Syrian Arab Republic		
Tokelau		
Trinidad and Tobago		
Türkiye		
Turkmenistan		
Uganda		
Ukraine		
United Arab Emirates		
Uruguay		
Uzbekistan		
Venezuela (Bolivarian Republic of)		
Yemen		
Zambia		
Zimbabwe		
Maldives		
Angola*		
Benin*		
Burkina Faso*		
Comoros*		
Guinea-Bissau*		
Madagascar*		
Marshall Islands#		
Qatar*		
Saint Kitts and Nevis*		
92	55	10

*Countries with no census during the last 10 or 20 years but with **ongoing** censuses during the current WCA 2020 round
Agricultural module in Population and Housing Census (AM in PHC) **ongoing**
Source: FAO ESS, Agricultural Census Team

Food is a fundamental human right, yet too many people in the world do not have secure access to the food they need. High-quality data and their accurate analysis are essential to design, monitor and evaluate effective food security and nutrition (FSN) policies. Data are also fundamental to ensure accountability of government policies and to monitor their implementation and impact. The data revolution, driven by new technologies, is increasing exponentially the volume and types of data available. This provides great opportunities for informing and transforming food systems, but also presents new challenges which, if not properly tackled, can deepen inequalities. This report presents the inherent complexity and multiple dimensions of FSN data collection, analysis and use – including economic, social, institutional, political, legal and technical dimensions; the types of users involved and the numerous and diverse purposes for which data may be used in food security and nutrition efforts, as well as the extant challenges. The report also advances actionable recommendations to enhance the contribution that data can make to ensuring food security and nutrition for all.

CC1865EN