ISO/ TMB/ SAG SF

STRATEGIC ADVISORY GROUP REPORT ON SMART FARMING:

FINAL REPORT
WITH RECOMMENDATIONS

Scope: Addressing the mandate of the ISO/TMB Strategic Advisory Group on Smart Farming ("SAG-SF") by a) identifying the challenges and opportunities, relevant standards, possible synergies and gaps in the work of ISO technical committees in the context of smart farming and the United Nations Sustainable Development Goals (SDGs); and b) proposing next steps and priorities for ISO action.

Contents

1. Executive summary

1.1 Smart farming

The concept of smart farming is not new. Producers have always looked for more efficient ways to grow food and raise livestock, but their task is increasingly difficult. Producers and myriad other agrifood stakeholders like processors or food manufacturers (see Figure 1) pursue often-competing objectives such as profitability, sustainability, and the freedom to operate, under an ever more challenging set of constraints such as climate change, regulatory pressure, changes in consumer preferences, increasing cost of inputs, commodity price volatility and an increasingly complex geopolitical situation. The availability of critical resources like fertilizers and irrigation water is uncertain, weather-related stresses are increasingly extreme and unpredictable, and market signals are ambiguous at best.

Given the critical role that data and its exchange must necessarily have in this context, smart farming today:

- is data-driven
- bases decisions on sound scientific principles and generally accepted good agricultural practices
- involves multiple stakeholders in the value chain (i.e., farmers, their advisors, equipment manufacturers, post-harvest sector, customers, regulators, to name a few)
- happens in a volatile, uncertain, complex and ambiguous world (e.g., the prices of both crop inputs and harvested commodities are volatile, yields and the availability of resources like irrigation water are uncertain, growing a crop is getting increasingly complex, and market signals are ambiguous at best).

Considering the above factors and in support of its mandate, the SAG-SF used the following definition for smart farming:

> *Smart Farming is data-driven, principled decision making in agricultural and food value chains occurring as multi-objective optimization in the context of global volatility, uncertainty, complexity and ambiguity.*

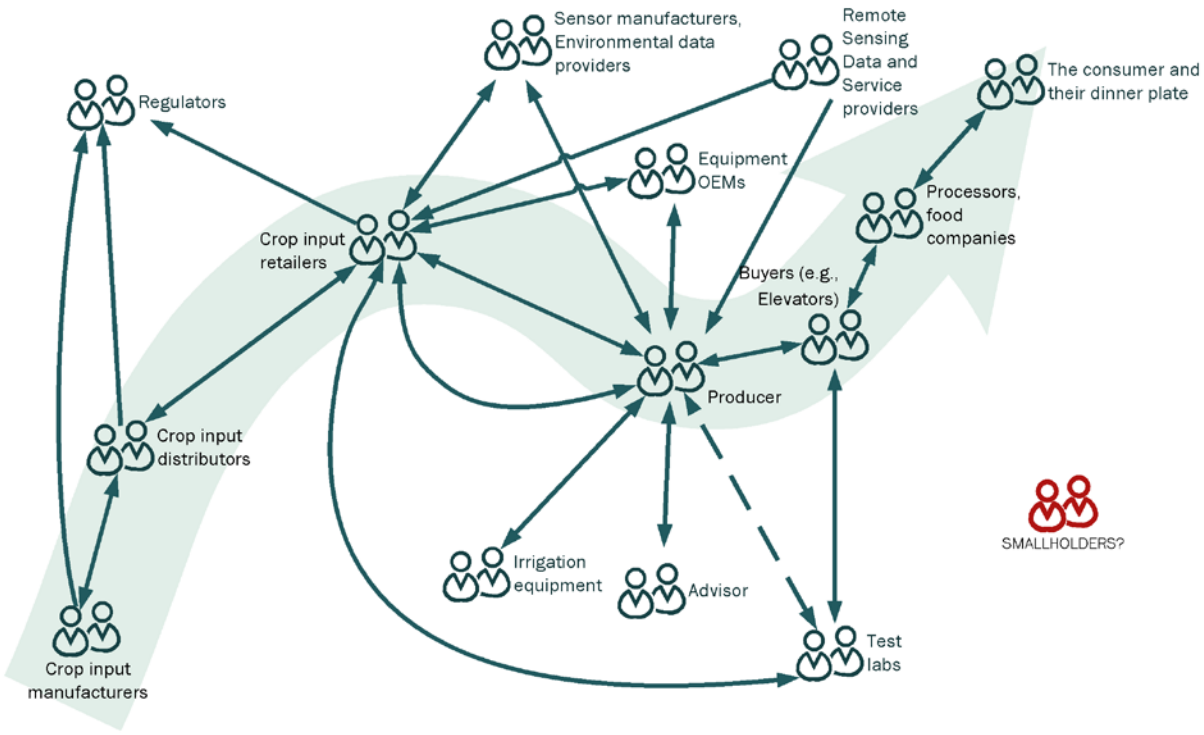

Figure 1: An example of stakeholders and data flows in an agrifood system. Very small producers (i.e., smallholders) are shown apart from the system to highlight the challenges associated with making the promise of smart farming and data-driven agrifood systems in general apply to them too.

Bringing about smart farming to scale requires data standardization as the need to capture, use and share massive amounts of data across the agriculture and food system – from crop input and equipment manufacturers to distributors to producers to consumers and government agencies – becomes a necessary part of doing business. Data collection and sharing is at the heart of smart farming, but not all data are equally usable. For things to work, the data must be findable, accessible, interoperable and reusable, or FAIR (Wilkinson et al, 2016), and have robust and trustworthy governance mechanisms.

1.2 A note on smart farming vs. data-driven agrifood systems

In the course of the work of the SAG-SF it became clear that the term *smart farming* is interpreted very differently by different parties, and even more so in an international context. This led to some strategic moves:

1) The SAG-SF initially took a constructionist approach to determining its scope. Starting from the mandate from the ISO/TMB resolution that created it (See Annex A), the conveners asked members of core group and the advisory group for as many specific items they could propose that should be within (or outside) the scope of "smart farming" and therefore the SAG-SF.

2) The resulting set of *scope items* (See Annex E.1) had a scope clearly beyond the system boundaries of the farm and more consistent with the idea of *agrifood systems*.
3) Moreover, there are many items in scope that are important and pertain to data in agrifood systems that do not necessarily fall within the definition of smart farming presented above, but rather act as enabling technologies. An example is calculating costs of production; this is an important function of farm management information systems, but is not necessarily used in the context of principled decision-making, optimization, etc. This led to describing the scope of this work more in terms of *data-driven agrifood systems*, a broader and more encompassing term than *smart farming* or *smart agrifood systems*.
4) Figure 2 shows these scope descriptions in terms of a Venn diagram.
5) For all of the above, the scope of the SAG-SF and of its recommendations corresponds to the idea of data-driven agrifood systems (or which smart farming is a subset), and that term shall be used throughout.

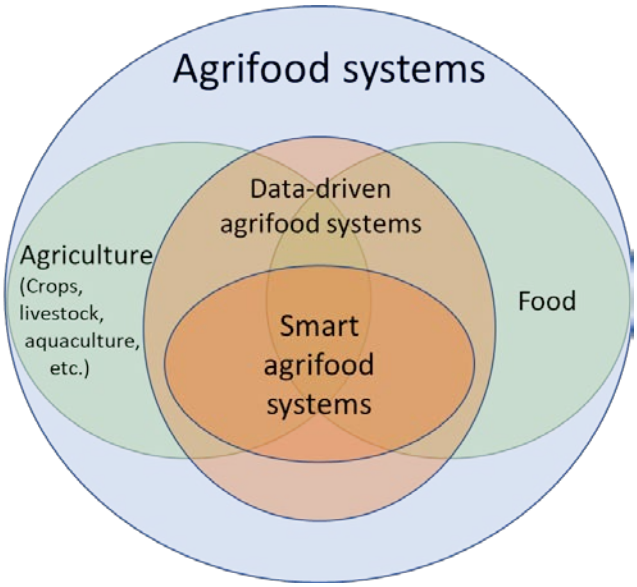

Figure 2: Venn diagram showing how agrifood systems contain both agricultural- and food-related aspects, how a subset of the domain is data-driven; and how a narrower subset of these corresponds to smart agrifood systems.

1.3 SAG-SF mandate and deliverables

The ISO Strategic Advisory Group on Smart Farming (SAG) received a specific mandate from the TMB resolution 60/2021. Table 1 below parses the mandate into individual parts

listed top-down in the left column. The corresponding SAG deliverable is referenced in the corresponding row of the right column.

The SAG SF completed the mandate as requested by ISO TMB resolution 61/2021 and expected output by delivering its summarised findings in the form of a Roadmap on Smart farming and presenting the following recommendations for consideration by the ISO Technical Management Board (TMB)

Table 1 below summarizes the mandate given to the SAG SF as fulfilled by the SAG deliverables.

Table 1— ISO/TMB mandate to the SAG-SF, and the corresponding deliverables

Mandate item	Deliverable
Define a set of parameters for the classification of “Smart Farming” for the purposes of the SAG.	Working definition (Clause 1.1) + Capability Model (Clause 4.3, Annex C.1)
Build a matrix between the Sustainable Development Goals (SDGs) and the definition of Smart farming (…)	Capabilities vs SDG targets: Annex C
(…) in order to establish an overview of current and potential future challenges in relation to the Sustainable Development Goals (SDGs)	Please refer to Annex C.
Recommend actions to address these challenges	Recommendations in Clause 3. Please note that it is a two-tiered system, with a set of General Recommendations for the ISO/TMB (Clause 3.1) followed by three additional sets of specific recommendations (3.2 - 3.4).
List standards and other documents relevant to Smart Farming that are, or have been, developed by existing ISO Technical Committees	Capabilities vs Standards : Annex D
Analyze any synergies in the current work of existing ISO technical committees relevant to Smart Farming, and consider opportunities to coordinate or collaborate across ISO committees where overlaps exist	Recommendations in Clause 3.3

Set up a gap analysis in order to identify areas important for standardization in the field of Smart Farming not currently addressed by an existing ISO committee	Recommendations in Clause 3
Recommend standardization activities	Recommendations in Clause 3
Set up recommendations for the structuring of these standardization activities, which includes consideration of existing ISO committees, new technical committees, and ongoing coordination mechanisms	DA Matrix: (Standardization) activities vs People (TCs/SCs) and Systems (e.g., infrastructure)
Establish a priority list of any new work to be undertaken in the short term that should be progressed as an immediate priority	Horizon Model (Clause 2) and Recommendations (Clause 3)
Main output: The SAG on SF is expected to deliver its summarised findings in the form of a Roadmap on Smart farming	This final report, encompassing and contextualizing all of the above.

1.4 Acknowledgements

The Co-conveners sincerely thank the members of the Strategic Advisory Group for their participation in the work, noting the challenges in working virtually across multiple time zones and with the complexities of addressing the extensive and fragmented domain of smart farming and agrifood systems in general. Special thanks go to the leaders of the subgroups who tirelessly organized their teams to meet across time zones and moved the work forward.

Many thanks also go to the ISO Secretariat staff (Monica Ibido and Blandine Garcia), as well as the Convener Support experts (Dan Berne, who elicited knowledge from experts, collated their output and was a primary contributor to this manuscript; and Frank Riddick, who provided modelling expertise and support to the subgroups). Thanks are also due to DIN and ANSI for providing working resources and submitting the original proposal, thus providing the overall strategic direction of the ISO SAG Smart Farming.

This work would have been much more difficult, especially regarding collaboration management and harmonizing content creation in our multi-team, without the generous assistance of Trisotech, who provided licenses to their Digital Enterprise Suite for the whole SAG-SF team.

Finally, our gratitude goes to Syngenta Crop Protection AG for its commitment to this standardization effort, including funding the Convener Support staff, procuring collaboration tools and resources, and funding time and travel related to this work.

It is our hope that the body of work of the Strategic Advisory Group for Smart Farming will not only initiate a set of prioritized ISO activities but will streamline and enable future work of technical committees and subcommittees as they leverage the work produced here and strengthen collaboration among international standardization institutes in the area of data-driven agrifood systems.

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2. The roadmap for smart farming

Figure 3 below summarizes key activities recommended to support the SAG-SF's objectives, in the context of a horizons model (White et al., 1999).

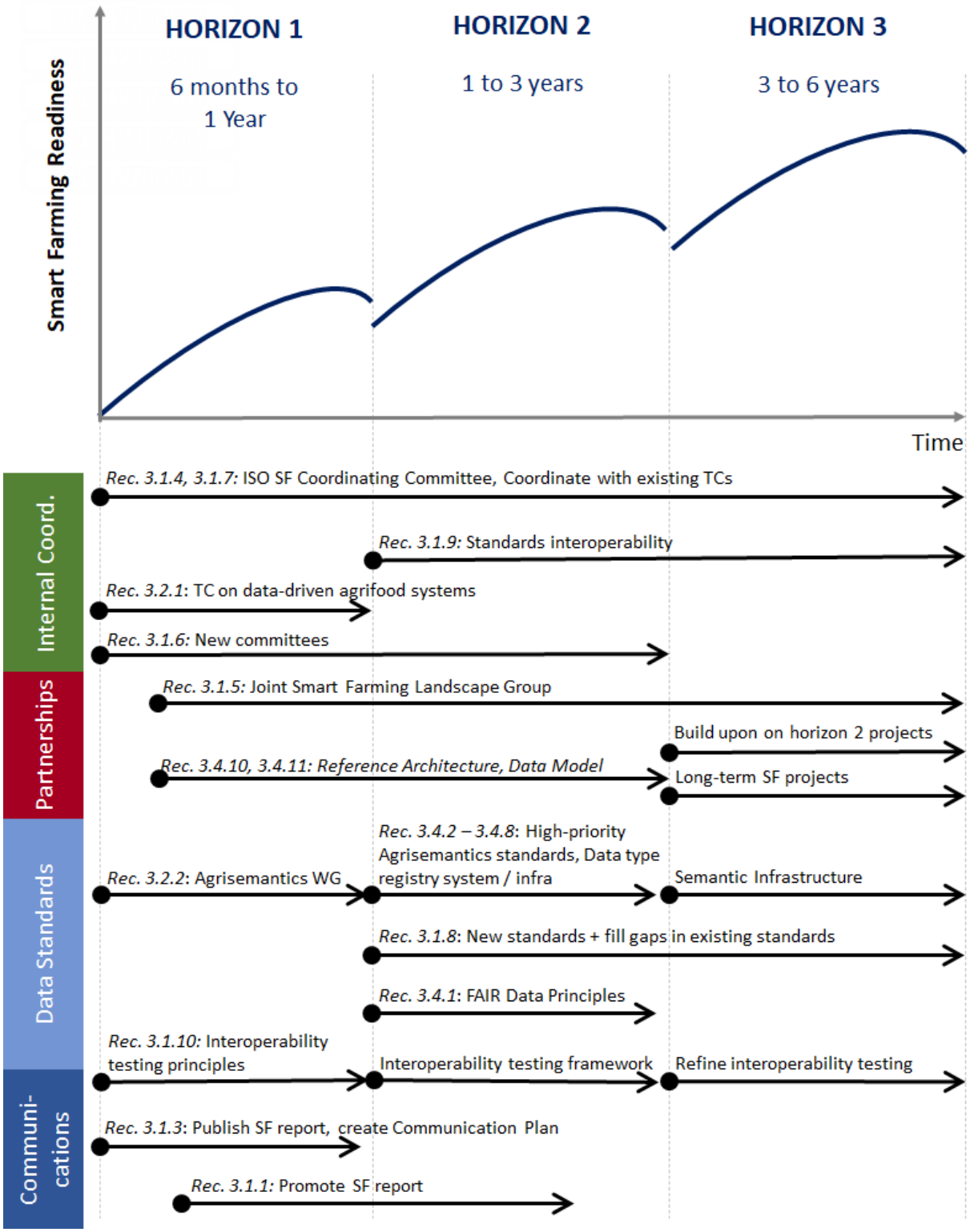

Figure 3: Roadmap and horizons model for implementing ISO SAG-SF recommendations. When multiple arrows are arranged end-to-end, the rightward arrows are dependent on completion of the arrows to their left.

The horizon model above serves to clarify and visualize that the recommendations of the SAG-SF build on each other over time, and that there are certain dependencies for their implementation. The horizon model is divided into three successive horizons and serves as a guideline for developing a strategy for short-term, medium-term, and long-term measures. **Horizon 1** of the roadmap is aimed at the necessary structural changes that can be implemented or initiated in the short term and are required to adequately address the horizontal topic of the SAG-SF by ISO and thus implement the recommendations of the SAG-SF. It forms the foundation of the subsequent horizons and should be implemented within a year. The first horizon suggests a mix of themes:

- Internal coordination: Kicking off the proposed coordination committee and new ISO committees (see General Recommendations 3.1.4, 3.1.6).
- Partnerships: Kicking off the proposed Joint Smart Farming Landscape Group (see General Recommendations 3.1.5), as well as an international workshop for a reference architecture for Smart Farming (See Recommendation 3.4.10).
- Data Standards: Organizing an Agrisemantics Working Group within the proposed Technical Committee on Smart farming (See Recommendation 3.2.2) and preparing reference data and semantic infrastructure standards NWIPs (for Recommendations 3.4.2 to 3.4.9).
- Communications: Publishing and initiating the promotion of this SAG-SF report (see General Recommendations 3.1.1 and 3.1.3).

Horizon 2 uses the structures created in Horizon 1 to close major identified gaps in the current ISO standardization landscape, initiating work on some major themes (e.g., Recommendation 3.4.1 regarding FAIR data, Recommendations 3.4.2 – 3.4.9 regarding semantic infrastructure, etc.). It also includes the setting in motion of work regarding considering interoperability as part of the ISO standardization process (3.1.9) and making further progress on interoperability testing (3.1.10). Horizon 2 should also see major progress in the joint landscaping work proposed in General Recommendation 3.1.5.

Horizon 3 is primarily about continuing the recommendation implementation and standardization processes begun in Horizon 2 and building upon the semantic infrastructure and associated standardization also merging from it. An important aspect of Horizon 3 should also be the ongoing evaluation of the established processes to determine whether they are sufficient to achieve the goals of FAIR data, whether all necessary stakeholders have been considered (especially smallholders), and whether work is being done at the right points with the right intensity to contribute to the achievement of the Sustainable Development Goals through standardization.

3. SAG Recommendations

3.1 General Recommendations to the ISO/TMB

General Recommendation 3.1.1: SAG SF report and recommendations

The SAG recommends that the ISO/TMB accept the report and recommendations of the SAG as presented in this document and its annexes and make them publicly available.

General Recommendation 3.1.2: ISO smart farming landscape

The SAG recommends that the ISO/TMB accept the landscape assessment as presented using the capability/maturity model in clause 4.3 and make this landscape publicly available on ISO's website.

Gap / rationale

- Access to the findings can benefit the entire global agricultural community. Digital agriculture practitioners have a long history of "reinventing the wheel" regarding data and data standards, in great part due to not knowing what already exists, and not understanding what may be standardized soon.

General Recommendation 3.1.3: Communicate and promote SAG-SF results and agrifood systems standardization

The SAG recommends that the ISO Communications Department develop and implement a **communications plan** in collaboration with the Smart Farming Coordinating Committee (see General Recommendation 3.1.4) to promote the work of the SAG SF, agrifood systems, and corresponding standards and proposed infrastructure.

Gap / rationale

- Planning and implementing a long-range Communication Plan can help generate interest and participation in future ISO Smart Farming standards development efforts.
- This extends to communication with smallholder farmers to help them not only use the data for their farming practices but to also understand the collective value of their data.
- The recommendation also includes putting in place mechanisms to request feedback from standards user communities regarding the standards they use, their usability, etc. as a way of enriching the results of the standardization process.

General Recommendation 3.1.4: ISO Smart Farming Coordinating Committee

The SAG recommends that the ISO/TMB establish an ISO Smart Farming Coordinating Committee (SFCC).

Terms of reference

- Oversee the implementation of ISO/TMB SAG-SF General Recommendations 3.1.6, 3.1.7 and 3.1.8.
- Identify cases of coordination needed among various ISO committees on new or existing projects
- Make recommendations to the committees and/or ISO/TMB for action.
- Work with ISO Communications on the implementation of ISO/TMB SAG-SF General Recommendation 3.1.3
- Pursue families-based methodology for finding intra-standard gaps. (Clause 6.3.3)
    - The way this could take place is that, consulting with TC211 and other TCs as needed, the proposed Technical Committee on Data-Driven Agrifood Systems identify different families of standards that primarily involve measuring things (e.g., TC34 and TC93 analytics standards) as per Clause 6.3.3, and apply a battery of questions to test them for smart-farming-readiness / FAIR data, including:
        - Samples are identified uniquely, and instructions are provided for parameters (e.g., depth below ground at which a soil sample is taken) and the metadata that should accompany the sample.
        - The use of controlled vocabularies of observed properties (this topic is covered in Recommendation 3.4.2)
        - The use of controlled vocabularies of analytical methods.
        - The use of controlled vocabulary for codes representing units of measure.
- Advise the ISO Central Secretariat on ISO interfaces with external organizations in relation to Smart Farming
- SFCC Membership: Chairs and Committee Managers of ISO committees relevant to Smart Farming (see the SAG-SF Consultative Group listing)
- SFCC Leadership: Convenor: To be chosen from among the SFCC members, allowing for the rotation on a regular basis to representatives of the other committees
- Secretary: To be provided by ISO staff or a willing national standards body.
- Duration: Ongoing

Gap / rationale

- The development of ISO smart-farming digital agriculture standards requires precise coordination among a diverse set of stakeholders, including committees

in ISO and other standardization bodies to ensure both semantic and syntactic interoperability. A steering committee can ensure that conflicts and confusion in standardization and harmonization within ISO are avoided.

- Inconsistent implementation of standards (by market actors) reduces the impact of those standards and causes confusion in the market.
- There are many ISO standards, for example, in TC 34 and TC 93, that define a substance or product, then define properties of those substances or products (e.g., the starch content of barley, or the sugar content of royal jelly), the sampling and analytical methods used to obtain a value for the properties, and then acceptable ranges for those values. These standards currently do not emphasize the digitization of the data and metadata involved in these observations and measurements. This limits the smart-farming-readiness of these standards, but also presents an opportunity in the context of ISO 19156 / 7673-2. Coordination is needed to efficiently effect the necessary changes.

General Recommendation 3.1.5: External coordination

The SAG recommends that the ISO/TMB work together with the IEC and the ITU-T to establish a Joint Smart Farming Landscape Group (JSFLG).

Terms of reference

- Develop and maintain a comprehensive Smart Farming standards landscape document across ISO, IEC and ITU-T, and if possible, with other relevant global standards developing organizations (for example, the UN Food and Agriculture Organization (FAO), Codex Alimentarius, the Institute of Electric and Electronic Engineers (IEEE), etc.)
- This landscape would include initiatives, standards, and terms / definitions maintained by each organization.
- Take into account the results of the ISO/TMB SAG-SF landscape and the ITU-T landscape document under development by the ITU-T Focus Group on "Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture" (FG-AI4A).
- Promote cooperation and coordination across organizations developing relevant global standards and make recommendations to the appropriate parties (e.g., ISO/TMB, IEC/SMB, ITU-T TSAG).
    - Coordination needs could refer to initiatives, standards, and terms / definitions.
    - Examples of coordination topics include Cybersecurity (the object of ISO/IEC JTC 1/SC27, yet very significant to food security), electrification (e.g., electrical farm veh-

icles), on-farm electric power generation, and rural broadband (a necessary condition for successful adoption of many of the technologies described in this report).

- Secretary: To be initially provided by ISO staff and subsequently rotated on a schedule to be determined among the participating organizations.
- Duration: Ongoing

Gap / rationale

Other organizations, such as IEC and ITU-T have either completed, or have underway, standards projects which address some of the challenges in smart farming. A shared standards landscape will enable strategic planning across the different organizations, reduce overlapping efforts and abate confusion in the marketplace.

General Recommendation 3.1.6: New committees

The SAG recommends that the ISO/TMB advance the suggestions on the creation of new committees as presented in clause 3.2 of this report.

Furthermore, it is recommended that the ISO/TMB SFCC (see General Recommendation 3.1.4) oversee the implementation of these suggestions on behalf of the ISO/TMB.

Gap / rationale

- Bringing smart farming to scale requires coordinated work across the agrifood system value chain. Inconsistent implementation of standards reduces the likelihood of adoption by market actors and causes confusion in the industry.

General Recommendation 3.1.7: Internal coordination

The SAG recommends that the ISO/TMB accept the suggestions on internal coordination of existing ISO projects as presented in Clause 3.3 of this report.

Furthermore, it is recommended that the ISO/TMB SFCC (see Recommendation 4) oversee the implementation of these suggestions on behalf of the ISO/TMB.

Gap / rationale

- Bringing smart farming to scale requires coordinated work across the Agrifood system value chain. Inconsistent implementation of standards reduces the likelihood of adoption by market actors and causes confusion in the industry.

General Recommendation 3.1.8: New data-driven agrifood standards and other deliverables

The SAG recommends that the ISO/TMB accept the suggestions on possible new ISO Smart Farming deliverables as presented in Clause 3.4 of this report.

Furthermore, it is recommended that the ISO/TMB SFCC (see General Recommendation 3.1.4) oversee the implementation of these suggestions on behalf of the ISO/TMB.

General Recommendation 3.1.9: Standards interoperability

The SAG recommends that the ISO/TMB explore the development of directives and procedures:

- For committees to assess and address the interoperability of their standards with other related ISO standards, during the development of new standards and in the review and revision of existing standards, and
- Provide guidance, in cooperation with ISO/DEVCO (given the importance of this subject area for developing countries), for committees and ISO national standards bodies to engage the relevant stakeholders from within their countries and from other global standards-developing organizations in future ISO standards development related to data-driven agrifood systems in general and smart farming in particular. Appropriate stakeholder categories may include:
    - Companies (for example, crop input manufacturers, distributors, retailers; manufacturers of agricultural, irrigation, sensors; providers of environmental and remote sensing data and services, processors, food companies)
    - Government/regulators
    - Producers (large, medium and small farmers / smallholders), buyers, advisors, test labs
    - Grocery stores, restaurants, consumers
    - Organizations that have regular contact with stakeholders (e.g., smallholders) that would otherwise be inaccessible, such as the Consultative Group for International Agricultural Research (CGIAR), national agricultural research and extension services, and FAO.
- To instruct committees developing standards in this subject area to have a standing agenda item at their annual plenary meetings in which participating members will share their experiences, challenges and best practices on engaging this range of stakeholders (especially smallholders) in their national mirror committees.

Gap / rationale

- Traditional liaisons among committees or joint working groups and directives on the drafting of ISO standards may not be sufficient to ensure interoperability between or among standards.
- Future ISO standards related to smart farming will need to engage specialized experts not currently engaged in ISO standards development, including small and medium sized enterprises.

General Recommendation 3.1.10: Enable user implementation interoperability

The SAG SF recommends that ISO explore and establish mechanisms, including a cooperative framework with other standards development organizations, governments and agrifood sector stakeholder communities, to enable users to **ensure interoperability** in their **implementation** of ISO agrifood-related standards, especially as pertains to data.

Such mechanisms could include, depending on criteria such as the maturity of the corresponding industry segment and the users therein, the complexity of the standard in question:

- user communities which ISO can enable and collaborate with
- third-party conformity assessment schemes/programme
- guidance (e.g., in the form of implementation standards and guidelines for self-assessment)
- and simple, inexpensive software tools

Gap / rationale

Maintaining effective implementation interoperability requires an ongoing conformance validation effort. Examples:

- AEF's Plugfest system for ISO 11783
- ISO TR 28380 Health informatics - IHE global standards adoption

The challenge is to keep a validation system *inexpensive* enough so that even small players can participate.

Explore ways to make self-declaration (i.e. 1st party attestations) viable and practical (e.g., accompanied by integration partner attestations) by accommodating it in the standardization process.

3.2 Recommendations for new ISO committees

Recommendation 3.2.1: Technical Committee on Data-Driven Agrifood Systems

The SAG-SF recommends that the ISO/TMB implement the process to consider forming a Technical Committee to develop and maintain standards in the field of **data-driven agrifood systems**

Terms of reference

- The scope is the big-picture, data-driven, principled-decision-making, multi-objective optimization *perspective* of smart farming, not currently covered anywhere else within the ISO structure.

Recommend liaisons with:

- TC 34 Food Products
    - SC 17 Management Systems for Food Safety (and others)
- TC 207 Environmental Management
- TC 331 SC 2 Biodiversity: Measurement, data, monitoring and assessment
- TC 184 (Automation systems and integration)
- JTC 1 SC 41 (IoT and Digital Twin)
- TC 23 SC 19 (Agricultural electronics)
- TC 154 (Processes, data elements and documents in commerce, industry, and administration)

Gap / rationale

While ISO has multiple Technical Committees and Subcommittees whose work intersects the agrifood systems domain, its current approach is insufficient to provide a comprehensive planning and management perspective that supports data-driven principled decision making in the multi-objective context of Smart Farming.

This lack of a big-picture view poses two key problems:

1. In the absence of an agrifood-data-specific TC there would not be a source for ongoing direction for the Coordination Committee (Proposed in Gen. Rec. 3.1.4).
2. There will be an increasing number of data-related standards in the future; fitting them into the current ISO structure will be suboptimal, as it will tend to place the standards in TCs / SCs that lack a high concentration of agricultural data expertise.

Note that the proposal is for a TC in “Data-Driven Agrifood Systems” as opposed to a TC on “Smart Farming”. The proposed naming is deliberate, explained in Clause 1.2.

Recommendation 3.2.2: Agrisemantics Working Group

The SAG recommends that the proposed TC on Data-Driven Agrifood Systems create a working group on **agrisemantics** (see corresponding glossary entry in Annex F).

Terms of reference

- Quickly develop the standards described in recommendations 3.4.2 – 3.4.9.
- Provide continuing expertise and standards development and maintenance associated with semantic infrastructure, semantic resources contained therein, and other relevant agrisemantics topics.
- Proposed placement is under the proposed TC on Data-Driven Agrifood Systems

Gap / rationale

Agrisemantics plays a key role in preserving the meaning of data and consequently, making data FAIR. The need for expertise and standards work on this topic will only increase over time. That being said, there is a need for quick implementation of the standards in Recommendations 3.4.2 - 3.4.9, hence the recommendation for the agrisemantics topic to be initially covered by a working group. This could change over time to a subcommittee if demand justifies it.

Recommendation 3.2.3: Subcommittee on Sustainability Models, Metrics and Data

The SAG recommends that the proposed TC on Data-Driven Agrifood Systems create a subcommittee on **sustainability models, metrics and data**.

Terms of reference

Broadly, the Subcommittee scope is to enable the development of environmental, economic, and social sustainability models for agrifood systems through data.

- Enable standardization of the inputs (i.e., observations and measurements) and outputs of models used to assess sustainability of agrifood systems or parts thereof, including data models, standardized data exchange messages, and the semantic infrastructure (e.g., data type registry and controlled vocabularies) necessary to support them.
- The scope of this subcommittee includes:
    - Standardizing, jointly with the Agrisemantics Working Group, the different aspects of observations and measurements (features of interest, observed properties, etc,) applicable to sustainability
    - Standardizing the inputs and outputs of simulation models used in the sustainability domain, since these variables fit the data model of observations

and measurements and the user community would benefit from having their definitions available through a data type registry.
    - Enable prioritization through the formalization of sustainability indicators (variables) and machine-actionable methods for representing prioritization.
- Proposed placement is under the proposed TC on Data-Driven Agrifood Systems

Recommended liaisons with:

- TC 207 (Environmental Management)
- TC 34 SC 17 (Management systems for food safety)
- TC 331 SC 2 (Biodiversity: measurement, data, monitoring and assessment)
- TC 184 (Automation systems and Integration)

Gap / rationale

One of the key challenges in sustainable agriculture is how to prioritize, measure and report sustainability problem(s), how to implement changes and how to measure the impact(s) when those changes are made. Where measurements or model results do exist today, they are hard to scale, intercompare / interoperate with / use.

When possible and feasible, direct measurements of indicators (i.e., variables) of concern are preferred. However, when direct measurements are not feasible or possible (especially at scale) then surrogate measurements and/or simulation models that are properly calibrated and validated should be used.

There is standardization work to do here that will likely translate into an ongoing effort of identifying properties / variables / indicators of interest, standardizing their definition, standardizing models and machine-actionable descriptions thereof, and so forth.

Recommendation 3.2.4: Subcommittee on Greenhouse, Controlled Environment, and Urban Farming

The SAG recommends that the TC on Data-Driven Agrifood Systems create a subcommittee to create and manage urban and controlled-environment farming-related data interoperability standards.

Terms of reference

- Proposed placement is under the proposed Technical Committee on Data-Driven Agrifood Systems

- Dual scope:
  - Data modelling, representation and exchange standards required for the operational and technological aspects of farming in controlled environments such as hydroponics, aquaponics, aeroponics, etc.
  - Data modelling, representation and exchange standards that can support re-use of urban/industrial land for agricultural purposes (e.g., measurement of pollutants in re-used soil) as far as they are not available yet.
- Recommended liaisons with:
  - JTC1 SC 41 (Internet of things and digital twin)
  - TC 23 SC 19 (Agricultural electronics)
  - TC 34 (Food products), especially regarding food safety
  - TC 268 (Sustainable cities and communities)
  - TC 274 (Light and lighting)
  - TC 184 (Automation systems and integration)
  - TC 299 (Robotics)
  - TC 190 (Soil Quality) especially for the second scope point.

Gap / rationale

Greenhouse, controlled-environment and urban farming (domains loosely represented by Figure 4) are not represented directly within ISO; neither in their operational and technological aspects, which blend automation, control, and agronomy, nor in their social aspects that pertain to land use/allocation in urban settings. Moreover, emerging methods for managing these environments rely on the models and the idea of a digital twin; the combination of these reasons suggests that establishing a long-term pool of expertise on these topics is necessary, including the necessary liaisons (e.g., with JTC 1 SC 41 for digital twin).

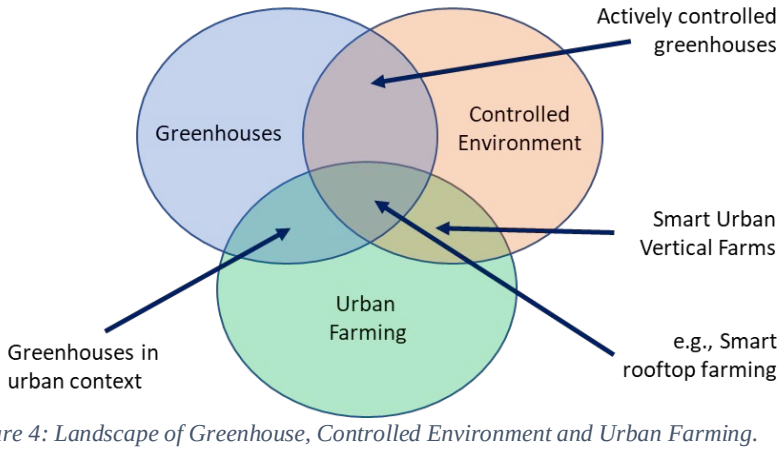

Figure 4: Landscape of Greenhouse, Controlled Environment and Urban Farming.

Recommendation 3.2.5: Subcommittee on Livestock Activities Data Management

The SAG recommends that the Technical Committee on Data-Driven Agrifood Systems create a subcommittee on **Livestock Activities Data Management**.

Terms of Reference

The purpose of this proposed subcommittee is to create and manage livestock data interoperability standards, especially related to the tracking and management of individual animal and herd activities (e.g., feeding, movement, diseases, etc.)

Recommended liaisons with:

- TC 34 / SC 5 (Milk and milk products)
- TC 34 / SC 6 (Meat, poultry, fish, eggs and their products)
- TC 34 / SC 10 (Animal feeding stuffs)

Gap / rationale

- Livestock production is a resource-intensive endeavour. Optimizing resource use through standards is a straightforward opportunity to advance SDGs (e.g., 12).
- Requirements and specifications for livestock and dairy data exchange are important not only at the commercial and scientific level, but to provide harmonization to enable governments to ensure and improve productivity. This is only possible through international standards development.
- TC 34 has subcommittees (5, 6 and 10) that create standards related to livestock. However, these standards focus primarily on the determination of properties of products or substances (e.g., milk, rennet). There is no group within ISO that focuses on managing animals or herds (beyond TC23/ SC19 work on RFID identification).
- It is important to emphasize that animal and herd management is an increasingly data-intensive activity, hence its proposed placement under the proposed TC on Data-driven Agrifood Systems.

Recommendation 3.2.6: Enable a delegation model of technology adoption

The SAG-SF recommends that the Technical Committee on Data-Driven Agri-food Systems proposed under Recommendation 3.2.1 consider the Delegation Model presented in the rationale below when working on the initiatives proposed under Recommendations 3.2.2, 3.2.3 and 3.2.4.

The new TC is therefore encouraged, when implementing Recommendations 3.2.2, 3.2.3 and 3.2.4, to consider the emergence of specialists who would be engaged by producers to act on their behalf, as distinct from, *and in addition to*, producers obtaining such expertise from technology vendors.

Specific considerations the proposed TC might consider is how to facilitate and optimise the work of professional service providers deploying the delegation model, in terms of standards, interoperability and outcome optimisation, especially for smallholder farmers where such a model can potentially provide significantly improved outcomes from agricultural technology adoption.

Gap / rationale

Agricultural technology adoption can be imagined in terms two approaches:

- **Competency transfer model**: The common approach is based on producers acquiring expertise to help them make optimal decisions in agricultural technology adoption and value extraction, based on training, mentoring, coaching, consulting, or other methods of skills enhancement.
    - This approach is the “competency transfer model” and moves expertise to the person with the need to fulfil or problem to solve.
- **Delegation model**, which moves the need or problem to the person with the expertise. This less common approach is based on farmers and growers delegating the outcomes they want to achieve to experts, as with the tradespeople and professions mentioned above.
    - This approach is the “delegation model” and moves the need or problem to the person with the expertise.

Whereas producers, including smallholder farmers, delegate the remedying of complex problems to sophisticated specialists such as electricians, diesel mechanics, agronomists and veterinarians, there is a lack of similar specialists in agricultural technology in general, and data management in particular, to whom producers can delegate responsibility to achieve the producers’ desired outcomes. This impacts the ability of many, typically smaller producers to derive the full value of data-driven opportunities.

3.3 Recommendations for Internal Coordination

Recommendation 3.3.1: Coordination with TC 211

- Establish a mechanism whereby TCs that create / manage standards associated with Observations and Measurements data are made fully aware of the potential of the standards created by TC 211.
- For this purpose, ISO might consider creating training materials (e.g., a series of short videos) to show both experts involved in standards-making on non-211 TCs, as well as digital agriculture practitioners, how to use the ISO 191XX series of standards.

Gap / rationale

- TC 211 has created, largely through a collaboration with the Open Geospatial Consortium, a series of standards (ISO 191XX) related to geographical data and its representation. Much of the data created in agriculture has a geographical component and fits the TC 211 model well. Moreover, another large fraction of agriculture-adjacent data that one might not automatically associate with geographical data such as that pertaining to manufacturing processes, can still fit the model, referencing assets such as machinery, methods of data capture, etc. as the observations' feature of interest.
- Of particular importance is standard ISO 19156 related to Observations and Measurements. This abstract standard, and a corresponding agricultural implementation standard being pursued in TC 23 SC/19 WG 1, NWIP 7673-2, provide a model for representing observations and measurements that are pervasive in agriculture. These range from scouting of field conditions to soil and plant tissue laboratory test results, to the conditions of assets such as scales and grain dryers.

Recommendation 3.3.2: Coordination with JTC 1 SC 41

- Establish a mechanism whereby TCs that create / manage agronomic or other smart-farming-related standards associated with digital twins are made fully aware of the potential of the standards created by JTC 1 SC 41.
- For this purpose, ISO might consider creating training materials (e.g., a series of short videos) to show both experts involved in standards-making on non-1 JTCs, as well as digital agriculture practitioners in general, how to use the series of standards created by JTC 1 SC 41.
- Explore how JTC 1 SC 41 reference architecture can contribute to a reference architecture for Smart Farming (See Recommendations 3.4.10 and 3.4.11), at least to the IoT and Digital Twin – related capabilities therein.

Gap / rationale

IoT networks

- IoT (the “Internet of Things”) is a pervasive source of Observations and Measurements data in agriculture (e.g., weather data, soil water content, grain scales, sensors in commodity storage /drying assets, etc.)
- Management of IoT networks in agriculture is currently mostly *ad-hoc* and messy at best. As a result, there is a growing number of networks of vulnerable, difficult-to-service devices being installed in the field.
- JTC 1 SC 41 has done much work on this topic.
- IoT device metadata management at scale is also a limiting factor for agricultural applications of IoT
    - NWIP 7673-2 includes metadata management component, but only pertaining to data model aspects.

Digital twin

- Simulation of crop eco-physiological processes is a core capability in smart farming
- Doing this at scale is extremely complex. Challenges include:
    - Managing multiple sets of model input data, e.g., for Monte Carlo analysis.
    - Model calibration and sensitivity analysis
    - Model validation
    - Data fusion at different scales

JTC 1 SC 41 has already done work on the digital twin topic. While this work is not specific to plant growth and development, it may be applicable to the management of ecophysiological simulation model parameters.

Recommendation 3.3.3: Coordination with ISO/TC 154

- Establish a mechanism whereby TCs that create / manage smart farming-related standards associated with trade facilitation including, notably, supply chain data standards, are made fully aware of the potential of the standards created by TC 154.
- For this purpose, ISO might consider creating training materials (e.g., video) to introduce both experts involved in standards-making, as well as digital agriculture practitioners in general, to the range of TC 154-managed standards, which may prove useful to them.
- Consider whether any TC 154-managed standards should be promoted in smart farming-related work (e.g., ISO 8601).

Gap / rationale

- Many agriculture processes and data requirements are unique to the industry. However, many smart farming practitioners are inclined to assume agriculture-industry uniqueness in areas where there is in fact shared process and data characteristics across industries. Such assumptions can lead to "reinvent-the-wheel" scenarios. ISO/TC 154 coordination should reduce the occurrence or severity of some scenarios.
- One challenging data-continuity issue in agriculture occurs atv the intersection of input supply chain and field operations. From a systems perspective, this is the intersection of ERP / accounting / logistics systems and farm management information systems and/or farm equipment. While smart farming systems and related data management initially focussed on field operations, addressing the intersection with input supply chain is becoming increasingly important. Coordination with TC 154 will not provide immediate solutions, but TC 154 has experts that can assist in leveraging the rich set of supply chain-related standards to work toward solutions in a steady and low-risk manner.

3.4 Recommendations for new data-driven agrifood standards and deliverables

Several of the following recommendations for new standards are related, as shown in Figure 5.

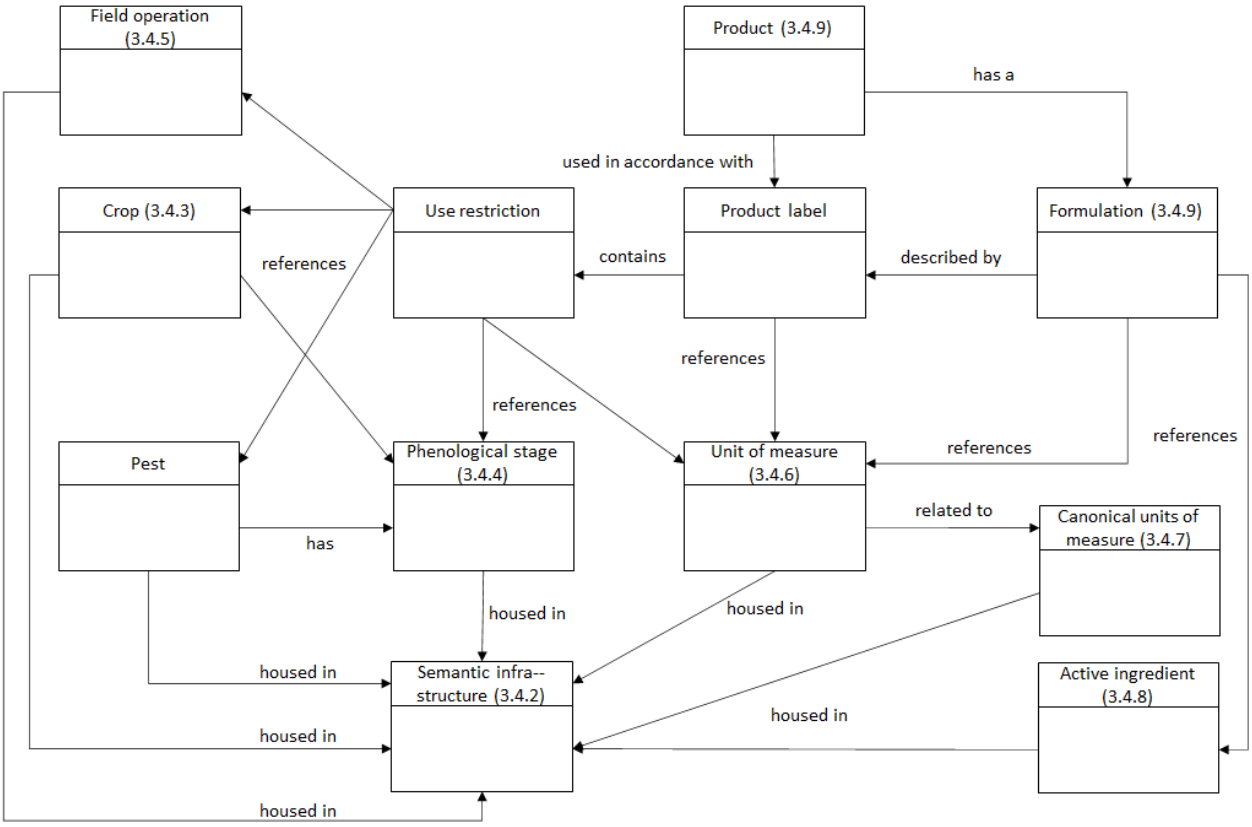

Figure 5: Relationships among semantic infrastructure-related proposed standards (Recs. 3.4.2 - 3.4.9).

Recommendation 3.4.1: Enable conformance assessment of FAIR Data Principles

The SAG recommends that ISO launch a project to develop an international standard(s) for assessing the conformance of data, data exchange, and data exchange processes to the principles of findability, accessibility, interoperability, and reusability (FAIR).

This could be implemented either horizontally by Technical Committees as coordinated by the SFCC or within ISO/CASCO in accordance with the World Trade Organization Code of Conduct for the Preparation, Adoption, and Application of Standards.

Gap / rationale

The FAIR principles (Wilkinson et al., 2016) are relatively new, but have become internationally recognized as an important mechanism for maximizing the value of data. The SAG-SF used FAIR as a proxy for assessing the smart-farming-readiness of a given standard; i.e., if the data produced / consumed / modified / exchanged by a system based on that standard is FAIR, then the standard is assumed to be smart-farming ready). The problem, however, is that there does not currently exist a standard for assessing the conformance of data, data exchange, and data exchange processes to the FAIR principles.

Note 1: Implementing FAIR principles is necessary but not sufficient. These principles were developed in the context of publicly funded research data; in a commercial context, data still must be findable, accessible, interoperable and reusable, but in a way that respects data ownership, intellectual property rights, business models, etc.

Note 2: Consistent with the previous note, FAIR data is not the same as “open” data; the latter implies free access to all; the former does not.

Recommendation 3.4.2: Data type registry (semantic infrastructure)

Develop and share a standard that defines and enables the sharing of agricultural **data type definitions** thorough appropriate data type registries, manifested as APIs, SPARQL endpoints, and other similar technologies. The definitions themselves can follow the model laid out in CD 7673-2 and the registries can follow patterns laid out in ISO 19135 for administration and governance.

Gap / rationale

Preserving the meaning of data in agriculture is an ongoing problem; agricultural management processes are plagued by the use of metadata-poor comma-separated-values (CSV) files and similar formats. This problem is compounded by the usual absence of unit of measure codes in the data, and, especially in the case of observations & measurements

data, in data formats' inability to capture parameters (such as the depth below ground at which a soil sample is taken) and other semantic refinements.

There is work currently in progress in TC 23 SC 19 WG 1 to produce an implementation standard for observations and measurements (CD 7673-2). While this work should provide a generalized model for data-type definitions, these definitions are only useful if they are shared widely across the industry.

Recommendation 3.4.3: Model and controlled vocabulary of crops

- Develop a standard to define a data model for the concept of "crop", representing an extended, albeit analogous version to the machine-oriented idea presented in ISO 11783-10. This standard would recognize (at least) the following aspects of a crop:
    - Botanical component (e.g., one or more botanical taxa)
    - Refinement component: non-taxonomic physical and physiological features of the organism, as well as other attributes that may contextualize it in the food system (e.g., bearing a specific trait/gene, or not suitable for human consumption)
    - Intended use component (e.g., fresh / processing)
    - Geopolitical context
- Enable a controlled vocabulary of these crop objects to be stored inside a registry. Make this available to the public in the form of machine-actionable data, through an electronic registry (e.g., a RESTful API).
  This implies of creating a relationship with an organization that can host this registry and establish an architecture and governance system as per ISO 19135.
- Help put in place the community to govern the vocabulary
    - There exists a precedent for a similar effort, established by the Verband Deutscher Maschinen- und Anlagenbau (VDMA) to deliver a human-readable data dictionary for the ISO 11783 standard (see www.isobus.net). However, in order to enable smart farming at scale, we propose that the data are made machine-readable and machine-actionable.
- It is important to recognize that there will be geopolitical context – dependent variations. This semantic infrastructure is meant to be a reference to which other systems can *map*. The registry should include mechanisms for actors to assert/manage relationships among different entries.
- This standard should be considered a candidate for the IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) program.

Gap / rationale

- The inability to unambiguously communicate something as fundamental as the crop being grown on a piece of land severely limits the ability of actors within the industry to exchange data electronically.
- There is a controlled vocabulary of tens of thousands of plant, animal, and pathogen species managed by the European and Mediterranean Plant Protection Organization (EPPO). These “EPPO Codes” are distributed with a very workable license model that enables users to house the vocabulary in their own systems, and exchange data using these codes in a royalty-free way. Moreover, there exist mechanisms for adding codes to the vocabularies.
- Agricultural reality, though, is that the idea of “crop” represents more than just the botanical / taxonomic component being expressible through an EPPO code. In addition to the botanical component, the idea of a crop also includes refinements that transcend the merely botanical; for example, whether the plants involved are genetically modified, or the type of an otherwise taxonomically equivalent tomato (e.g., round tomatoes, plum tomatoes and cherry tomatoes are considered different crops in many jurisdictions, even if they refer to the same species).
- The intended use of the crop (e.g., grain corn vs silage; fresh vs processing tomatoes, etc.) is also relevant for the producer to properly manage the allocation of land to different uses required by contracts, etc.

Recommendation 3.4.4: Controlled vocabulary of phenological stages

- Develop a standard for a controlled vocabulary and set of machine-readable codes to represent the phenological stages of major food, feed and fiber crops and their pests (e.g, insects).
    - Organize these vocabularies hierarchically by crop (e.g., the phenological stages of maize will be different from those of cotton)
    - Consider an existing dataset such as BBCH as a starting point.
    - Include labels in different languages
    - Note that this is essentially a data type definition, which could be delivered through a data type registry as described in a previous recommendation.
- Deliver the standard through a registry established via a cooperative agreement with another organization
- Help put in place the community to govern the vocabulary
    - There is a precedent for a similar effort, established by the VDMA to deliver a human-readable data dictionary for the ISO 11783 standard (see

www.isobus.net). The difference is that, in order to enable smart farming at scale, we propose that the data are made machine-readable and machine-actionable.

- This standard should be considered a candidate for the IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) program.

Gap / rationale

Many important crop management decisions, especially in crop protection, are contextualized and driven in no small part by the phenological (i.e., development) stage of the crop, and the life stage ("instar") of observed pests on those crops. While there exist regional variations in the scales used to represent phenological stages, there is prior work on standardizing development scales and codes in a way that lends itself to mapping between these codes and their regional equivalents. Of particular note is the BBCH set of scales available at http://www.reterurale.it/downloads/BBCH_engl_2001.pdf

Recommendation 3.4.5: Controlled vocabulary of field operations

- Develop a standard controlled vocabulary for different types of field operations (e.g., planting, harvest, tillage).
    - Organize it hierarchically (e.g., disking is a sub-type of tillage)
    - Include geopolitical-context-dependence in this registry, because some field operations may be specific to particular region(s).
    - Include labels in different languages
    - Note that this is essentially a data type definition, which could be delivered through a data type registry as described in a previous recommendation.
- Deliver the standard through a registry established via a cooperative agreement with another organization
- Help put in place the community to govern the vocabulary
    - There is a precedent for a similar effort, established by the VDMA to deliver a human-readable data dictionary for the ISO 11783 standard (see www.isobus.net). The difference is that, in order to enable smart farming at scale, we propose that the data are made machine-readable and machine-actionable.
- This standard should be considered a candidate for the IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) program.

Gap / rationale

- Under the general umbrella of "you can't manage what you can't measure", there is increasing emphasis being placed in the calculation of resource (energy, carbon, water, soil)

footprints for agricultural processes. Field operations such as tillage tend to have large resource footprints: tillage involves dragging a mechanical implement through the soil, thus consuming large amounts of energy; it also has implications on the susceptibility of the soil to erosion, entails the loss of soil moisture, etc.

- While there are models that allow calculating the energy consumption associated with different types of field operations (e.g., the Soil Tillage Intensity Rating, STIR associated with the Revised Soil Loss Equation, RUSLE used by USDA), this calculation cannot be performed at scale if there are no mechanisms in place for the unambiguous, automated identification of the different kinds of tillage (and, more broadly, agricultural-field operations-related) implements.

Recommendation 3.4.6: Standard machine-actionable set of unit of measure codes

- Develop a standard or technical specification that provides an unambiguous set of machine-readable codes for units of measure, as well as rules and syntax for the composition thereof.
- Deliver the standard through a registry established via a cooperative agreement with another organization
- Help put in place the community to govern the vocabulary
    - There is a precedent for a similar effort, established by the VDMA to deliver a human-readable data dictionary for the ISO 11783 standard (see www.isobus.net). The difference is that, in order to enable smart farming at scale, we propose that the data are made machine-readable and machine-actionable.
- This standard should be considered a candidate for the IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) program.

Gap / rationale

- Codes for units of measure in agriculture are not used or shared consistently. This leads to interoperability problems. The problem becomes more complex when laboratory measurements are involved.
- It is important to note that there is a profusion of units of measure in regular use in agriculture and food industry, and that a system that enables users to make combinations of existing units is highly desirable. For example, to combine basic units of mass or volume and units of area to represent a crop yield per area, etc.
- There already exist mechanisms for doing this. On one hand, ISO 80000 defines a comprehensive system of units of measure. An example of the creation of code systems, the Universal Code for Units of Measure (UCUM) has the capability to provide codes that can be compounded.

Recommendation 3.4.7: Enable nonstandard unit of measure conversions

- Develop guidelines for how to convert among units of measure that require ancillary information.
- This standard should be considered a candidate for an IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) standard.

Gap / rationale

Conversion among different units of measure is a common practice in agriculture. This is relatively straightforward when the units of measure involved exist in the same dimension, such as converting a value expressed in grams to kilograms. However, there are additional levels of complexity associated with conversions typically found in agricultural laboratory work, where the conversions cannot occur without additional information. Two agricultural examples:

- Conversions of concentrations that require knowing the molecular weight of the analyte.
- Conversions frequently used when making fertility recommendations, where concentrations (e.g., parts per million) are converted to a unit of mass per unit area. This conversion requires knowledge of the bulk density of the soil, the depth of soil represented by the sample, etc.

These conversions are often poorly understood and performed incorrectly by practitioners.

Recommendation 3.4.8: Standardize active ingredient reference data

- Develop a standard or guideline for representing the active ingredients of crop protection products in a machine-readable way.
- Deliver the standard through a registry established via a cooperative agreement with another organization
- Help put in place the community to govern the vocabulary
    - There is a precedent for a similar effort, established by the VDMA to deliver a human-readable data dictionary for the ISO 11783 standard (see www.isobus.net). The difference is that, in order to enable smart farming at scale, we propose that the data are made machine-readable and machine-actionable.
- This standard should be considered a candidate for the IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) program.

Gap / rationale

As the pressure on producers grows to farm sustainably and in compliance with ever more complex regulations, it becomes increasingly important for the producers to accurately document their use of seed, crop protection and crop nutrition products. This is made very difficult by the lack of uniformity in product identification, and by a lack of standardization of in-field data capture.

Recommendation 3.4.9: Enable standard crop input product label reference data

- Develop a standard for machine-actionable seed / crop protection / crop nutrition product label information regarding composition and instructions / limitations for use.
- This standard should build on the controlled vocabularies proposed in Recommendations 3.4.3, 3.4.4, 3.4.5, 3.4.6, 3.4.7.
- Provide guidelines for implementation of a registry to deliver product reference data.
- This standard should be considered a candidate for the IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) program.

Gap / rationale

As digital agriculture tools get more complex, the need to provide automated advice and warnings on the planned use of a given crop nutrition product increases. There is currently no widely accepted way of expressing product use constraints (e.g., buffer zones, maximum annual active ingredient loads, maximum annual number of applications, crop rotation limitations, etc.) in machine-actionable form.
Label data is complex, and the restrictions and directions for use contained therein are typically dependent on crop, pest, phenological stage (of both the crop and the pest), soil type, and geopolitical context (e.g., country). The value of label data to data-driven agrifood systems is maximized if the data are standardized and machine-readable and consistent in that the vocabularies used for the abovementioned attributes are also standardized and machine-readable.

Note: Unlike other reference data mentioned in previous recommendations (e.g., crop, phenological stages), which are relatively infrequently changing and for which it could be reasonably expected to have the data hosted by an industry association or other non-profit organization operating in a pre-competitive space, delivering product reference data is often a for-profit endeavor given that the data are relatively frequently-changing, geopolitical-context-dependent, and require maintenance and upkeep. For this reason, efforts are likely best expended in publishing guidelines for how to stand up a standardized reference data API or other mechanism to access the data, rather than attempt to publish it through a central system.

Recommendation 3.4.10: Initiate work on a reference architecture for smart farming though an international workshop

- Convene an international workshop to initiate work on a standard for a reference architecture to describe generic smart farming data system characteristics, a conceptual model, a reference model and a number of architectural views aligned with the architecture descriptions defined in ISO/IEC/IEEE 42010.
- The Smart Farming Reference Architecture should outline what the overall structured approach for the construction of smart farming data systems shall be by providing an architectural structure framework. In short, the proposed reference architecture will provide guidance for the architect developing a smart farming data system and aims to give a better understanding of such systems to the stakeholders thereof, including device manufacturers, application developers, customers and users.
- This effort should have the SAG-SF capability model as its starting point. This effort should be followed by the development of a data model (see Recommendation 3.4.11).

Gap / rationale

Contemporary data-driven agriculture in general, and smart farming in particular, can be imagined as a system of systems requiring extensive data exchange both within and among systems. Interoperability (and FAIR in general) become especially challenging in this situation in the absence of standardized capabilities and interfaces. A reference architecture enables standardization thereof.

The variety of stakeholders in smart farming is very broad, and only a small subset of them are currently represented as ISO experts. While this is one of the motivations for Recommendation 3.2.1 (the proposed new TC), convening an international workshop would enable reaching a wider audience, both for their input to the critically important idea of a reference architecture for Smart Farming, but also as a mechanism for kickstarting, and recruiting experts to the TC for Data-Driven Agrifood Systems through exposure to ISO and its processes.

Note: Clause 1.2 presented a rationale for why the SAG-SF broadened its scope beyond smart farming to data-driven agrifood systems. In that light it may seem counter-intuitive to convene a workshop and create a reference architecture standard for *smart farming*, but the current global context requires a bold approach to growing and processing food; enabling the decision support and optimization aspects of smart

farming along with the broader data-driven aspects of agrifood systems seems appropriate.

Recommendation 3.4.11: Standard for reference architecture for Smart Farming

- Develop, following the international workshop described in 3.4.10, a standard for a reference architecture to describe generic smart farming data system characteristics, a conceptual model, a reference model and a number of architectural views aligned with the architecture descriptions defined in ISO/IEC/IEEE 42010, and following the initial work of recommendation 3.4.10.
- We recommend that this standard be developed by the proposed Technical Committee on Data-Driven Agrifood Systems, in consultation with JTC 1 SC 41, and patterned after ISO/IEC 30141:2018 (Internet of Things (IoT) — Reference Architecture) developed by that subcommittee.

  Gap / rationale

  Contemporary data-driven agriculture in general, and smart farming in particular, can be imagined as a system of systems requiring extensive data exchange both within and among systems. Interoperability (and FAIR in general) become especially challenging in this situation in the absence of standardized capabilities and interfaces. A reference architecture enables standardization thereof.

Recommendation 3.4.12: Enable food loss and waste management through data

- Develop a standard for Food Loss and Waste data payloads at different stages of the supply chain. This is meant to be an enabling complement to an MSS standard on Food Loss and Waste from TC 34 SC 20.
- We recommend that this standard be developed jointly between the Agrisemantics Working Group of the proposed TC on Data-Driven Agrifood Systems (given its focus on data) and TC 34 SC 20. A liaison with TC 184 (for aspects related to observations in smart manufacturing) may also be desirable.
- Its scope should include controlled vocabularies and data objects for representing on-farm food loss (and associated disposition events where lost food is allocated to some other purpose or destination such as feeding to animals, plowing underground, composted, sent to the landfill, etc.), as Observations and Measurements as per ISO 19156 / ISO CD 7673-2.
- The scope of the proposed standard should also include disposition events associated with loss and waste at subsequent points of the supply chain (e.g., processors, retailers).

Gap / rationale

- According to the UN's *The Sustainable Development Goals Report* for 2022, over 30% of the world's food is lost or wasted at some point from harvest onward. Food loss and waste (FLW) contributes to greenhouse gas production (e.g., through disposal in landfills) and food insecurity (e.g., food could otherwise be made available to vulnerable populations).
- Reducing this FLW could thus contribute toward making progress on the UN SDGs (e.g., Zero Hunger, Responsible Production and Consumption).
- Improving management of a problem such as FLW requires accurate data collection, ranging from observations of harvest efficiency to representing complex on-farm dynamics such as feeding a lost crop to livestock, ploughing it into the soil, etc.
- The ISO SAG anticipates an emergent MSS on FLW to be developed in the context of TC 34 SC 20 and believes this to be a **critically important standard**.
- ISO Management System Standards, however, tend to be abstract in nature, so an MSS on FLW is unlikely to include in its scope detailed data collection, both on-farm and in subsequent stages of the supply chain.

Accompanying an MSS with a data-focused implementation standard is likely to reduce barriers to implementation of the MSS.

Recommendation 3.4.13: Standardize a data model for field boundaries, nomenclature for field boundary use, and data quality measures associated with field boundaries.

- Develop a standard describing a data model to represent field boundaries, their change over time, a nomenclature for their different purposes, and data quality measures usable to assess their fitness for a particular use.
- We recommend that this standard be developed by the proposed TC on Data-Driven Agrifood Systems in consultation with TC 211.
- Consider using the TC 211 concept of a simple feature (defined in ISO 19125-1: 2004) as a starting point for representing the geographical aspects of the problem.

Gap / rationale

Although the meaning of the concept of an agricultural field or paddock (henceforth “field”) may be highly dependent on a particular producer’s needs, a field may have multiple boundaries (imaginable as a multi-polygon *simple feature*, as per TC 211 nomenclature) that change over time and have different purposes.

Examples of different purposes include:

- nominal boundaries used to represent the idea of the field in a farm management information system,
- operational or prescription boundaries used to control planting, spreading and spraying field operations,
- ex-post boundaries obtained from the spatial footprint of a recorded field operation (e.g., seeding),
- administrative boundaries used to communicate with regulators, and
- spatial allocation boundaries used to allocate incoming geographical field operations work record data to a given field.

A boundary used for each of these different purposes would conceivably have different data quality requirements (e.g., a prescription boundary used to control a spraying operation would typically need to be very accurate compared to a nominal boundary).

The shape of the boundaries may vary over time as a result of changing planting patterns, equipment size, land ownership or usage patterns, and so forth.

Keeping accurate track of these different boundaries, determining their suitability for different purposes, and exchanging purpose information between the producer and other actors (e.g., advisor) is complex, and not currently standardized.

Recommendation 3.4.14: Enable clear data contract labelling

Develop a standard for a simple, usable framework for summarizing and communicating terms, conditions and privacy policies used in producer- and service-provider-facing data contracts (e.g., based on a set of graphic symbols). The framework should be able to communicate:

- the types of data involved (e.g., production data, personally identifiable information, geographically explicit data, etc.),
- aspects of intended use (e.g., whether the data are going to be sold / shared with other parties, whether the customer has the right to request deletion of the data, etc.) and
- what the customer receives in exchange for their data.

Gap / rationale

A lack of legal knowledge and literacy hinders informed consent and transparency (and therefore data sharing / use) associated with digital tools in agriculture, especially when smallholders are the target audience. Promoting transparency and informed consent through a simplification of the language and structure used to communicate aspects of data privacy, ownership and other terms and conditions would likely

increase adoption of smart farming tools by producers, with the concomitant increase in efficiencies and principled decision-making in agriculture.

Recommendation 3.4.15: Enable electronically representing (and exchanging) the terms and features of producer-facing risk-management instruments

Develop a standard for representing and exchanging risk management data, including the terms, features, contract creation and validation inputs of producer-facing instruments.

Gap / rationale

Risk management instruments (e.g., crop insurance tools based on smartphone-mediated photos, on weather derivatives, or remote sensing data) are a very promising tool for small producers to rise out of poverty and for producers of any size to be more able to invest in crop inputs and protect their business. The lack of standardization and interoperability of the data involved hinders developing and deploying these tools at scale and makes it more expensive and difficult for small producers to participate.

Recommendation 3.4.16: Co-registration of differential (e.g., RTK) positioning networks

Develop a standard for the co-registration of differential positioning networks, providing clear guidance for the determination of a conventional position (including surveying guidelines) for base stations in RTK (and other differential) networks.

We recommend this standard be developed jointly by TC 211, TC 23 and the proposed TC on Data-Driven Agrifood Systems

Gap / rationale

A rapidly developing aspect of smart farming is the use of multiple mobile platforms in the field, cooperating in pursuit of a common goal. For example, using unmanned aerial vehicles to observe the presence of weeds in the field, followed by the creation of a prescription, which is then used to guide an autonomous vehicle to target those weeds, either through precision application of a chemical, or through other (e.g., mechanical) means. These operations are inherently geospatial in nature and require the use of accurate and precise determination of the direct position of equipment on the ground. This is typically performed using GNSS equipment, and increasingly, using real-time kinematic (RTK) units. While these differential systems are very precise, the accuracy of their position determinations is only as good as that of the base station used as a differential reference. If the different parts of the system that require positioning data (e.g., the GPS unit used to capture the field boundary, the GPS unit used to determine the position of the UAV, and the GPS unit to position the precision sprayer) are all using the same RTK system and base station, then any inaccuracies are rendered moot for the purposes of the operation at hand (because all the units will have the same error), but if they happen to use different RTK base stations, as is

becoming likelier as the market for RTK services grows, there may be significant errors, as the same feature on the ground is represented by different latitude/longitude coordinates by the different devices.

Recommendation 3.4.17: Observations and measurements associated with dust

Develop a standard for representing and exchanging observations and measurements associated with the phenomenon of dust, both in terms of particles suspended in the air, and particles present on plant surfaces.

This effort is fully compatible with the ISO 19156 abstract standard and the CD 7673-2 implementation standard currently under development, so the proposed standard implies creating controlled vocabularies for dust-related observed properties, features of interest, observation methods, etc.

Gap / rationale

Agricultural production as well as the environment has faced a serious challenge due to the phenomenon of dust caused by global warming and dehydration or drying of water resources. Dust is one of the most important atmospheric phenomena and source of natural disasters in some regions of the world. It is considered an emergent effect of climate change and is occurring more frequently in recent years, occurring in the western and southwestern regions of Iran and other countries in the region. The destructive effects of dust include reduced light reaching the plant, reducing photosynthesis, preventing the absorption of micronutrients through foliar spraying, and as a result, reducing the yield of agricultural products.

Standardized measurement and (data) representation of suspended particles in the air would help provide practical advice to producers and better detect and communicate when dust systems are passing through their region. (For example, sprinkler irrigation is recommended in those situations to prevent or minimize dust damage).

Standardized measurement and (data) representation of the presence of dust on plant surfaces (which is associated with a reduction of chlorophyll content) can also be used to drive remedial action (e.g., sprinkler irrigation) and delay / pause foliar spraying, which is not recommended under those conditions.

Recommendation 3.4.18: Controlled vocabulary and data model for a hierarchical, geopolitical-context-dependent, mappable reference data system to represent actors and their roles in agrifood operations

- Develop a standard for a controlled vocabulary and data model for a hierarchical, geopolitical-context-dependent, mappable reference data system to represent actors and their roles in agrifood operations (e.g., the actors declared in the stories of Annex E.2, or the agricultural technology advisor mentioned in Recommendation 3.2.6).
- Deliver the standard through a registry established via a cooperative agreement with another organization.
- Each item should include a unique identifier that enables asserting relationships among different entries.
- Help put in place the community to govern the vocabulary
    - There is a precedent for a similar effort, established by the VDMA to deliver a human-readable data dictionary for the ISO 11783 standard (see www.isobus.net). The difference is that, in order to enable smart farming at scale, we propose that the data are made machine-readable and machine-actionable.
- This standard should be considered a candidate for the IEC-ISO Standards Machine Applicable Readable and Transferable (SMART) program.

Gap / rationale

Keeping track of the identity and role of people involved in agrifood operations is often very important, in applications ranging from payroll to occupational safety and health, to tracing back what happened during a particular operation. Socioeconomic analyses of agrifood systems also draw heavily from representing roles within the agrifood system.

Modeling these roles is somewhat complex, since they are often hierarchical and geopolitical-context dependent, and there is currently no standardized vocabulary for actor/party roles in agrifood systems, although work has been done in that direction (e.g., the CGIAR SocioEconomic Ontology, SEOnt, https://github.com/AgriculturalSemantics/SEONT)

Recommendation 3.4.19: A standard to support data exchange between crop and livestock management systems

- Develop a standard to enable data exchange at different spatial (e.g., farm, field and subfield) and temporal (seasonal, daily) scales between farm and livestock management

systems. Identify points of contact between these syshtems, model the data involved, and enable their exchange. Examples include daily pasture biomass production, grazing by the herd, water and nutrient balance, applications of manure, disposition of a lost crop as animal feed, manure pit management, etc.

- This standard would be developed in the context of the proposed subcommittee on Livestock Activities Data Management (Recommendation 3.2.5), in consultation with TC 34.

Gap / rationale

There is an increasing global emphasis on reducing the resource footprint of agriculture and livestock production. Integrated crop-livestock systems can be a powerful tool to advance this idea, but when lifecycle analyses are performed and sustainability indicators are calculated, it is often the case that they fail to properly account for the transfer of materials and energy between crop and livestock components (e.g., a crop not suitable for sale can be fed to cattle, waste from livestock can be used to reduce commercial fertilizer use, etc.).

This is the result of a lack of standardization and of management information systems for crops and livestock having typically been developed independently and by different providers.

Recommendation 3.4.20: Standard for representing provenance of agricultural inputs and calculating upstream energy requirements

Develop a new, or adapt an existing, standard for a controlled vocabulary and framework to describe the sources, provenance, and upstream energy requirements for producing and using agricultural inputs (e.g., fuel, machinery, fertilizer, animal feed, etc.).

Gap / rationale

It is relatively common to evaluate resource footprints associated with the use of agricultural inputs (e.g., diesel consumption associated with each pass over the field, etc.) but there is less emphasis on tracking, and including in decision-making, upstream embedded energy in those inputs. Lack of accounting for upstream processes can have substantial implications on assessments of net greenhouse gas emissions and sustainability.

There are a number of existing ISO standards in the Environmental Management, Carbon Footprint, and Lifecycle assessment domains that take a unique view of upstream emissions relative to non-ISO carbon footprinting standards where these are grouped into a “Scope 3” category that may not require even a qualitative assessment.

The ISO 14064 series requires categorization of upstream emissions as “Controlled”, “Related” or “Affected”, thus identifying a direct link between the management of an agricultural product and its impact. Complexity is reduced by addressing only the conditions where a management change from a baseline condition has a material effect/impact on upstream emissions.

There are, however, many gaps in collecting representative data and in standardizing inputs on a per unit of production basis. These data and quantitative approaches are needed to enable industry and consumers to make informed choices about products relative to the specific regional conditions where they were produced. For example, accurate data and comparable approaches are needed to compare concentrated protein sourced from beef cattle conversions of plant materials (indigestible by humans) on marginal lands, with protein sourced from a range of plant components grown using intensive agricultural production systems. Enhancing the capacity to make informed comparisons will help identify optimal management strategies suited to regional characteristics in support of UN SDGs, specifically 12, 13, 15.

Recommendation 3.4.21: Standard for representing the source, provenance and disposition of irrigation water

Develop a standard for a controlled vocabulary and framework for describing the sources, provenance, and ultimate disposition of water use for irrigation.

Gap / rationale

Irrigation water is an increasingly valuable and scarce resource. Moreover, irrigation water can rarely be used without some kind of environmental impact and/or tradeoff. This impact is contingent on the water’s source (e.g., groundwater, snowmelt, runoff, grey water, etc.) and provenance (where/how the water was received will translate into different embedded energy), so unambiguously representing the sources, origin / provenance and disposition of different irrigation water options would be a helpful way of making these tradeoffs more explicit during decision-making. This would enable documenting and quantifying the sustainability of irrigation with respect to UN SDGs 6, 12, 13, 14 and 15, for example.

Recommendation 3.4.22: Standardize the data produced and consumed by fine bubble technology in agrifood systems.

- Develop a standard to represent the *data* associated with aspects of fine bubble technology that can enable its evaluation / use in agrifood systems. These aspects

include observations and measurements (e.g., of fine bubble concentration in growth solution), and the control variables (e.g., of concentration of fine bubbles in a growth medium or irrigation water) used in managing fine bubbles, as covered by existing gISO/TC 281 (Fine Bubble Technology) standards.

- We recommend that this standard be developed jointly between ISO/TC 281 (Fine Bubble Technology) and the proposed SC on Greenhouse, Controlled-Environment, and Urban Farming Data.

Gap / rationale

Fine bubble technology is an area of active research in (especially controlled-environment) agriculture, with multiple known applications ranging from promoting germination, to disinfection of surfaces and promoting nutrient uptake. ISO has a technical committee (TC 281) dedicated to this domain, but its standards focus primarily on processes for implementation of the technology, and not on representing the processes or their inputs and outputs in terms of data. Standardizing the data associated with fine bubble systems in agriculture will increase the reach of the existing TC 281 standards, paving the way for further evaluation of the technology in operational systems, as well as its use at scale.

Recommendation 3.4.23: Standards for machine-actionable a) data product specifications and b) data management plans.

- Develop a standard to create machine actionable data product specifications, and a standard for creating machine-actionable data management plans.
- We recommend that this standard be developed by the proposed TC on Data-Driven Agrifood Systems jointly with TC 211.

Gap / rationale

The ISO 19131 standard defines data product specifications as descriptions of a dataset or dataset series together with additional information that will enable it to be created, supplied to and used by another party. That standard provides a framework for representing these documents but falls short of making such documents machine actionable; this limits the scale at which they can be used.

Additionally, the velocity and volume of agricultural data that an even modestly sized farm must handle are ever-increasing. The lifecycle management of these data cannot be left to chance because some of it is very valuable and reusable, whereas other datasets may be very voluminous and not be required beyond a certain time horizon.

Being able to intentionally manage what happens to the data, where it is stored, for how long, etc. and to do so in a data-driven way and at scale is the motivation behind wanting a machine-actionable data management plan. A good example is the case of an agricultural technology advisor described in Recommendation 3.2.6. This kind of professional can only deliver services at scale if the data flows are streamlined, the necessary data is readily available, and data that are no longer as relevant are not cluttering available storage. This motivates the need for machine-actionable data management plans.

Recommendation 3.4.24: Standardized metadata for annotating multi- and hyperspectral imagery

Create a standard for machine-actionable metadata for annotating multi- and hyperspectral remote sensing (satellite, UAV and ground vehicle) imagery, including specifying the data format (e.g., of tags within imagery files), the semantic resources (data types / variables, the controlled vocabularies required when those variables are enumerated) required, and the semantic infrastructure (e.g., data type registry) needed to distribute the semantic resources.

We recommend that this standard be developed by TC 211 in consultation with the proposed TC on Data-Driven Agrifood Systems.

Gap / rationale

Multi- and hyperspectral remote sensing images are used extensively in agriculture and livestock management for a variety of purposes. Moreover, there is an increasing interest in performing data fusion of images taken at different scales with different equipment such as satellites, unmanned aerial systems, and ground-based systems (e.g., sprayers and center-pivot irrigation systems). The interoperability of these images at scale is hindered, however, by a lack of standardization of metadata regarding the spectral bands or derived products represented by the image layers.

Recommendation 3.4.25: Update and contextualize ISO 22006

Revise the ISO 22006 standard, emphasizing enhancing and updating Annexes A and B, that provide a set of reference processes and sub-processes for describing crop production (e.g., by including risk management).

We suggest this revision be performed by TC 34, working in consultation with the proposed TC on Data-driven Agrifood Systems.

Gap / rationale

Enabling producers to formally represent the processes in their operations unlocks important strategic capabilities such as establishing management systems, from which the producers can derive multiple sources of benefit (e.g., understanding the costs associated with the different processes in their operations, managing working capital, etc.).

Farm management systems typically organize and represent production processes using an ad-hoc nomenclature, which makes it difficult for producers to exchange data with partners such as advisors, bankers, insurers, etc. The current version of the ISO 22006 standard provides an excellent list of processes and sub-processes (for which reason it was used as a starting point by the SAG-SF to contextualize stories, standards and capabilities), but the list is incomplete; e.g., it does not include several data-intensive processes such as risk management. A revision that included data-related aspects would render it even more useful.

Recommendation 3.4.26: Create a quality management system standard for livestock production (analogous to ISO 22006)

Create a standard providing guidelines for the application of ISO 9001 to livestock production. Special case should be taken with the analog of Annexes A and B of ISO 22006, because the providing a set of reference processes and sub-processes for describing livestock production is very valuable, but these processes / subprocesses differ significantly from those of crop production.

We suggest this standard be created by TC 34, working in consultation with the proposed TC on Data-driven Agrifood Systems.

Gap / rationale

It is important for producers to understand the costs associated with the different processes in their operations. Farm management systems typically organize and represent production processes using an ad-hoc nomenclature, which makes it difficult for producers to exchange data with partners such as advisors, bankers, insurers, etc. The ISO 22006 standard provides an excellent list of processes and sub-processes (to the extent that it was used as a starting point by the SAG-SF to contextualize stories, standards and capabilities), but it is incomplete. A revision would render it even more useful.

Recommendation 3.4.27: Enable smart spraying

- Develop a standard for a framework for automating the geopolitical-context-dependent and environmental and other context-sensitive decision of whether spraying of a particular tank mix is acceptable ("OK to spray") in a way that can be evaluated during the *planning, preparation*, and *execution* of a spraying operation.
    - Planning example: Ensure that the product application would not exceed annual maximum active ingredient load
    - Preparation example: Ensure that the application is consistent with restricted entry intervals that may be active in the field.
    - Execution example: Wind speed has increased during the operation, and the current configuration of sprayer parameters such as boom height, pressure, speed and nozzle package is inconsistent with limiting drift to the field, given the sprayer's current position with respect to the wind and the field boundary.
- This standard should be developed jointly by the proposed TC on Data-Driven Agrifood Systems, and TC 23 SC 6.

Gap / rationale

Agricultural chemicals are both expensive and have can produce deleterious effects when applied off-target. It is thus a sound practice to optimize product placement, avoiding unintended drift and ensuing efficacy on the intended target.

There is often tension, however, between the timing windows available for producers to apply chemicals in, and environmental and safety considerations, especially regarding the complex and multi-factorial topic of spray drift.

ISO has a tool, ISO TS 11356 that enables accurately capturing the spray parameters during a spraying operation for *ex-post* analysis. While this may be valuable for understanding how a spray drift event or other problem happened, it does not help prevent such *problems*.

Contemporary sprayers have the capability to adjust their operating parameters (boom height, pressure, speed, nozzles) to manage drift. In parallel, the availability of IoT-mediated environmental data (wind speed and direction, inversion conditions, etc.) as well as the capability to communicate these in real time and to run models, both on the cloud and on the machine controllers themselves, has grown significantly.

A framework is needed that can bring together the need for a systematic way of representing spray-limiting conditions in real or near-real time, for modelling how the machine parameter reactions can translate into effects under those conditions, and for

solving the resulting optimization problem (i.e., for machines to change their operation parameters in real time in order to remain compliant with regulations and other limitations). This requires integrating multiple capabilities: Configuration management (i.e., correct nozzles), machine communication, near-real-time weather data, model execution, etc.)

Recommendation 3.4.28: Enable smart apiculture

- Develop a standard to enable smart apiculture, through:
    - Creation of a controlled vocabulary of features of interest, observed properties, observation and measurement methods (both in-field and laboratory, and metadata variables of relevance to apiculture.
    - Creation of a data model and standard messages to represent the documents used in apiculture (e.g., colony inspections, management recommendations, etc.).
- We suggest this standard be developed jointly by the proposed Technical Committee on Data-Driven Agrifood Systems and TC 34 SC 19 (Bee Products).

Gap / rationale

Pollinators are a vitally important part of many agricultural ecosystems. In many cases, producers rely on honey bees that are managed through apiculture (i.e., beekeeping). Data-driven, principled decision-making is a good fit for apiculture, and is likely very urgently needed in many ecosystems, to assist in the management of colony health, for example. Enabling standards are needed that can thus bring the concepts and technologies of smart farming to pollinator management.

Recommendation 3.4.29: Enable codification of agronomy

- Create one or more standards for representing, in a machine-actionable way, causal relationships in agronomy and agricultural management. This includes:
    - Representing input and output data variables (in accordance with Recommendation 3.4.2), including limiting factors in a given context.
    - Having a controlled vocabulary for models that act upon the input variables, and a data model and registry that expresses, for those models, different versions, which inputs are required, which are optional, information regarding the sensitivity of the inputs, where to go for more information, etc.
    - The possibility of representing mechanistic/functional models, statistical models, machine-learning models and expert-opinion-driven and indigenous-knowledge-

based models in a standard, machine-actionable way (e.g., PMML, DMN, etc.) that enables model-execution-as-a-service.

Gap / rationale

Mathematical models are increasingly used to advise producers and other decision-makers. Using these models at scale to deliver advice in environments where there is scant availability of human capital mediated extension and advisory services is promising, but limited in part by interoperability problems, and a lack of understanding about how representative a model might be to specific conditions, and whether it captures the limiting factors correctly in a given environment. We need standards for both making the structure and functions of models clearer to their potential users and enable their use at scale.

Recommendation 3.4.30: Enable testing and learning through data

Create a standard for representing, in a machine- actionable way, on-farm and on-premise (for processors and manufacturers) experiments, the variables used therein, the hypotheses being tested, and the results and learnings therefrom.

Gap / rationale

The goal of the SAG-SF has fundamentally been to make recommendations that enable using data to make better management decisions in the agrifood system. While standardization of agricultural technology is an important aspect of this, it is also important to enable stakeholders to use data to test ideas and to *learn* from the data. This can take several forms, including:

- Testing emerging digital technologies and learning about their fitness for use in solving specific problems in the context of the user, and
- Testing and learning from on-farm or on-premise (e.g., for a processing plant) agronomic and management experiments.

Having standardized mechanisms for technology providers, advisors, non-governmental organizations, extension services, etc. to integrate the tools and data collection mechanisms supported by them with a learning framework would be very advantageous for helping make data more usable.

4. Fulfilling the TMB mandate

4.1 Mapping the TMB mandate to the SAG deliverables

Planning the work of the SAG-SF required merging two very different categories of actors / stakeholders involved:

- on one hand there are the multiple stakeholders who operate in the *agricultural and food domain*, conducting some form of primary or supporting activity related to farming and the further processing of the products therefrom, a subset of whom is shown in Figure 1 above.
- on the other, there are the stakeholders in the *standards domain*, who conduct standardization processes such as create and review standards.

This dual-domain situation was challenging because the SAG-SF's deliverable should make recommendations in the *standards* domain, but input about pain points in agricultural processes and food systems due to a lack of interoperability is primarily available through actors that operate in the *agricultural and food* domain. The challenge was to develop a model of knowledge elicitation and representation that lent itself to bridging the two domains.

The multiple differences among the two domains, expressed in terms of who / what/ when / where / how and why questions, are shown in Table 2 below.

Question	Agrifood Domain	Standards Domain
WHO (actors)	Stakeholders in agricultural and food processes: producers, agronomists, consultants, processors, retailers, etc.	Stakeholders in standardization processes: ISO TCs, SCs, conveners, experts, etc.
WHAT (artifacts)	Data payloads	Standards
HOW (processes/ activities)	Agricultural processes (e.g., planting, harvest, marketing a crop, examining an animal for clinical signs of disease) and food processes (e.g., further processing, supply chain management, labelling).	Standardization processes (e.g., creating a standard, performing the periodic review of a standard, conducting an international workshop, etc.).
WHEN (events)	An event occurs in the context of an agricultural (e.g., crop seasons start, conditions are met for planting / harvest, a pest is detected on a crop, etc.) food process (e.g., slaughter of an animal, food contamination, post-harvest, etc.).	An event occurs in the context of a standardization process (e.g., a standard comes up for periodic review and a vote is taken).

WHERE (systems)	Infrastructure used to support an agricultural food process (e.g., equipment, software, databases, infrastructure, reference data APIs).	Infrastructure used to support standardization creation and implementation processes (e.g., the ISO11783-10 data dictionary).
WHY (goals)	Goals of the actors in the agricultural and food domain (e.g., maximize profitability, sustainability, and compliance of their operations, traceability).	Goals of the actors in the standards domain (e.g., the UN Sustainable Development Goals).

Table 2: Comparison between the agricultural domain and the standards domain.

4.2 Bridging the domains gap with capabilities in an end-to-end model

Bridging the gap between the two domains posed a significant challenge. The SAG determined that business capability was a useful concept to represent the domains of smart farming, as well as that of the Standards domain, and use it to connect the two.

A business capability and maturity model summarized the needs in smart farming, and their relationships to processes, actors, data artifacts, etc. The capabilities identified the core skills, knowledge and access to data that were necessary for an actor within an agricultural domain. Note that these capabilities did not focus on the agricultural or communication technologies per se, as these have evolved over time and will continue to do so. Figure 6 below shows a fragment of the capability model, organized as a hierarchical set of capabilities and containers thereof.

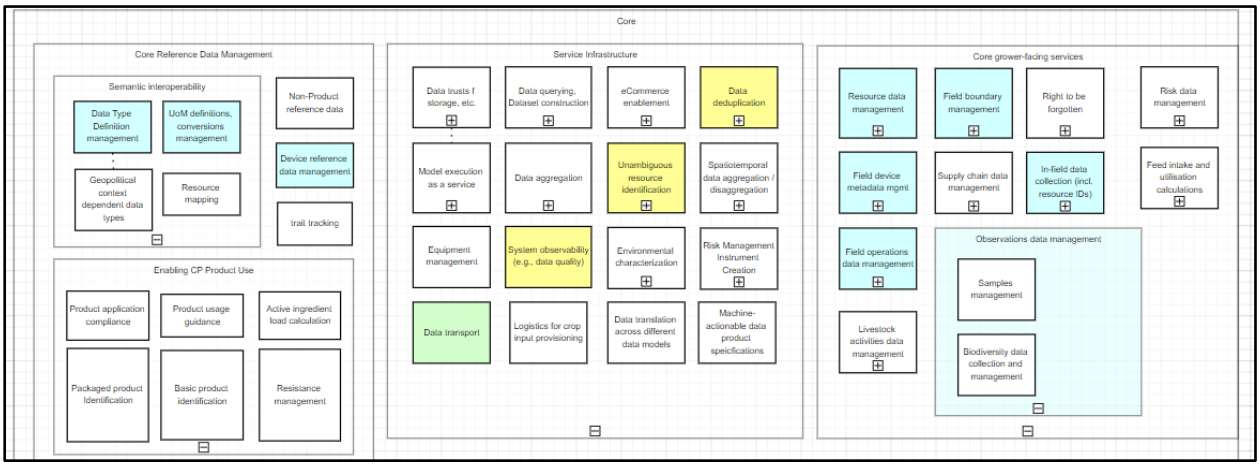

Figure 6: An example part of the capability model used to organize the roadmap document

Once the capabilities were derived and verified by the process diagrams (Annex E.3), personas and/or causal loop diagrams (Annex E.4), the subgroups mapped the capabilities to standards, SDGs, and organizations both within and outside ISO.

The capability models also enabled the *Organizational Perspective*, which links capabilities to ISO technical committees (TCs) and subcommittees (SCs), or other, non-ISO organizations

responsible for existing (or proposed) standards. The capability models, then, became the connecting mechanism between the Agricultural Domain and the Standards Domain. This framework, dubbed the “end-to-end model”, is shown in Figure 7 below.

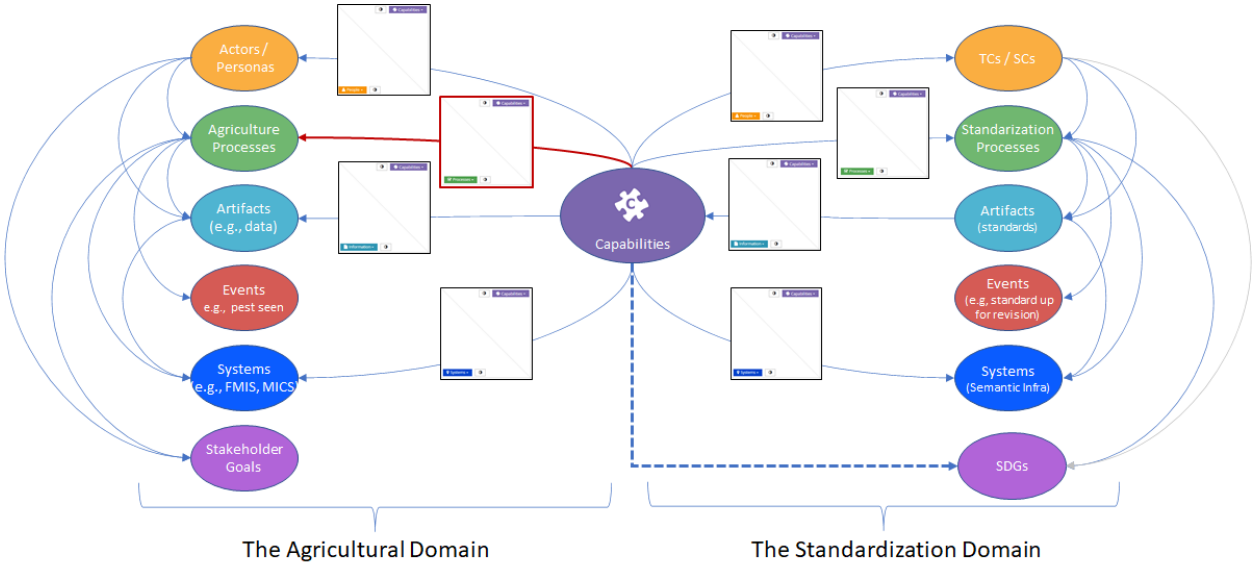

Figure 7: The End-to-End Model

4.3 The capability model

BUSINESS CAPABILITIES ARE THE EXPRESSION OR THE ARTICULATION OF THE CAPACITY, MATERIALS, AND EXPERTISE AN ORGANIZATION NEEDS TO PERFORM CORE FUNCTIONS.
The Manufacturer’s Guide to Business Capabilities, LeanIX

Figures 8-12 below present a business capability model for performing core functions in data-driven agrifood systems (which includes smart farming). The capability model includes agricultural business capabilities but does not attempt to be a comprehensive catalogue thereof. Rather, it is more focused on capabilities pertaining to the creation, management and exchange of data.

Perhaps the most important set of capabilities in the model is the one pertaining to *reference data*. Documenting a sequence of field operations involved in producing some agricultural commodity (e.g., a crop) typically involves referencing a set of *resources* (farms, fields, machines, people) that were allocated to the operation and are specific to the producer in question. Documenting the operation also involves referencing a set of other resources that are best identified in terms that are **not** specific to the grower (e.g., products, crops, etc.) The data that describe the former are usually called master (or setup) data; the latter are called reference data.

When a document, for example, a work order describing an operation that must be performed in the field (e.g., spraying), is exchanged between two actors, such as a producer

and a custom applicator, a perfect frictionless scenario would involve all the data being machine-readable and machine-actionable, such that:

- The data contained in the work order can be accurately and automatically converted to a format that can be sent to a machine or implement that will be performing the field operation.
- The products, crops and operations involved can be automatically recognized by the receiving party's system, in order to populate regulatory (e.g., product use) reports, for example.

These things are only possible if the identifiers used in all these documents are common and can be recognized. That means that the reference data that underlies those identifiers can be standardized and shared across the different participating systems. Unfortunately, there is a lack of standards related to reference data in agriculture, to the extent that we do not even have a standardized set of codes or identifiers to denote crops.

Figure 8 below shows capabilities pertaining to reference data.

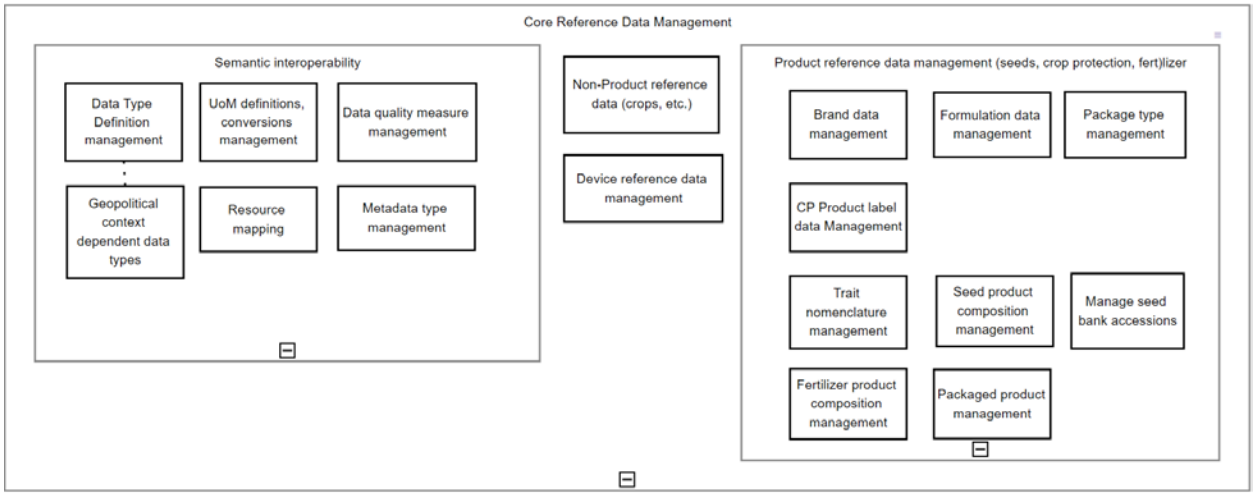

Figure 8: Reference data - specific business capabilities to enable smart farming.

The group of capabilities labelled *Semantic interoperability* in Figure 8 is also critically important for reducing friction and enabling interoperability. It pertains to representing and standardizing the *meaning* of data. For example, using the same, machine-readable codes for representing data types (i.e., variables) such as temperature, crop yield, protein content and net income. Another related problem pertains to representing data types that are geopolitical context dependent (e.g., a product registration number that only has meaning in a specific country). Yet another important problem has to do with representing units of measure ("UoMs"); this is often an afterthought in agricultural data systems, especially those created for a specific geography and specific commodities, where the units of measure are implicit and generally consistent.

Despite the industry's best intentions and attempts at standardizing, inevitably different systems might refer to the same resource (e.g., a specific producer's field or paddock, a specific machine, a specific product, etc.) using different identifiers. Interoperability can be enabled in these scenarios through *resource mapping* infrastructure, i.e., services that enable users to assert relationships among different identifiers. A typical scenario might be establishing the equivalence between the identifier used to denote a particular crop variety in a) the mobile implement control system on a planter and b) the producer's farm management software, to enable the frictionless import of work records from the field.

Managing metadata and data quality are two very important capabilities required for attaining scale in data-driven agrifood systems. Fortunately, there are ISO standards for representing metadata elements (ranging from an identifier to represent the person performing a given field operation to the license under which a dataset is distributed), ISO 19115, and data quality measures (e.g., an estimate of the error with which the latitude/longitude data of a field boundary are collected), ISO 19157. Implementation standards are still needed for applying these concepts in agrifood systems and establishing the necessary semantic infrastructure for delivering the corresponding (meta)data type definitions and data quality measure definitions in machine-actionable ways.

Figure 9 below describes service infrastructure – related capabilities.

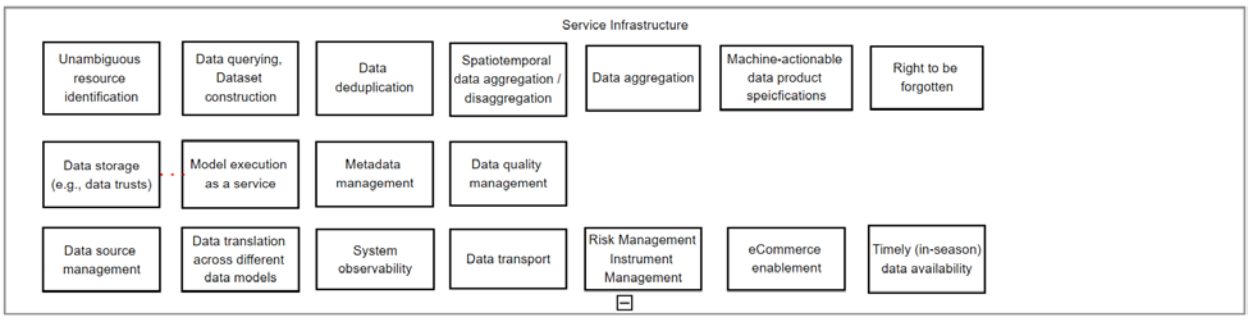

Figure 9: Service infrastructure - specific business capabilities to enable smart farming.

Some salient capabilities included in this set:

- Unambiguous resource identification: In the early days of precision agriculture, systems that were meant to be used by only one actor (e.g., the producer) did not need unique identifiers for resources; it was acceptable to identify a field or a product using, say, an integer number (e.g., "748"), because there was not a clear expectation that there might be data exchange with another system in which that same number might already be used to denote a different resource. It is now an industry standard best practice to use unique identifiers to denote resources, but more guidance is needed for when to use different identification options (e.g., universally unique IDs vs Universal Resource Identifiers).

- Data deduplication: A frequent problem in field operations agriculture is that data describing the same event (e.g., the application of a product to a field / paddock) might reach a system (e.g., the producer's farm management information system) through different paths such as a) direct data import from a machine using a USB drive, and b) importing data using the equipment manufacturer's cloud infrastructure, after a telematics system on the farm equipment uploads the data. This creates challenges for farm management information systems because activities on the farm may be recorded two (or more) times. Detecting these scenarios manually at any but the smallest scale is time-consuming and prone to error. Standardized approaches to automated de-duplication of data are needed.
- Spatiotemporal data aggregation / disaggregation: It is generally important in farm management to allocate geographical field operations data to the corresponding field / paddock where the operations happened. The reasons for this importance range from the need to calculate profits and losses at the field level as a mechanism to drive land allocation decisions (e.g., "This paddock is consistently not very productive—we will take it out of production and place it in a conservation program") to accurately managing active ingredient loads for regulatory compliance. When field operations are performed by machines, however, the data in an incoming dataset may require allocation over space and time. For example, it may represent more than one field (requiring allocating data over space, using field boundaries to decide what field / paddock a given piece of geographical information belongs to), and may only represent part of the field operation (the rest of which may be present in a different dataset happening later or earlier). Being able to spatially allocate incoming data to the corresponding field / paddock and grouping those data temporally into meaningful products (e.g., a yield dataset for a field that was collected over two days) is valuable, and a capability that the industry would benefit from standardizing.

Figure 10 below presents a set of core customer-facing capabilities, where "customer" refers to the user of a management information system at the farm or similar level. Note that capabilities that are not specific to agrifood systems (e.g., inventory management) are not shown.

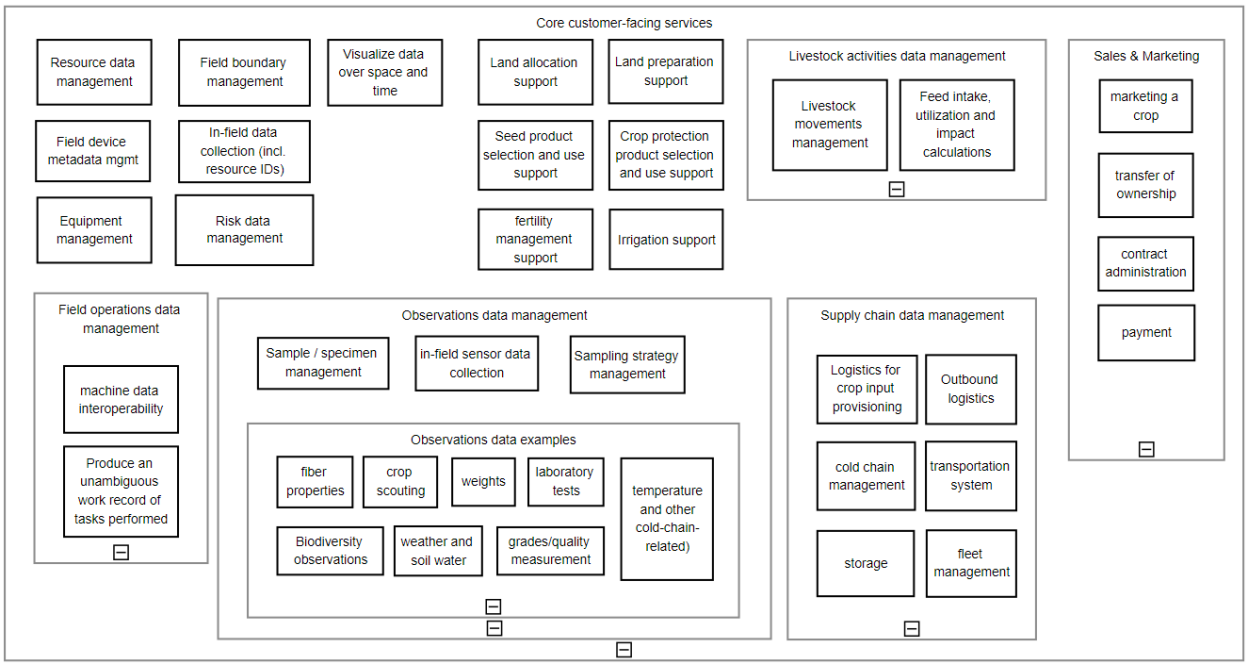

Figure 10: Core-customer-facing-services- specific business capabilities to enable smart farming.

Figure 11 below presents a set of support capabilities, meant to enable the customer-facing capabilities.

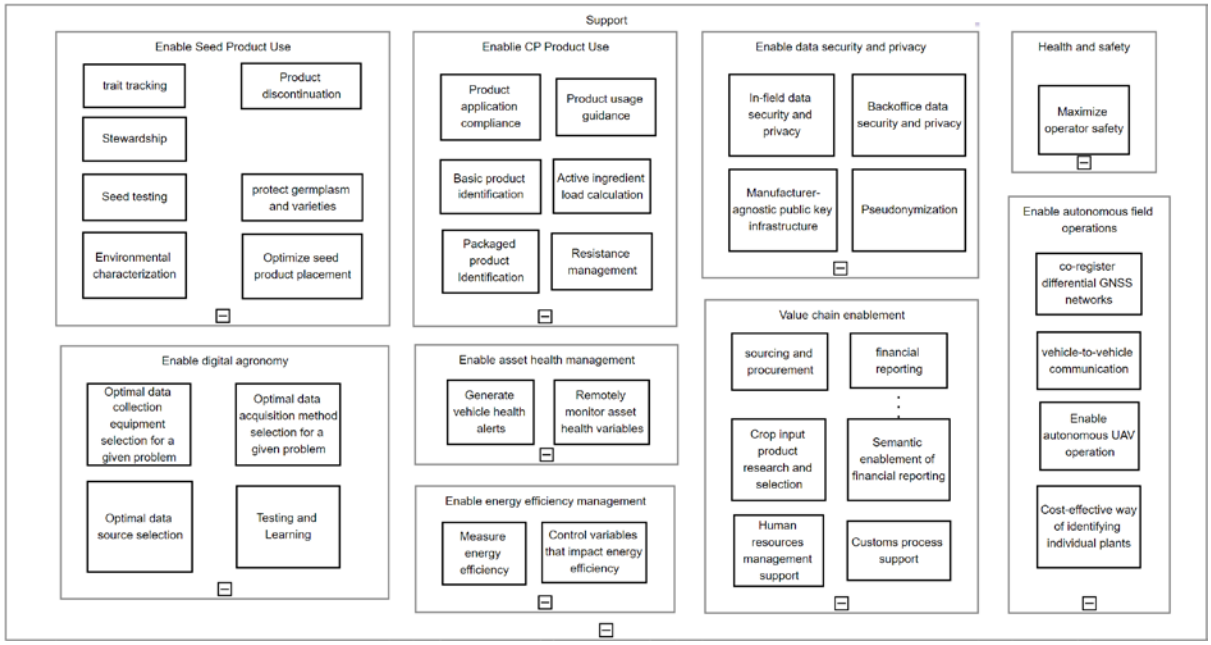

Figure 11: Support capabilities, meant to enable the customer-facing capabilities. Note that the "CP" acronym refers to crop protection; i,.e., chemicals.

Some salient capabilities included in this set:

- Enable autonomous field operations: This is a "hot" topic in agriculture, very relevant as rural populations tend to decrease in many countries, regulatory pressure on traditional forms of crop protection tends to grow in many jurisdictions, and producers face labour shortages when harvesting and managing crops. Autonomous operation of equipment in the field involves a complex choreography of multiple interoperating systems (e.g., drones / UAVs, ground robots, smart machines and/or implements,

autonomous data collection platforms, static IoT devices, and so forth) and their corresponding data layers. This is currently not possible at scale. Several recommendations in this document (e.g., 3.4.1-3.4.9, 3.4.13, 3.4.16, 3.4.24, 3.4.27 and 3.4.29.) aim to lay a foundation for progress in this area.

- Enable energy efficiency management: Making principled use of resources is at the heart of the definition of smart farming used by the SAG-SF. Agricultural operations involve the expenditure of great amounts of energy, whether in the form of diesel fuel or electricity from a utility grid or on-farm microgrid. Enabling data capture and resource management at scale on this front requires standardization.

4.4 Notable emergent properties

Over the course of their work, SAG experts identified several important end results of smart farming. These are not capabilities, however, but rather as emergent properties of the use of the capabilities in an agrifood system. Some of these emergent properties are:

- Food safety
- Food security
- Food system resiliency

4.5 Linking capabilities and SDG targets

Once subgroups identified the core capabilities for their domains, they linked those capabilities with the SDG goals and targets. See Annex C for more details.

5. Smallholder farmers

5.1 Challenges

Smallholder farms (typically <2 hectares, although the exact definition will vary by geopolitical context) account for 84% of all farms worldwide, operating about 12% of all agricultural land, and accountable for 35% of the world's food supply. In lower-income regions, smallholder farmers operate a far greater share of agricultural land. In Sub-Saharan Africa, for example, the average farm size is only 1.6 hectares, yet these farms account for 35% of food production regionally. (Marie, 2022).

A promise of smart farming is to reduce the barriers to interoperability and make data-driven agronomic advice more affordable to the smallholder, which in turn can lead to higher productivity and income, as well as reducing the food insecurity for the surrounding population.

Structural and socio-economic issues, however, can hobble smallholder farmers from fully reaping the benefits of that promise.

Data-driven services afford multiple opportunities to smallholders:

- Access to financial services, such as banking, money transfer, credit, and micro-loans
- Access to risk management instruments such as crop insurance
- Access to market data, such as product requirements, pricing/selling, buyer location
- Land and crop allocation optimization in planning, field operations and going-to-market
- Weather forecasts and alerts
- Asking questions and receiving expert advice

Large farms globally and smallholder farms in higher-income regions are well-positioned to take advantage of improvements in data interoperability. While broadband access remains an issue for both large and smallholder farms, smallholder producers face unique challenges, including:

- Limited access to capital for investments
- Disproportionate impact of climate change
- Lack of access to high-quality inputs, which can lower the yield and quality of crops
- Limited or single access to markets
- Greater impact from market downturns
- Lack of knowledge/expert service advice to optimize the use of small parcels of land

- Lack of knowledge to fully understand complex legal contracts and agreements
- Limited to no broadband access, especially in Sub-Saharan Africa
- Issues with “last mile” infrastructure needed to bring technological advances to the farm
- Lack of open data standards
- Data that is hard to find, access, interoperate with, and reuse; in other words, un-FAIR
- Limited access to labour. The producer must thus cover all or most of the items in their value chain and are therefore caught in an activity trap and unlikely to be able to perform those functions well.
- Lack of availability and scalability of crop advisor / agronomist services. While there is an emergence of local governmental and extension services available to small holders, the lack of interoperability in the industry limits the geographical area a crop advisor can service, and therefore increases the program costs and/or the price of the services beyond the affordability to the smallholder.

DIGITAL DISRUPTION

Digital approaches are needed for accelerated and sustainable agricultural transformation that addresses these internal and external factors. At scale, digital disruption is driven by the collection, use, and analysis of massive amounts of **agricultural data** that can be digested and interpreted by advanced systems. Accessing data-driven digital transformation for smallholder farmers requires advancements in three areas:

1) last-mile infrastructure,
2) open standards, and
3) contextually relevant **software services**

Antoinette, Marie. 2022. Addressing the Digital Divide for Smallholder Farmers. ALI Social Impact Review (harvard.edu).

5.2 Opportunities

Smart farming can, through higher efficiency and transparency in the supply chain, improve access to small quantities of crop inputs and provide access to risk management instruments.

Digital solutions at scale can help smallholder farmers achieve greater participation across the Agri-food value chain, from greater access to capital to improved field operations to market access. Standardized data can help provide:

- Greater access to more cost-effective crop inputs (e.g., crop varieties) tailored to a smallholder’s environment and field conditions
- Safer field operations due to better access to product safety data
- Improved soil testing and faster test results
- Better identification of plant stresses, nutritional deficiencies, etc.

- Decision support tools and highly contextualized expert help which are unavailable at scale to smallholders today.
- Understandable contract language, including icons, increasing transparency in business transactions.

Moreover, the impact of higher efficiency and transparency can go beyond the farm, and trickle over to non-farmer consumers. Likewise, access to standardized product data can help local suppliers and agents provide better products and services to their smallholder customers.

6. Background, structure and function of the SAG

6.1 SAG structure

The ISO Strategic Advisory Group on Smart Farming (SAG SF) was approved by the TMB in June 2021 with its mandate and membership defined by TMB Resolution 60/2021.

The SAG SF Secretariat launched 4 calls for nomination in July 2021.

For the SAG-SF core group:

- Call for experts nominated by TMB members
- Call for experts nominated by non-TMB members
- Call for experts nominated by SMB and IEC members

For the SAG-SF consultative group:

- Call for experts opened to all ISO committees listed in TMB resolution 60/2021, in addition to ISO/CASCO, ISO/COPOLCO and interested IEC committees

The calls for experts highlighted the opportunity to include additional experts for domain specific subgroups working on the scope items identified by the SAG SF activities and strived to ensure a balanced geographical representation to promote the participation of developing countries in this important area.

It was composed of over 140 experts from twenty-one national standards bodies, organized into a Core Group comprised of ISO member country representatives, a Consultative Group of representatives from ISO committees, and nine domain-specific subgroups with experts designated by national standard body and ISO committee representatives (see Figure 12).

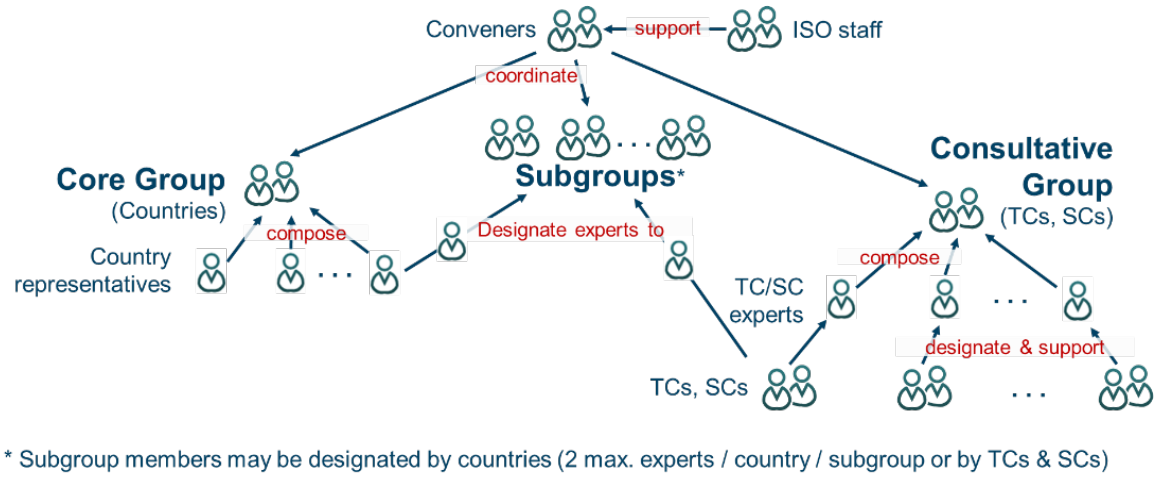

Figure 12: SAG-SF Structure.

- There are 21 representatives from ISO member countries in the Core Group (one each from ABNT, AFNOR, ANSI, BIS, BSI, DIN, GOST-R, INSO, IRAM, JISC, KATS, NEN, NZSO, RSB, SA, SAC, SASO, SCC, SNV, SSC, UNI) and one representative of the IEC SMB, for a total of 22 members. See Annex B for the Core Group composition. The Core Group met 15 times over the term of its mandate. It benefitted from the input of its Consultative Group, which met 11 times over the same period.
- The SAG SF had a liaison with CGIAR the Consultative Group for International Agricultural Research
- A collaboration with ITU-T Focus Group on "Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture" (FG-AI4A)
- The Consultative Group had representatives from 35 ISO committees (TCs and SCs, see Annex B). The Consultative Group provided valuable input as to how work from ISO TCs and SCs might support smart farming, the availability of standards to support specific business capabilities, and known difficulties and “hotspots” in their domain. See Annex B for the Consultative Group composition
- The nine Subgroups, which were composed of members of the core group and the consultative group, recruited via a call for experts, worked on specific aspects related to Smart Farming. All Subgroups were reporting to the SAG SF core group at each meeting, through their ‘Chairs and co-Chairs’, appointed on a voluntary basis by the SG members. See Annex B for the Subgroups’ composition.
- The domains addressed by the subgroups were (listed by subgroup number, and shown in Figure 13):
  1. Crop Production
  2. Livestock

3. Urban Farming
4. Climate and Environment
5. Original Equipment Manufacturers (OEM)
6. Terminology and Semantics
7. Social Aspects
8. Data
9. Supply Chain

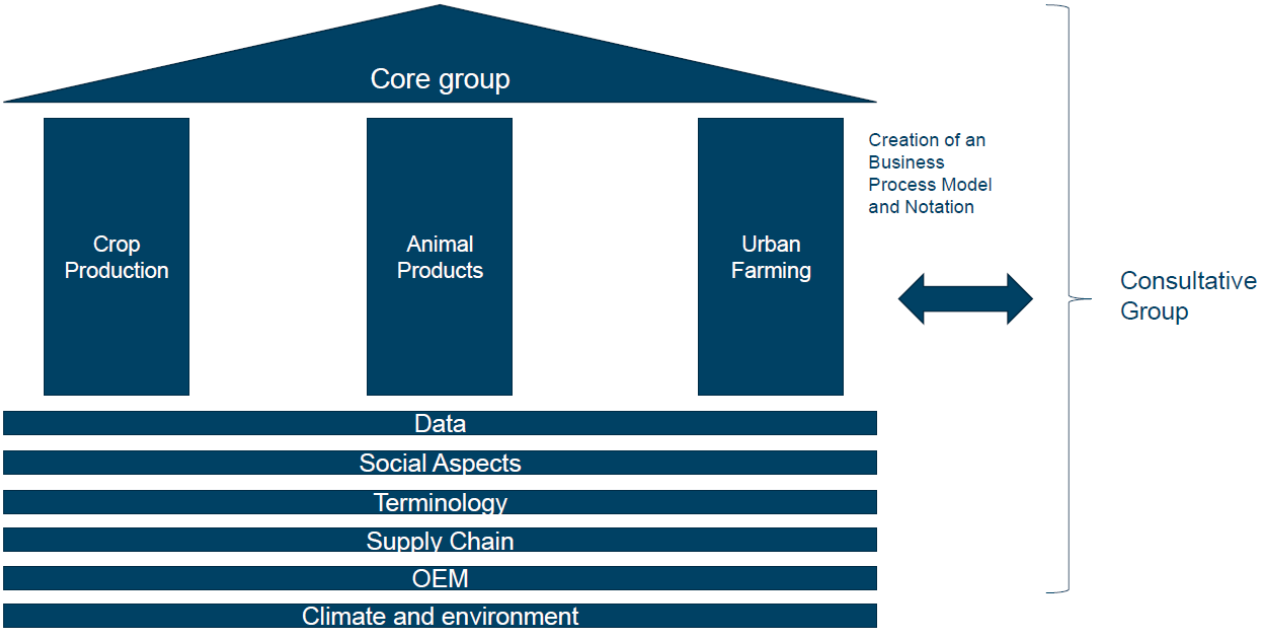

Figure 13: Visualization of the structure of the SAG, showing the two different kinds ("vertical" and "horizontal") of subgroups within the SAG,

6.2 The role of standards

Standards are "recipes for reality". When they are shared across an industry they typically pave the way for scalability in technology adoption. However, and despite decades of good standardization work in multiple agrifood technologies, the ***data*** standardization landscape is still fragmented and incomplete.

The SAG focused on tackling the challenge of data interoperability so that smart farming practices and solutions can be brought to scale across agrifood systems.

In this context, the International Organization for Standardization (ISO) chartered a Strategic Advisory Group for Smart Farming (SAG). This group of over 140 experts from 21 countries worked over eighteen months to

1. document the landscape of standards pertaining to smart farming
2. document the gaps in that landscape and assess their impact on ISO's ability to make (and measure) progress toward the UN Sustainable Devel-op-ment Goals (SDGs); and
3. make prioritized recommendations for action.

6.3 Multiple methodological perspectives

Three different perspectives enabled the SAG to structure and view their work through different points of view and activities.

6.3.1 The Scope Item Perspective

Since the definitions of smart farming vary widely and available time was limited, the ISO SAG on Smart Farming decided to take a bottom-up approach in the form of a survey of what should be in scope. To this end, the experts in the Core and Consultative groups provided over 300 topics, or "scope items" (See Annex E.1), that represented ideas they considered to be in scope of smart farming, as well as topics that they excluded. The scope items ranged in complexity and granularity, from "Fertilizer" to "Greenhouse gas emissions (CO_2) / unit of production" to "Methods and models for using ontologies to facilitate interoperability," but generally aligned to one or more processes / sub-processes (as per the ISO 22006 Annex A/B nomenclature). The scope item perspective seeks to identify underlying processes implicit within a scope item provided and serves as an enabler for the Process perspective as well as a basis for the derived subgroup topics (see Figure 14).

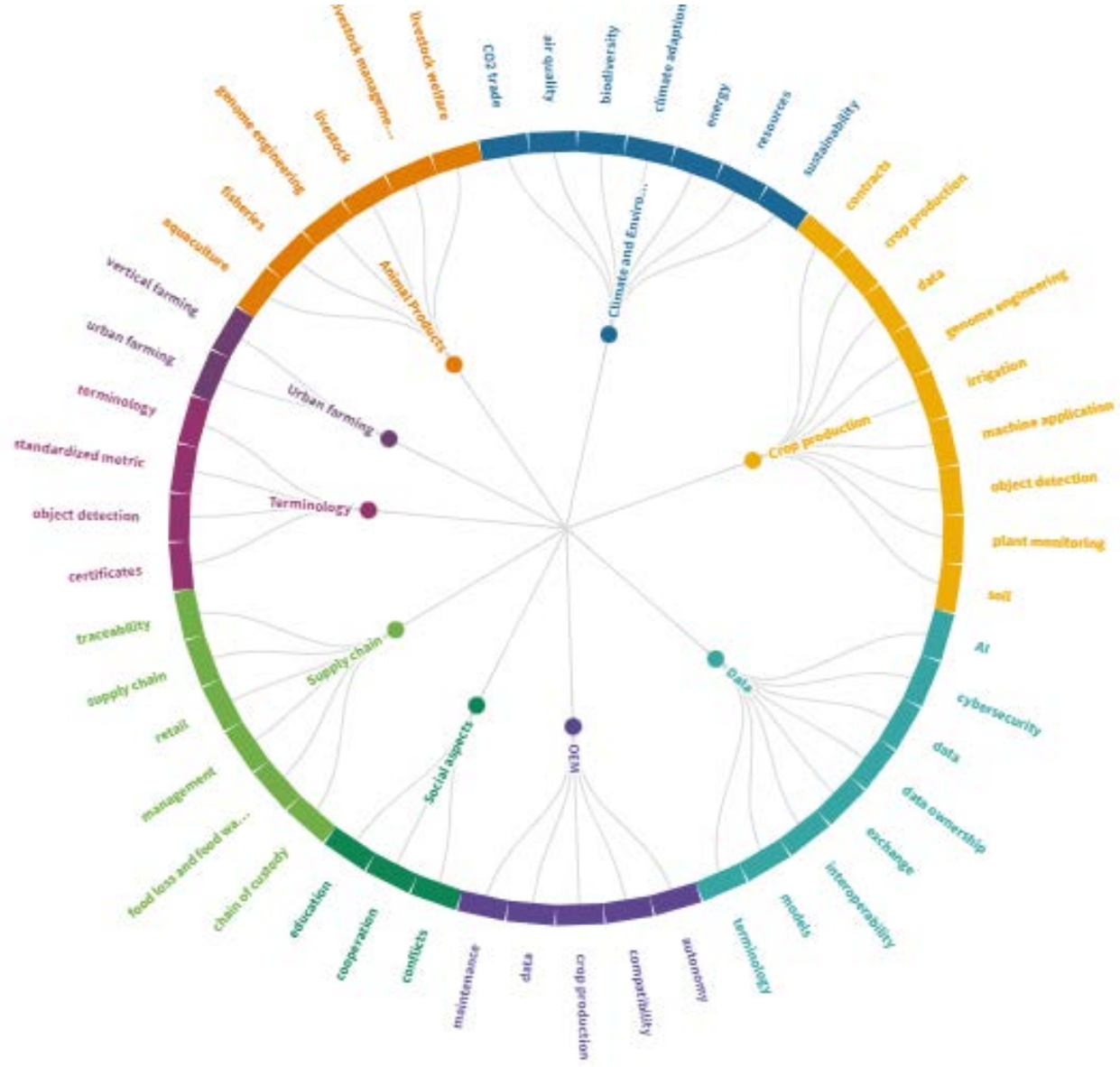

Figure 14: Categories and sub-categories of the scope items elicited from experts to determine scope of the SAG.

6.3.2 The Process Perspective

Experts in the SAG's subgroups reviewed the ISO 22006 reference lists of processes and sub-processes (Annex A in that standard) and to propose modifications to those lists as needed to more accurately describe the reality of the domain they were working in. While the SAG's ultimate aspiration was to have a single list of processes, this may prove of diminishing returns, e.g., attempting to force the processes and subprocesses at work in crop farming and those from livestock production into a single framework. Along with the revision of those processes, the experts were asked to write stories (in narrative form), and to annotate those stories in a way that can answer fundamental *who*, *what*, *when*, *where*, *how* and *why* questions. This work was done using a tool called the Trisotech Discovery Accelerator (Figure 15), which shows the annotations very explicitly.

One of the annotation types in Discovery Accelerator is the *artifact*, which corresponds to the *what* questions, and is used to represent physical objects and data artifacts. One of the objectives pursued by providing experts with the Discovery Accelerator was to motivate discussion and enable the groups to quickly identify and reflect upon the actors (the *who*) involved in the processes, the activities (*how*) they perform, the events that trigger those activities (*when*), the actors' goals (*why*), the systems the activities take place in (the *where*), and the data payloads (*what*) involved in the processes under consideration.

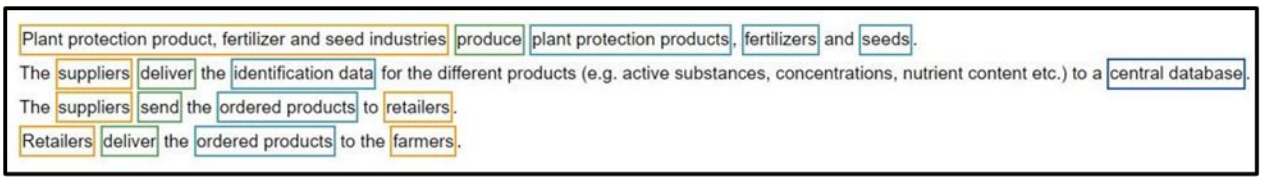

Figure 15: Example of the Discovery Accelerator Text view from the Crop Production Subgroup.

Once this exercise was completed, a subgroup identified a subset of stories that merited representation in the form of a BPMN diagram (Figure 16), where actors, activities, events, systems and artifacts are explicitly and unambiguously shown. At this point, where data exchanges are laid out explicitly, it is possible to shift to the standards perspective.

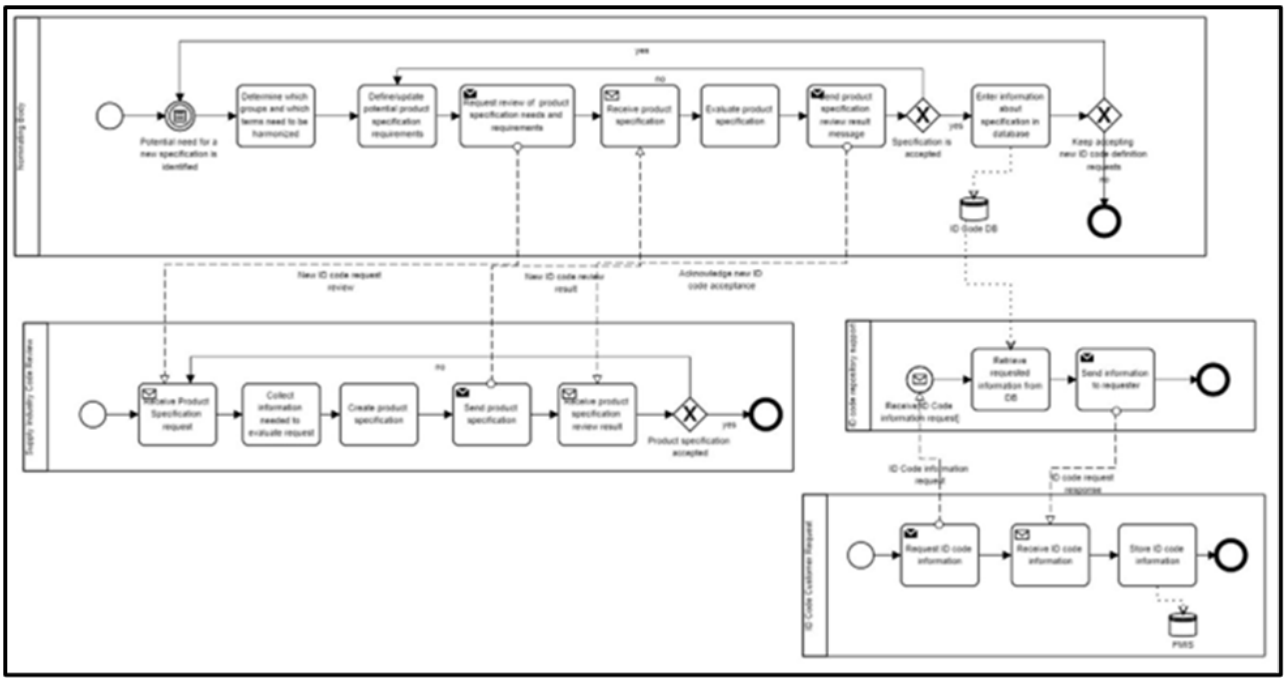

Figure 16: Example of a BPMN created by the Crop Production Subgroup

6.3.3 The Standards Perspective

This perspective identified standards which might be relevant to a particular context. These candidate standards were gap-checked against the criteria used to determine relevance to Smart Farming. This perspective was key, as it is the one that all others ultimately lead to.
The Core Group developed hypotheses for determining if a standard is smart-farming-ready:

i. The smart-farming-readiness of a standard can be assessed using a simple set of questions.
ii. Standards can be grouped in families, such that the questions needed to establish smart-farming-readiness are the same for all standards in a family.
iii. Placing a standard within an existing family can be done using a simple set of questions.
iv. Families of standards can be identified by classifying on some set of attributes of the standards contained therein.

7 Key findings from the SAG subgroups

The following clauses briefly describe the scope of, and key insights emerging from, the nine subgroups that the domain of the SAG-SF was organized into. Clause 1.2 describes the constructionist approach used to define that domain (instead of *a priori*, top-down definitions which would have, in the judgement of the conveners, consumed too much time). The categorization process is also further described in clause 6.3.1.

7.1 SG1: Crop Production

Scope:

The subgroup identified the standards/definitions required for:

- data categories (reference data, setup/master data, configuration data and field operation data)
- crop types
- soil types
- crop field identification and crop field boundaries
- multi- and hyperspectral imaging
- data structure (class model) for the exchange of crop related operations that were carried out in the field.
- connection to process computers for climate control for storing batches of produce

Insights:

- There are no smart-farming specific standards or definitions existing for reference data, setup/master data, configuration data and field operation data etc. Such definitions and standardisation are required internationally for:
    - data categories (reference data, setup/master data, configuration data and field operation data)
    - crop types
    - soil types
    - crop field identification and crop field boundaries
    - multi and hyperspectral imaging
    - data structure (class model) for the exchange of crop related operations that were carried out in the field.
    - connection to process computers for climate control for storing batches of produce

Items which may be addressed by future ISO efforts:

- consideration of drones in the application of products, as well as other uses in crop production (payload, duration, flight permissions, receive precise maps, applicable to small holders as well as drone and robot information in agriculture)
- continuation of the work that ISO is doing with smart irrigation
- sensors and dosing/fertigation/fertilisation
- water testing/water quality
- integration of environmental data into autonomous control systems
- field sanitation
- data exchange with climate control systems
- trade agreements

Organisations with which ISO should engage to help develop standards in crop production

- AgGateway
- AEF - Agricultural Industry Electronics Foundation CropLife Organisation
- Agro-EDI-Europe
- European Plant Protection Organisation (EPPO)
- Food and Agricultural Organization (FAO)
- Global Reporting Initiative (GRI) – Global Sustainability Standards Board (GSSB)
- GS1
- Kuratorium für Technik und Bauwesen in der Landwirtschaft e.v. (KTBL)

7.2 SG2: Livestock

Scope:

- planning
  - livestock systems
  - inventory
- space or housing allocation
- procurement of inputs
  - automated re-ordering from feeding systems
  - ration formulation and feed mixing
  - analysing livestock feed components
- monitoring environmental factors
- reproduction
- traceability of livestock in motion

Insights:

- data standards are needed for reporting historical livestock events such as drug treatments, diseases, and genetic indicators.
    - date and time of movement (loading, herding) and/or
    - date and time of unloading, herding
    - premises of departure
    - premises of destination
    - identification number of the animal
    - conveyance identification number
- data for tracing/reporting the movement of animals identified as a group uses the following data scheme:
    - date of movement (loading)
    - premises of departure
    - premises of destination
    - number/quantity of animals sent and received
    - species/production type
    - conveyance identification number
    - daily batch number

7.3 SG3: Urban Farming

Scope:

- production and product processing for the most common/commercialized types of urban/vertical farming types:
    - hydroponics
    - aeroponics
    - greenhouse
    - precision fermentation
    - aquaponics
- production steps
- data collection, processing, and security
- processing and environmental controls
- energy use and efficiency
- supply chain: storage

Insights:

- Urban farming has the ability to bring fresh and readily available food to underserved urban communities. This also extends to urban and vertical farming's ability to serve

remote communities that have limited access to fresh food, due to environmental conditions or geographical location.

- Urban farming processes are extremely complex and require a data-driven system.
- There are different levels of maturity in the industry regarding automation, interoperability, etc.
- There are many core linkages and commonalities between the various types of Urban Farming, especially on the most common types, such as those listed above.
- These linkages may also extend to traditional farming, (e.g., sterilization of the soil being analogous to tray sterilization).
- From an automation perspective, urban farming systems, ranging from sunlight / soil - based, to fully artificially lit, have similar data collection and process control requirements, and interoperability challenges. Standardizing the Observation.

Insights in relation to urban farming and smart farming:

- While there are a wide range of urban farming types, higher volume mechanized/automated product (i.e.: hydroponics) have unique aspects and requirements compared with terrestrial or rooftop farming, which are more closely related to traditional broad acre farming.

7.4 SG4: Climate and Environment

Scope:

- inputs / resources, e.g. water, nutrients, energy
- quality / health, e.g. impacts on soil, water, air, biodiversity
- resilience / adaptation / sustainability
- production efficiencies, e.g. grams of protein or CO2e per kilogram of product

This group recognized the overarching or horizontal context of the scope and focused on identifying “hot spots” that overlay the wide range of specific topics identified by the Crop Production, Animal Products and Urban Farming subgroups.

Insights:

Optimizing agricultural systems in unique environmental contexts requires standardization of inputs, processes and outputs to make efficient use of resources while minimizing adverse impacts beyond managed system boundaries. For example, inefficient management of nitrogen inputs results in the release of potent greenhouse gas emissions of nitrous oxides, as well as damage to freshwater systems by eutrophication. Impacts will have varying degrees of severity that will be influenced by the type of hotspot driver, as well as the

vulnerability of the broader environmental context, e.g., whether a constraining threshold is exceeded to trigger a non-linear response.

The ISO/TC 207 (Environmental Management) have developed 64 published standards and are developing 14 new standards to address environmental and climate impacts aspects of UN SDG 13. However, their application to agricultural production systems has been limited. In addition, data needed to characterize agricultural production systems in regional contexts is very limited, very diverse, and in some cases, only available behind paywalls. Standards with direct applicability to smart farming / data-driven agrifood initiatives can be found within subcommittees: Environmental Management Systems (SC 1), Life Cycle Assessment (SC 5), Greenhouse Gas and Climate Change Management and Related Activities (SC 7), including Carbon Footprints, Water Footprints, Adaptation to Climate Change, Land Degradation and Desertification, Circular Economy Coordination and Carbon Neutrality.

7.5 SG5: Original Equipment Manufacturers (OEM)

Scope:

- production equipment and sustainable agriculture
- autonomy and interoperability
  - autonomous vehicles
  - drones
  - robotics data
  - co-registration of different sources of position data
  - interoperability and data management
- smart spraying of crop protection products
- machine-to-machine data transfer
- machine-to-cloud data transfer
- equipment compatibility
- sensors, IoT, and AI

Insights:

- The development and application of intelligent agricultural equipment and unmanned agricultural machinery are developing rapidly around the world. The software, hardware, and data interfaces and formats used by various R&D and production institutions vary widely. The development of intelligent sensors, control systems, data, and network, cloud platform and other international standards.

- ISO standards should consider the agricultural development of less developed countries, and relevant standards for low-cost smart equipment should be formulated.

7.6 SG6: Terminology and Semantics

Scope:

- standardized terminology
- vocabulary and syntax
- ontology
- semantics
- sustainability metrics
- (FAIR) data principles (findable, accessible, interoperable, and reusable)
- CARE data principles (collective benefit, authority to control, responsibility, ethics)
- units of measure
- certificates

While other subgroups were writing stories about the activities and processes of their stakeholders, this subgroup extracted, developed, and recorded the terminology related to smart agriculture based on the relevant scientific sources and recorded them in the appropriate software. The subgroup assembled over 200 terms in the Trisotech knowledge entity accelerator.

Insights:

- smart farming is dependent upon the ability to provide consistent syntactic and semantic interoperability
- controlled vocabularies are key to allowing for geopolitical context without overburdening a semantic infrastructure

7.7 SG7: Social Aspects

Scope:

- conflicts
- health and safety
- contracts
- education
- training
- access to data
    - market

    - economic
    - agronomic
    - supply chain
    - legal
    - labour policies, practices, and availability
- data ownership and privacy

Insights:

- ISO Agrifood standards should be written with low-income country smallholder farmers and agribusiness entrepreneurs in mind. Application of Agri-technology in the developing world is essential to achieving the SDGs, but standards are often written for better educated and well capitalized farmers and agribusinesses in industrialized countries.
- Agrifood standards should take into account the health, safety and quality of life concerns of non-farm rural residents and those who come to the countryside for recreation.
- Agrifood standards should explicitly be developed to encourage trust among farmers, agribusinesses and government agencies that could benefit from access to farm data. “Big Data” has the potential to improve food security and environmental performance, but that potential can be achieved only if farmers trust those who aggregate and analyse data. Improved standards for anonymizing data would help; even so, commodity buyers might use supply information to manipulate prices. input suppliers could target those areas where growers are in urgent need of specific inputs and governments could use the data in regulatory enforcement.
- ISO standards should be developed to enable collection, sharing and analysis of farm data for policy development in areas such as: farm labour, agricultural energy use, water use, greenhouse gas emission, field biodiversity, food waste, and land tenure

7.7.1 Food loss / food waste

Insights:

- Due to a lack of data and standardized ways to measure food loss, farm-level losses aren't as visible and have less economic value than consumer food waste. Growers can use data specific to their farm using the same method to determine which of their crops may have the potential for higher utility and possible profit. (Johnson, L.K., Dunning, R.D., Gunter, C. C., Bloom, J. D., Boyette, M.D.,

Creamer N.D. (2018) Field measurement in vegetable crops indicates need for reevaluation of on farm food loss estimates in North America. *Agricultural Systems*,167, 136-142).

- Interoperable, shared data is required to meet the preferred paths of preventing food loss. As shown in Figure 17 below.

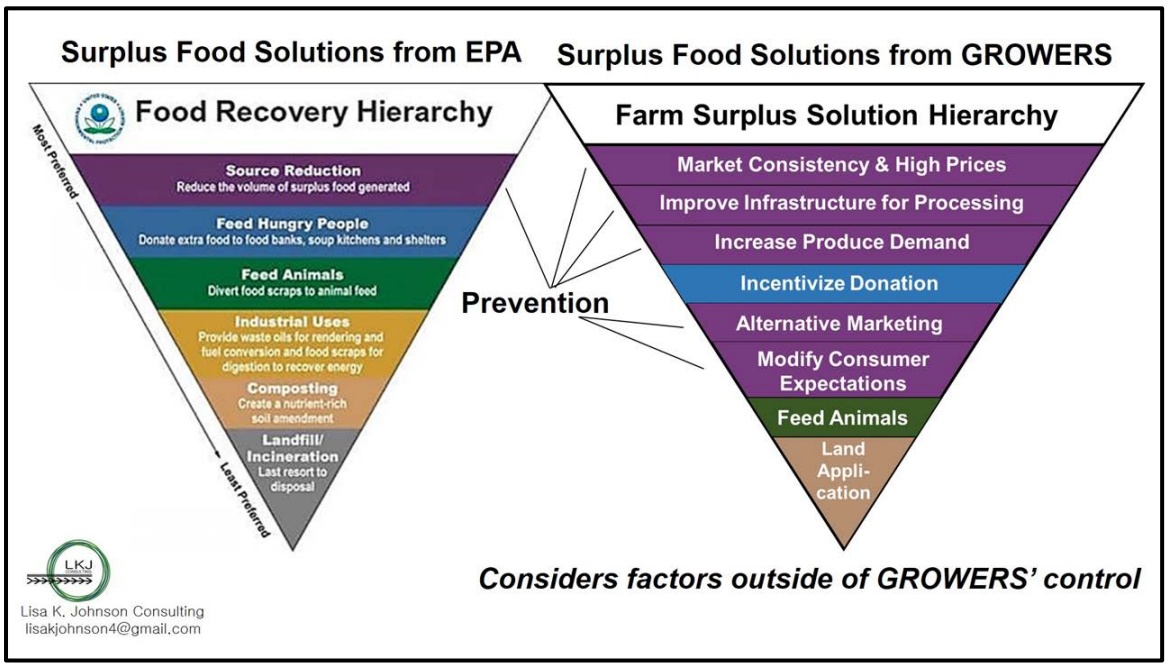

Figure 17: Factors impacting food loss

7.8 SG8: Data

Scope:

- The main task of Subgroup 8 (Data) was to make recommendations on data standardization, activities and priorities in the scope of smart farming, actively working on the United Nations Sustainable Development Goals (SDGs), while taking into account the interests of small landowners.
- Subgroup 8 developed a work plan based on a Business Process Modeling and Notation (BPMN) diagram used to create a process model and putting forward the ISO reference framework of "physical layer - base layer - service layer- analysis layer - application layer" for smart farming.
- Subgroup 8 built a capability model (merged into the model of Clause 4.3) and used it to analyze metadata and process views of smart farming.
- The group focuses on data exchange involved in agricultural production, combing and analyzing the current situation and gaps in existing standards.

- Subgroup 8 successfully held 20 group meetings and used Trisotech Discovery Accelerator to write and analyze 86 stories that were created by other ISO working groups (based on ISO 22006); 216 metadata notes and 124 notes on data-related process were preliminarily confirmed, and 173 potential standard gaps were found.

Insights:

Data is the core of smart farming; however, currently, agricultural production needs a complete standard system of data coding, data security and data sharing.

- The lack of a standardized, globally accepted and used data model for agriculture is a major gap. Recommend more focus on this and identification of motives that help to develop and maintain the model.
- Standard(s) for reference data are a key gap.
- Standard system is needed on data coding, data security and data sharing.
- Basic data standards are needed
- Data standards among agriculture, processing industry and commercial are needed.
    - Emphasize on enterprises
    - Emphasize on standardization organization and industry associations.
    - Emphasize on the Media

7.9 SG9: Supply Chain

Domain

A supply chain is a network of facilities that procure raw materials, transform them into intermediate goods and then final products to customers through a distribution system. It includes storage and brokerage. It refers to the network of organizations, people, activities, information, and resources involved in delivering a product or service to a consumer. Supply chain activities involve the transformation of natural resources, raw materials, and components into a finished product and delivering the same to the end customer [adapted from https://en.wikipedia.org/wiki/Supply_chain].

Scope:

- food production
- food transfer and distribution
- agriculture
    - horticulture
    - fiber production (e.g., cotton)

- biofuel production (e.g., ethanol)
- animal products (e.g., fish, pork, beef, honey, dairy)

Insights:

- traditional agricultural supply chains are well-understood supply
- many of the processes and principles of supply chain for smart farming are the same as for any other industry
- the complexities of the smart farming supply chains are on par with those of other industries
- recent examples of supply chain disruptions indicate the need for supply chains with increasing flexibility

8 References

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Annex A: ISO/TMB Resolution 60/2021

TECHNICAL MANAGEMENT BOARD RESOLUTION 60/2021

Creation of an ISO Strategic Advisory Group on Smart Farming (SAG SF)

Adopted at the 81st meeting of the Technical Management Board, Virtual Meeting, 16-17 and 23 June 2021

The Technical Management Board,

Noting the proposal from DIN and ANSI and the draft Terms of Reference as presented in the TMB document for Agenda item 4.2 of the June 2021 TMB meeting;

Agreeing that the scope of "smart farming" covers innovative technical aspects of agriculture and aquaculture as well as the sustainability and improved efficiency of food production and its value chain;

Decides to create a new ISO Strategic Advisory Group (SAG) on *Smart farming* with a 12-month mandate as follows:

Mandate

- Define a set of parameters for the classification of "Smart Farming" for the purposes of the SAG
- Build a matrix between the Sustainable Development Goals (SDGs) and the definition of Smart farming in order to establish an overview of current and potential future challenges in relation to the Sustainable Development Goals (SDGs)
- Recommend actions to address these challenges
- List standards and other documents relevant to Smart Farming that are, or have been, developed by existing ISO Technical Committees
- Analyze any synergies in the current work of existing ISO technical committees relevant to Smart Farming, and consider opportunities to coordinate or collaborate across ISO committees where overlaps exist
- Set up a gap analysis in order to identify areas important for standardization in the field of Smart Farming not currently addressed by an existing ISO committee
- Recommend standardization activities
- Set up recommendations for the structuring of these standardization activities, which includes consideration of existing ISO committees, new technical committees, and ongoing coordination mechanisms
- Establish a priority list of any new work to be undertaken in the short term that should be progressed as an immediate priority

Main output

- The SAG on SF is expected to deliver its summarised findings in the form of a Roadmap on Smart farming.

Leadership

- Co-Convenors: DIN and ANSI
- Secretariat: ISO/CS
- Members:
  - *Experts nominated by TMB members.*
  - *Experts nominated by non-TMB ISO members (selected via an Expression of Interest process to TMB).*
  - *Experts nominated by SMB and IEC members.*
  - *Supported by a consultative group composed of experts from relevant ISO/TCs involved in the general realm of Smart Farming (maximum 1 representative per TC).*
    - ISO/TC 23 Tractors and machinery for agriculture and forestry (and especially its subcommittee 19)
    - ISO/TC 34 Food products
    - ISO/TC 126 Tobacco and tobacco products
    - ISO/TC 134 Fertilizers, soil conditioners and beneficial substances
    - ISO/TC 146/SC 5 Meteorology
    - ISO/TC 147 Water quality
    - ISO/TC 154 Processes, data elements and documents in commerce, industry and administration
    - ISO/TC 172 Optics and photonics
    - ISO/TC 184 Automation systems and integration
    - ISO/TC 190 Soil quality
    - ISO/TC 207 Environmental management
    - ISO/TC 211 Geographic information/Geomatics
    - ISO/TC 282 Water reuse
    - ISO/TC 299 Robotics
    - ISO/TC 323 Circular economy
    - ISO/TC 326 Machinery intended for use with foodstuffs
    - ISO/TC 331 Biodiversity
    - ISO/TC 234 Fisheries and aquaculture
    - ISO/IEC JTC 1/SC 41 Internet of Things
    - ISO/TC 308 Chain of custody

- ISO/TC 307 Blockchain
- ISO/TC 20/SC16 Unmanned aircraft systems (drones)
- ISO/TC 23/SC 6 Equipment for crop protection
- ISO/TC 23/SC 7 Equipment for harvesting and conservation
- ISO/TC 23/SC 18 Irrigation and drainage equipment and systems
- ISO/TC 23/SC 19 Agricultural electronics
- ISO/TC 34/SC 17 Management systems for food safety
- ISO/TC 34/SC 18 Cocoa
- ISO/TC 93 Starch
- ISO/TC 268 Smart Cities
- ISO/TC 281 Fine bubble technologies
- ISO/TC 282/SC 1 Treated wastewater reuse for irrigation
- ISO/TC 282/SC 3 Risk and performance evaluation of water reuse systems
- ISO/TC 293 Feed machinery
- ISO/TC 315 Cold chain logistics
- ISO/TC 204 Intelligent transport systems

Asks the SAG to confirm its membership to TMB by September 2021.

Asks the SAG to report for each TMB meeting and deliver the final report, with a roadmap, for September 2022.

Annex B: SAG SF membership

SAG SF Core Group

Name	Surname	Appointed by	Country	Role
Rafael Andres	Ferreyra	ANSI	US	SAG SF Convenor
Johannes	Lehmann	DIN	DE	SAG SF Convenor
Steven P.	Cornish	ANSI	US	SAG SF Convenor Support
Dan	Berne	ANSI	US	Convenor Support
Frank	Riddick	ANSI	US	Convenor Support
Monica	Ibido	ISO/CS	CH	SAG SF Secretary
Blandine	Garcia	ISO/CS	CH	SAG SF Secretary Support
Sibelle de Andrade	Silva	ABNT	BR	Member
Aurélie	Thiébaud	AFNOR	FR	Member
Jim	Wilson	ANSI	US	Member
Mukesh	Jain	BIS	IN	Member
James	Lowenberg-deBoer	BSI	GB	Member
Wilfried	Aulbur	DIN	DE	Member
Elena	Kostyleva	GOST R	RU	Member
Farahnaz	Ghollasi Moud	INSO	IR	Member
Federico	Elorza	IRAM	AR	Member
Chie	Shindo	JISC	JP	Member
KyoungSook	Jung	KATS	KR	Member
Hein	Goeyens	NEN	NL	Member
Kenneth	Irons	NZSO	NZ	Member
Sylvestre	Habimana	RSB	RW	Member
Angela	Schuster	SA	AU	Member
Heng	Qian	SAC	CN	Member
Suliman	Al-Khateeb	SASO	SA	Member
Paul	Laronde	SCC	CA	Member
Thomas	Anken	SNV	CH	Member
Melin	Lim	SSC	SG	Member
Alessio	Bolognesi	UNI	IT	Member
Robert	Sherwin	IEC SMB	US	Member

SAG SF Consultative Group

Name	Surname	Role / Representative
Rafael Andres	Ferreyra	SAG SF Convenor
Johannes	Lehmann	SAG SF Convenor
Steven P.	Cornish	SAG SF Convenor Support
Dan	Berne	Convenor Support
Frank	Riddick	Convenor Support
Monica	Ibido	SAG SF Secretary
Blandine	Garcia	SAG SF Secretary Support
Hermann	Buitkamp	ISO/TC 23 Tractors and machinery for agriculture and forestry
Emilio	Gil Moya	ISO/TC 23/SC 6 Equipment for crop protection
Enrico	Giuliani	ISO/TC 23/SC 7 Equipment for harvesting and conservation
Yoram	Engel	ISO/TC 23/SC 18 Irrigation and drainage equipment and systems
Paul	Muller	ISO/TC 23/SC 19 Agricultural electronics
Sandrine	Espeillac	ISO/TC 34 Food products
Servet	Atayeter	ISO/TC 34/SC 3 Fruits and vegetables and their derived products
Yan	Zhang	ISO/TC34/SC 4 Cereals and pulses
Marcel	De Vreeze	ISO/TC 34/SC 5 Milk and milk products
Chunbao	Li	ISO/TC 34/SC 6 Meat, poultry, fish, eggs and their products
S. N	Saxena	ISO/TC 34/SC 7 Spices, culinary herbs and condiments
Sally	Gibbs	ISO/TC 34/SC 8 Tea
Ray	Shillito	ISO/TC34/SC 16 Horizontal methods for molecular biomarker analysis
Hiroyuki	Morita	ISO/TC 34/SC 17 Management systems for food safety
Jack H.M	Steijn	ISO/TC 34/SC 18 Cocoa
Xuan	Li	ISO/TC 34/SC19 Bee products
Xiang	Wang	ISO/TC 154 Processes, data elements and documents in commerce, industry and administration

Klaus	Liphard	ISO/TC 190 Soil Quality
Patrick	Lamboley	ISO/TC 184 Automation systems and integration
Sheilah	Nolan	ISO/TC 207 Environmental management
Liping	Di	ISO/TC 211 Geographic information/Geomatics
Naty	Barak	ISO/TC 282 Water reuse
Osman	Tokhi	ISO/TC 299 Robotics
Aleksey	Zaytsev	ISO/TC 323 Circular economy
Carol	Jones	ISO/TC 326 Machinery intended for use with foodstuffs
Caroline	Lhuillery	ISO/TC 331 Biodiversity
François	Coallier	ISO/IEC JTC 1/SC 41 Internet of Things and digital twin
Raylee	Dunkley	ISO/TC 93 Starch (including derivatives and by-products)
Bernard	Gindroz	ISO/TC 268 Sustainable cities and communities
Peter	Thorns	ISO/TC 274 Light and lighting
Akira	Yabe	ISO/TC 281 Fine Bubble technologies
Hiroki	Nakamura	ISO/TC 282/SC 3 Risk and performance evaluation of water reuse systems
Toshinori	Nemoto	ISO/TC 315 Cold chain logistics
Anna	Koroleva	ISO/CASCO
Dana	Kissinger-Matray	ISO/COPOLCO

SAG-SF subgroups

Role	SG1 Crop production	SG2 Livestock	SG3 Urban Farming	SG4 Climate and environment	SG5 OEM	SG6 Terminology and semantics	SG7 Social aspects	SG8 Data	SG9 Supply chain
Chair	**Mrs Angela Schuster (Core-SA-AU) co chairing with Dr. Akira YABE (Consult.G-TC 281)**	**Mr Andrew COOKE (NZSO-NZ)**	**Mr Greg Man-sing JAEGER CHONG (DIN-DE) // Dr. Paul MULLER (Consult.G-TC 23/SC 19) // Ms Melin LIM (Core-SSC-SG)**	**Mr Robert SHERWIN (Core-IEC SMB) // Mr Arend KOEKKOEK (NEN-NL) // Mr Tamme VAN DER WAL (NEN-NL)**	**Prof. Yanwei YUAN (SAC-CN)/ Todd Howatt (ANSI-US)**	**Dr. Xingjun XI (SAC-CN)**	**Ms Mary KOMBOLIAS (ANSI-US)**	**Mr Kenneth IRONS (Core-NZSO-NZ) / Prof. Ruoyu ZHANG (SAC-CN)**	**Mr Jim WILSON (Core-ANSI-US)**
Secretary	Mr Thomas ASCROFT (SA-AU)	Prof. Xuan LI (Consult.G-TC34/SC19)	Prof. Xuan LI (Consult.G-TC34/SC19)	Ms Mary Kombolias (ANSI-US)	Prof. Jiangtao Qi (SAC-CN) / Mr Jacob VAN BERGEIJK (TC23/SC19)	Mr Michael SUSSMAN (ANSI-US)	Prof. James LOWENBERG-DEBOER (Core-BSI-GB)	Mr Jacob VAN BERGEIJK (ANSI-US)	Vacant
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Member	Ms Sally GIBBS (Consult.G-TC34/SC8)	Mrs Farahnaz GHOLLASI MOUD (Core-INSO-IR)	Dr. Raymond (Ray) SHILLITO (Consult.G-TC 34/SC 16)	Dr. Kyoungsook JUNG (Core-KATS-KR)	Prof. James LOWENBERG-DEBOER (Core-BSI-GB)	Mr Stuart RHEA (ANSI-US)	Prof. Junning ZHANG (SAC-CN)	Dr. Kyoungsook JUNG (Core-KATS-KR)	Mr Heng QIAN (Core-SAC-CN)
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Member	Ms Melin LIM (Core-SSC-SG)	Mr Peter THORNS (Consult.G-TC 274)	Mr Ted SANTIESTEBAN (ANSI-US)	Mrs Sheilah NOLAN (Consult.G-TC 207)	Mr. Sarbjeet Singh PANESAR (BIS-IN)	Mr Hiroyuki MORITA (JISC-JP)	Mr Hiroyuki MORITA (JISC-JP)	Mr Heng QIAN (Core-SAC-CN)	Mr Paul CORDES (ANSI-US)

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Member	Mr Emilio GIL MOYA (Consult.G - TC23/SC6)	Ms Elizabeth BRADLEY (SA-AU)						Ms Gabriela CEREGRA (SA-AU)	
Member	Mr Heinz BERNHARDT (DIN-DE)	Mr Michael SUSSMAN (ANSI-US)						Ms Kim LANE (SA-AU)	
Member	Ms Holly MAYTON (ANSI-US)							Mr Brian KING (CGIAR)	
Member	Mrs Clémence GAUCHER (AFNOR-FR)								
Member	Mr Peter HLOBEN (Consult.G-TC23/SC6)								
Member	Ms Thaís BASSO AMARAL (ABNT-BR)								

Member	Mr Alaercio LONDE DA SILVA (ABNT-BR)								
Member	Dr. Narendra Singh CHANDEL (BIS-IN)								
Member	Dr. Surendra SINGH (BIS-IN)								
Member	Mr. Michael THEIN (DIN-DE)								

NOTE:

CORE: Core Group with the name of the NSB & Country code

CONSULT.G: Consultative Group with the TC number

Others: National expert with the name of its NSB & Country code

CGIAR - Consultative Group for International Agricultural Research

Annex C: Alignment of smart farming capabilities and SDG targets

C.1 High-Level capabilities / containers

These capabilities correspond to the second-level capability containers shown in Clause 4.3. Clause C.2 and Annex D use capabilities at this level of organization to map to the SDG targets and to existing standards.

- C01: Strategic
- C02: Semantic interoperability
- C03: Product reference data management
- C03: Non-product reference data management
- C04: Service infrastructure
- C05: Farm management
- C06: Decision support
- C07: Livestock activities data management
- C08: Sales & marketing
- C09: Field operations data management
- C10: Observations data management
- C11: Supply chain data management
- C12: Food loss/waste management
- C13: Enable seed product use
- C14: Enable crop protection product use
- C15: Enable data security and privacy
- C16: Enable digital agronomy
- C17: Asset health management
- C18: Value chain enablement

C.2 SDG targets and capabilities

The ISO/TMB mandate to the SAG-SF (See Annex A) refers to the UN Sustainable Development Goals, or SDGs. These 17 goals, shown in Figure 18 below, emerged from the 2030 Agenda for Sustainable Development adopted by the UN Member States in 2015, and serves as a valuable blueprint and framework for discussing global sustainable development.

Figure 18: The 17 UN Sustainable Development Goals (SDGs)

The SDGs are part of a tiered system, where each of the 17 goals has one or more targets (see "SDG target" entry in the Glossary for more detail) that may describe either

- desired outcomes (denoted as x.y, where x is the number of the goal and y is a number (e.g., "1.2")) or
- means of implementation (denoted as x.z, where x is the number of the goal and z is a letter (e.g., "1.a").

The ISO-SAG was made aware of Guide 82: 2019, Guidelines for addressing sustainability in standards, which led us, seeking to maximize specificity and the usefulness of the corresponding recommendations, to map capabilities and standards to the target level in Annexes C and D rather than to the SDGs themselves. The list of targets, their alignment with the SAG-SF scope, and notes about their relationship with the SAG-SF capabilities and recommendations follows below.

SDG Targets

SDG Target	Description	Alignment with SAG scope	Rationale
1.2	By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	MEDIUM	Many of the capabilities considered by the SAG-SF, and the recommendations resulting from them, target smallholders directly or indirectly.
1.4	By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	HIGH	Many of the capabilities considered by the SAG-SF, and the recommendations resulting from them, target smallholders directly or indirectly. In the case of this particular target, access to new technology, financial services and microfinance (and the data privacy policies and terms and contions that underlie them) are the object of several recommendations in Clause 3.4.
1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	MEDIUM	Many of the capabilities considered by the SAG-SF, and the recommendations resulting from them, target smallholders directly or indirectly. In the case of this particular target, increased access to risk management instruments and enabling decision support capabilities are the object of several recommendations in Clause 3.4.
1.a	Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
1.b	Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication action	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
2.1	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	MEDIUM	Enabling data-driven mechanisms to increase productivity, income, sustainabiliy and compliance at scale for producers both large and small is a core part of the work of the SAG-SF. Increasing access includes out-of-scope policy considerations, but is enabled by capabilities such as improved logistics and supply-chain traceability.

2.2	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	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope). The standards-actionable aspects seemed concentrated in 2.1
2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	**HIGH**	Enabling data-driven mechanisms to increase productivity, income, sustainability and compliance at scale for producers both large and small is a core part of the work of the SAG-SF.
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	**HIGH**	Enabling data-driven mechanisms to increase productivity, income, sustainability and compliance at scale for producers both large and small is a core part of the work of the SAG-SF.
2.5	By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	HIGH	The SAG-SF emphasis on semantic infrastructure, making data findable, accessible, interoperable and reusable (FAIR), and accurate field operations recordkeeping will enable this target.
2.a	Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries	MEDIUM	Semantic infrastructure, a core theme of the SAG-SF, increases the value of these resources and perhaps can translate into increased investment.

2.b	Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
2.c	Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility	MEDIUM	Enabling better traceability and data interoperability throughout the supply chain is an emergent property of the recommendations of the SAG-SF. (See Clause 4.4 for more detail on the concept of emergent property.)
3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of pollutants in the air, water and soil), and by better tracking of the field operations such as application of crop inputs, both core themes of the SAG-SF.
3.d	Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of contaminants, pathogens, etc.), a core theme of the SAG-SF.
4.3	By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
4.4	By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship	MEDIUM	The general recommendations 3.1.3 and 3.1.10 are meant to enable greater understanding by (current and prospective) practitioners of the value and applicability of standards to different parts of the agrifood systems domain. There is also a recommendation (and corresponding capabilities) about enabling better learning from on-farm research and technology adoption.
4.5	By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).

4.b	By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
5.a	Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of pollutants in the water), and by better tracking of the field operations such as application of crop inputs, both core themes of the SAG-SF.
6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of water content, pumped water, water levels, and evapotranspiration model inputs and outputs), and by better tracking of the field operations such as application of irrigation water and crop harvest, all core themes of the SAG-SF.
8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	HIGH	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.

9.3	Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets	MEDIUM	Many of the capabilities considered by the SAG-SF, and the recommendations resulting from them, target smallholders, their advisers and manufacturers and distributers of inputs and tooling, directly or indirectly. In the case of this particular target, access to new technology, financial services and microfinance (and the data privacy policies and terms and contions that underlie them) are the object of several recommendations in Clause 3.4.
9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	MEDIUM	The theme of enabling interoperable observations and measurements, standardizing asset health reporting and enabling process formalization through data product specifications are all aspects of the work of the SAG-SF.
9.5	Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending	MEDIUM	Standardization contributes to the upgrade of technological capabilities. The capabilities associated with data-driven agrifood systems were the focus of the SAG-SF.
9.b	Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, *inter alia*, industrial diversification and value addition to commodities	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
12.1	Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.
12.2	By 2030, achieve the sustainable management and efficient use of natural resources	HIGH	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.

12.3	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	HIGH	The SAG-SF considered food loss and waste an important topic, considered in the capability model and in one of its domain recommendations.
12.4	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, contaminants in the air, soil and water, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.
12.6	Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope). This IS enabled by greater interoperability, however.
13.2	Integrate climate change measures into national policies, strategies and planning	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
13.b	Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities	LOW	Although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, contaminants in the air, soil and water, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.
15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, contaminants in the air, soil and water, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.

15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, contaminants in the air, soil and water, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.
15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	MEDIUM	This target is enabled by interoperability of observations and measurements (in this case, of nutrient levels, water content, crop and livestock conditions, contaminants in the air, soil and water, etc.), and by better tracking of the field operations such as application of irrigation water, crop nutrition and crop protection products, as well as crop harvest, all core themes of the SAG-SF.
15.6	Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed	MEDIUM	The SAG-SF emphasis on semantic infrastructure, making data findable, accessible, interoperable and reusable (FAIR), and accurate field operations recordkeeping will enable this target.
16.6	Develop effective, accountable and transparent institutions at all levels	LOW	Although the topic intersects data-driven agrifood systems, and is enabled by better data findability, accessibility, interoperability, and reusability, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
17.7	Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed	MEDIUM	The general recommendations 3.1.3 and 3.1.10 are meant to enable greater understanding by (current and prospective) practitioners of the value and applicability of standards to different parts of the agrifood systems domain. There is also a recommendation (and corresponding capabilities) about enabling better learning from on-farm research and technology adoption.
17.16	Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries	MEDIUM	This data is enabled by good-quality, timely data. Enabling that agricultural data be findable, accessible, interoperable and reusable (FAIR) is a core theme of the work of the SAG-SF. Refer to General recommendation 3.1.9 and also Recommendation 3.4.1.

17.17	Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships	LOW	Coordination recommendations enable this, but the capability map does not target it. Also, although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).
17.18	By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts	MEDIUM	Enabling that agricultural data be findable, accessible, interoperable and reusable (FAIR) is a core theme of the work of the SAG-SF. Refer to General recommendation 3.1.9 and also Recommendation 3.4.1.
17.19	By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries	LOW	The SAG-SF's internal and external Coordination recommendations enable this, but the capability map does not target it specifically. Also, although the topic intersects data-driven agrifood systems, the strong policymaking component made it less compatible with the SAG-SF scope (SAG-SF experts flagged policy and regulation as NOT in scope).

Annex D: Relevant standards

Note: This is not a complete list, but can be used as starting point for the Joint Smart Farming Landscape Task Force

Standard	Description	SG
BS ISO 14055-1:2017	Environmental management. Guidelines for establishing good practices for combatting land degradation and desertification. Good practices framework	4
BS ISO 2451:2017 - TC	Tracked Changes. Cocoa beans. Specification and quality requirements	9
BS ISO/IEC 15459-4:2014	Information technology. Automatic identification and data capture techniques. Unique identification. Individual products and product packages	8
DIN EN ISO 14001:2015	Environmental management systems - Requirements with guidance for use (ISO 14001:2015);	1
DIN EN ISO 34101-3	Sustainable and traceable cocoa - Part 3: Requirements for traceability (ISO 34101-3:2019); German version EN ISO 34101-3:2019	9
DIN ISO 28000	Security and resilience - Security management systems - Requirements for the supply chain (ISO/DIS 28000:2021); Text in German and English	9
DS/ISO 15394	Packaging - Bar code and two-dimensional symbols for shipping, transport and receiving labels	9
EN ISO 28258-2013	Soil quality. Digital exchange of soil-related data	1
GSO ISO 28258-2015	Digital exchange of soil related data	1
ISO 10218-1:2011	Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots	5
ISO 10377:2013	Consumer product safety - Guidelines for Suppliers	9
ISO 10390:2021	Soil, treated biowaste and sludge – Determination of pH	1
ISO 10998:2008	Agricultural tractors — Requirements for steering	5
ISO 11074:2015	Soil quality — Vocabulary	1
ISO 11263:1994	Soil quality — Determination of phosphorus — Spectrometric determination of phosphorus soluble in sodium hydrogen carbonate solution	1
ISO 11265:1994	Soil quality — Determination of the specific electrical conductivity	1
ISO 11504:2017	Soil quality — Assessment of impact from soil contaminated with petroleum hydrocarbons	1
ISO 11783-1:2017	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 1: General standard for mobile data communication	5
ISO 11783-10:2015	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 10: Task controller and management information system data interchange	1, 5
ISO 11783-11:2011	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 11: Mobile data element dictionary	1, 5
ISO 11783-12:2019	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 12: Diagnostics services	5
ISO 11783-13:2022	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 13: File server	5
ISO 11783-14:2013	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 14: Sequence control	5
ISO 11783-2:2019	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 2: Physical layer	5
ISO 11783-3:2018	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 3: Data link layer	5

ISO 11783-4:2011	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 4: Network layer	5
ISO 11783-5:2019	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 5: Network management	5
ISO 11783-6:2018	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 6: Virtual terminal	5
ISO 11783-7:2015	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 7: Implement messages application layer	5
ISO 11783-8:2006	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 8: Power train messages	5
ISO 11783-9:2012	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 9: Tractor ECU	5
ISO 11784:1996	Radio frequency identification of animals — Code structure	2
ISO 11785:1996	Radio frequency identification of animals - Technical concept	2
ISO 11786:1995	Agricultural tractors and machinery - Tractor-mounted sensor interface - Specifications	5
ISO 11898:1995	Road vehicles - Interchange of digital information - Controller area network (CAN) for high-speed communication	5
ISO 12188-1:2010	Tractors and machinery for agriculture and forestry - Test procedures for positioning and guidance systems in agriculture - Part 1: Dynamic testing of satellite-based positioning devices	5
ISO 12188-2:2012	Tractors and machinery for agriculture and forestry - Test procedures for positioning and guidance systems in agriculture - Part 2: Testing of satellite-based auto-guidance systems during straight and level travel	5
ISO 12875:2011	Traceability of finfish products — Specification on the information to be recorded in captured finfish distribution chains	9
ISO 12878:2012	Environmental monitoring of the impacts from marine finfish farms on soft bottom	2
ISO 13482:2014	Robots and robotic devices — Safety requirements for personal care robots	5
ISO 13849-1:2015	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design	5
ISO 14001:2015	Environmental management systems - Requirements with guidance for use (ISO 14001:2015); German and English version EN ISO 14001:2015	4
ISO 14004:2016	Environmental management systems — General guidelines on implementation	4
ISO 14007:2019	Environmental management — Guidelines for determining environmental costs and benefits	4
ISO 14008:2019	Monetary valuation of environmental impacts and related environmental aspects	4
ISO 14015:2022	Environmental management - Guidelines for environmental due diligence assessment (ISO 14015:2022)	7
ISO 14024:2018	Environmental labels and declarations — Type I environmental labelling — Principles and procedures	4
ISO 14030-1:2021	Environmental performance evaluation - Green debt instruments - Part 1: Process for green bonds	4
ISO 14030-2:2021	Environmental performance evaluation - Green debt instruments - Part 2: Process for green loans	4
ISO 14030-3:2022	Environmental performance evaluation - Green debt instruments - Part 3: Taxonomy	4
ISO 14030-4:2021	Environmental performance evaluation - Green debt instruments - Part 4: Verification programme requirements	4
ISO 14044:2006	Environmental management — Life cycle assessment — Requirements and guidelines	4

ISO 14046:2014	Environmental management — Water footprint — Principles, requirements and guidelines	4
ISO 14051:2011	Environmental management — Material flow cost accounting — General framework	4
ISO 14052:2017	Environmental management — Material flow cost accounting — Guidance for practical implementation in a supply chain	4
ISO 14064-1:2018	Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals	4
ISO 14067:2018	Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification	4
ISO 14080:2018	Greenhouse gas management and related activities — Framework and principles for methodologies on climate actions	4
ISO 14090:2019	Adaptation to climate change — Principles, requirements and guidelines	4
ISO 14091:2021	Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment	4
ISO 14100:2022	Guidance on environmental criteria for projects, assets and activities to support the development of green finance	7
ISO 14223-1:2011	Radiofrequency identification of animals — Advanced transponders — Part 1: Air interface	2
ISO 14223-2:2010	Radiofrequency identification of animals — Advanced transponders — Part 2: Code and command structure	2
ISO 14223-3:2018	Radiofrequency identification of animals — Advanced transponders — Part 3: Applications	2
ISO 14982:1998	Agricultural and forestry machinery - Electromagnetic compatibility - Test methods and acceptance criteria	5
ISO 15003:2019	Agricultural engineering — Electrical and electronic equipment — Testing resistance to environmental conditions	5
ISO 15077:2020	Tractors and self-propelled machinery for agriculture — Operator controls — Actuating forces, displacement, location and method of operation	5
ISO 15176:2019	Guidance on characterization of excavated soil and other materials intended for re-use	1
ISO 15394:2017	Packaging - Bar code and two-dimensional symbols for shipping, transport and receiving labels	7
ISO 15639-1:2015	Radio frequency identification of animals - Standardization of injection sites for different animal species - Part 1: Companion animals (cats and dogs)	2
ISO 15639-2:2021	Radio frequency identification of animals — Standardization of injection sites for different animal species — Part 2: Equine (horses, donkeys and zebras)	2
ISO 15886-1:2012	Agricultural irrigation equipment — Sprinklers — Part 1: Definition of terms and classification	5
ISO 16119-1:2013	Agricultural and forestry machinery — Environmental requirements for sprayers — Part 1: General	5
ISO 16230-1:2015	Agricultural machinery and tractors — Safety of higher voltage electrical and electronic components and systems — Part 1: General requirements	5
ISO 16290:2013	Space systems — Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment	5
ISO 16622:2002	Meteorology — Sonic anemometers/thermometers — Acceptance test methods for mean wind measurements	1
ISO 16678:2014	Guidelines for interoperable object identification and related authentication systems to deter counterfeiting and illicit trade	7
ISO 1726-1:2000/Cor 1:2007	Road vehicles — Mechanical coupling between tractors and semi-trailers — Part 1: Interchangeability between tractors and semi-trailers for general cargo — Technical Corrigendum 1	5

ISO 1750:1981/Amd 7:2021	Pesticides and other agrochemicals — Common names	6
ISO 17532:2007	Stationary equipment for agriculture - Data communications network for livestock farming	2
ISO 17714 : 2007	Meteorology — Air temperature measurements — Test methods for comparing the performance of thermometer shields/screens and defining important characteristics	1
ISO 17989-1:2015	Tractors and machinery for agriculture and forestry — Sustainability — Part 1: Principles	5
ISO 18497:2018	Agricultural machinery and tractors — Safety of highly automated agricultural machines — Principles for design	5
ISO 18504:2017	Soil quality — Sustainable remediation	1
ISO 18537:2015	Traceability of crustacean products — Specifications on the information to be recorded in captured crustacean distribution chains	9
ISO 18539:2015	Traceability of molluscan products — Specifications on the information to be recorded in captured molluscan distribution chains	9
ISO 19156:2011	Geographic information — Observations and measurements	1
ISO 19157:2013	Geographic information — Data quality	1
ISO 19649:2017	Mobile robots — Vocabulary	6
ISO 20112-1:2018	Tractors and machinery for agriculture and forestry - Camera interface between tractor and implement - Part 1: Analogue camera interface	5
ISO 20419:2018	Treated wastewater reuse for irrigation — Guidelines for the adaptation of irrigation systems and practices to treated wastewater	1
ISO 20675:2018	Biogas — Biogas production, conditioning, upgrading and utilization — Terms, definitions and classification scheme	4
ISO 20951:2019	Soil Quality — Guidance on methods for measuring greenhouse gases (CO2, N2O, CH4) and ammonia (NH3) fluxes between soils and the atmosphere	1
ISO 20966:2007	Automatic milking installations — Requirements and testing	5
ISO 21895:2020	Categorization and classification of civil unmanned aircraft systems	5
ISO 21931-1:2022	Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 1: Buildings	1
ISO 21983:2019	Guidelines for harvesting, transportation, separation of stigma, drying and storage of saffron before packing	1
ISO 220006:2009	Quality management systems — Guidelines for the application of ISO 9001:2008 to crop production	1
ISO 22003-1:2022	Food safety — Part 1: Requirements for bodies providing audit and certification of food safety management systems	9
ISO 22005:2007	Traceability in the feed and food chain — General principles and basic requirements for system design and implementation	9
ISO 22006	Quality management systems - Guidelines for the application of ISO 9001:2008 to crop production	9
ISO 22006:2009	Quality management systems — Guidelines for the application of ISO 9001:2008 to crop production	5
ISO 22095:2020	Chain of custody — General terminology and models	9
ISO 22172-1:2020	Agricultural vehicles — Standardized access to repair and maintenance information (RMI) — Part 1: User interface requirements for web-based information systems	5
ISO 22300:2021	Security and resilience - Vocabulary (ISO 22300:2021)	6
ISO 22369-1:2006	Crop protection equipment — Drift classification of spraying equipment — Part 1: Classes	5

ISO 22975-1:2016	Solar energy — Collector components and materials — Part 1: Evacuated tubes — Durability and performance	4
ISO 23893-1:2007	Water quality — Biochemical and physiological measurements on fish — Part 1: Sampling of fish, handling and preservation of samples	2
ISO 24378:2022	Feed machinery — Vocabulary	6
ISO 24631-1:2017	Radiofrequency identification of animals - Part 1: Evaluation of conformance of RFID transponders with ISO 11784 and ISO 11785 (including granting and use of a manufacturer code)	2
ISO 24631-2:2017	Radiofrequency identification of animals - Part 2: Evaluation of conformance of RFID transceivers with ISO 11784 and ISO 11785	2
ISO 24631-3:2017	Radiofrequency identification of animals - Part 3: Evaluation of performance of RFID transponders conforming with ISO 11784 and ISO 11785	2
ISO 24631-4:2017	Radiofrequency identification of animals - Part 4: Evaluation of performance of RFID transceivers conforming with ISO 11784 and ISO 11785	2
ISO 24631-5:2014	Radio frequency identification of animals — Part 5: Procedure for testing the capability of RFID transceivers of reading ISO 11784 and ISO 11785 transponders	2
ISO 24631-6:2011	Radiofrequency identification of animals — Part 6: Representation of animal identification information (visual display/data transfer)	2
ISO 24631-7:2012	Radiofrequency identification of animals — Part 7: Synchronization of ISO 11785 identification systems	2
ISO 25119-1:2018	Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 1: General principles for design and development	5
ISO 25119-2:2019	Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 2: Concept phase	5
ISO 25119-3:2018	Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 3: Series development, hardware and software	5
ISO 25177:2019	Soil quality — Field soil description	1
ISO 26322-1:2008	Tractors for agriculture and forestry — Safety — Part 1: Standard tractors	5
ISO 28001	Security management systems for the supply chain - Best practices for implementing supply chain security, assessments and plans - Requirements and guidance	7
ISO 28003:2007	Security management systems for the supply chain - Requirements for bodies providing audit and certification of supply chain security management systems	7
ISO 28258:2013	Soil quality — Digital exchange of soil-related data	1
ISO 28902-2:2017	Air quality — Environmental meteorology — Part 2: Ground-based remote sensing of wind by heterodyne pulsed Doppler lidar	1
ISO 31000:2018	Risk management — Guidelines	9
ISO 32210:2022	Sustainable finance - Guidance on the application of sustainability principles for organizations in the financial sector	7
ISO 34101-1:2019	Sustainable and traceable cocoa - Part 1: Requirements for cocoa sustainability management systems (ISO 34101-1:2019); German version EN ISO 34101-1:2020	4
ISO 34101-2:2019	Sustainable and traceable cocoa - Part 2: Requirements for performance (related to economic, social and environmental aspects) (ISO 34101-2:2019); German version EN ISO 34101-2:2020	4
ISO 34101-3:2019	Sustainable and traceable cocoa - Part 3: Requirements for traceability (ISO 34101-3:2019); German version EN ISO 34101-3:2019	4
ISO 34101-4:2019	Sustainable and traceable cocoa - Part 4: Requirements for certification schemes (ISO 34101-4:2019); German version EN ISO 34101-4:2019	4
ISO 3600:2015	Tractors, machinery for agriculture and forestry, powered lawn and garden equipment — Operator's manuals — Content and format	5
ISO 3632-2:2010	Spices Saffron (Crocus sativus L.) - Part 2: Test Methods.	1

ISO 39001:2012	Road traffic safety (RTS) management systems — Requirements with guidance for use	5
ISO 4102:1984	Equipment for crop protection — Sprayers — Connection threading	5
ISO 4220:1983	Ambient air — Determination of a gaseous acid air pollution index — Titrimetric method with indicator or potentiometric end-point detection	1
ISO 4254-1:2013	Agricultural machinery — Safety — Part 1: General requirements	5
ISO 44002:2019	Collaborative business relationship management systems — Guidelines on the implementation of ISO 44001	9
ISO 44004:2021	Collaborative business relationship management — Guidelines for large organizations seeking collaboration with micro, small and medium-sized enterprises (MSMEs)	9
ISO 46001:2019	Water efficiency management systems — Requirements with guidance for use	4
ISO 5058-1:2021	Biotechnology — Genome editing — Part 1: Vocabulary	6
ISO 5231:2022	Extended farm management information systems data interface (EFDI) — Concept and guidelines	1
ISO 56000:2020	Innovation management - Fundamentals and vocabulary German version EN ISO 56000:2021	6
ISO 5681:2020	Equipment for crop protection — Vocabulary	1
ISO 5721-1:2013	Agricultural tractors — Requirements, test procedures and acceptance criteria for the operator's field of vision — Part 1: Field of vision to the front	5
ISO 7168-1:1999	Air quality — Exchange of data — Part 1: General data format	1
ISO 7560:1995	Cucumbers — Storage and refrigerated transport	9
ISO 789-1:2018	Agricultural tractors — Test procedures — Part 1: Power tests for power take-off	5
ISO 8157:2022	Fertilizers and soil conditioners — Vocabulary	6
ISO 9000:2015	Quality management systems - Fundamentals and vocabulary (ISO 9000:2015);	6
ISO 9409-1:2004	Manipulating industrial robots — Mechanical interfaces — Part 1: Plates	5
ISO 9999:2022	Assistive products — Classification and terminology	1
ISO TS 34700	Animal welfare management - General requirements and guidance for organizations in the food supply chain	7
ISO 26000:2010	Guidance on social responsibility	7
ISO/AWI 7088	Fish-meal — Vocabulary	6
ISO/AWI 7334	Earth-moving machinery — Taxonomy and definitions for terms related to automated and autonomous machines	6
ISO/AWI 8700	Plant-based foods — Terms and definitions	6
ISO/CD 1750	Pesticides and other agrochemicals — Common names	1
ISO/DIS 11783-7	Tractors and machinery for agriculture and forestry - Serial control and communications data network - Part 7: Implement messages application layer	7
ISO/DIS 14093	Mechanism for financing local adaptation to climate change - Performance-based climate resilience grants - Requirements and guidelines	7
ISO/DIS 16577 - 2021-08	Molecular biomarker analysis — Vocabulary for molecular biomarker analytical methods in agriculture and food production	6
ISO/DIS 22003-1	Food safety — Part 1: Requirements for bodies providing audit and certification of food safety management systems	9
ISO/DIS 22003-2	Food safety — Part 2: Requirements for bodies providing evaluation and certification of products, processes and services, including an audit of the food safety system	9
ISO/DIS 22378	Security and resilience - Authenticity, integrity and trust for products and documents - Guidelines for interoperable object identification and related authentication systems to deter counterfeiting and illicit trade	7
]ISO/DIS 6165:2021	Earth-moving machinery — Basic types — Identification and vocabulary	6

ISO/DTS 20224-8	Molecular biomarker analysis — Detection of animal-derived materials in foodstuffs and feedstuffs by real-time PCR — Part 8: Turkey DNA detection method	9
ISO/DTS 20224-9	Molecular biomarker analysis — Detection of animal-derived materials in foodstuffs and feedstuffs by real-time PCR — Part 9: Goose DNA detection method	9
ISO/IEC 14496-10:2022	Information technology — Coding of audio-visual objects — Part 10: Advanced video coding	3
ISO/IEC 15459-1	Information technology - Automatic identification and data capture techniques - Unique identification - Part 1: Individual transport units	8
ISO/IEC 15459-2	Information technology - Automatic identification and data capture techniques - Unique identification - Part 2: Registration procedures	8
ISO/IEC 15459-3	Information technology - Automatic identification and data capture techniques - Unique identification - Part 3: Common rules	8
ISO/IEC 15459-5	Information technology - Automatic identification and data capture techniques - Unique identification - Part 5: Individual returnable transport items (RTIs)	8
ISO/IEC 15459-6	Information technology - Automatic identification and data capture techniques - Unique identification - Part 6: Groupings	8
ISO/IEC 15961-3:2019	Information technology — Data protocol for radio frequency identification (RFID) for item management — Part 3: RFID data constructs	2
ISO/IEC 19794-5:2011	nformation technology — Biometric data interchange formats — Part 5: Face image data	1
ISO/IEC 19944-1:2020	Cloud computing and distributed platforms – Data flow, data categories and data use — Part 1: Fundamentals	8
ISO/IEC 22989:2022	Information technology — Artificial intelligence — Artificial intelligence concepts and terminology	1
ISO/IEC 23090-10:2022/Amd 1:2022	Information technology — Coded representation of immersive media — Part 10: Carriage of visual volumetric video-based coding data — Amendment 1: Support of packed video data	3
ISO/IEC 23090-7:2022	Information technology — Coded representation of immersive media — Part 7: Immersive media metadata	3
ISO/IEC 24668:2022	Information technology — Artificial intelligence — Process management framework for big data analytics	3
ISO/IEC 27006:2020	Information technology - Security techniques - Requirements for bodies providing audit and certification of information security management systems (ISO/IEC 27006:2015, including Amd 1:2020)	7
ISO/IEC 27559:2022	Information security, cybersecurity and privacy protection – Privacy enhancing data de-identification framework	3
ISO/IEC 30105-4:2022	Information technology — IT Enabled Services-Business Process Outsourcing (ITES-BPO) lifecycle processes — Part 4: Key concepts	3
ISO/IEC 30161:2020	Internet of Things (IoT) — Requirements of IoT data exchange platform for various IoT services;	8
ISO/IEC AWI 19762	Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary	6
ISO/IEC AWI 22460-3	ISO license and drone identity module for drone (Ultra Light Vehicle or unmanned aircraft system) — Part 3: Logical data structure, access control, authentication and integrity validation for drone licence	5
ISO/IEC CD 17364	Supply chain applications of RFID — Returnable transport items (RTIs) and returnable packaging items (RPIs)	9
ISO/IEC CD 22460-1.2	ISO license and drone identity module for drone (Ultra light vehicle or unmanned aircraft system) — Part 1: Physical characteristics and basic data sets for drone licence	5

ISO/IEC CD 27036-3.2	Cybersecurity — Supplier relationships — Part 3: Guidelines for hardware, software, and services supply chain security	9
ISO/IEC DIS 17367	Supply chain applications of RFID — Product tagging	9
ISO/IEC DIS 23092-3	Information technology — Genomic information representation — Part 3: Metadata and application programming interfaces (APIs)	8
ISO/IEC DTS 5723	Trustworthiness — Vocabulary	6
ISO/IEC FDIS 2382-37	Information technology — Vocabulary — Part 37: Biometrics	6
ISO/IEC FDIS 30134-9	Information technology — Data centres key performance indicators — Part 9: Water usage effectiveness (WUE)	1
ISO/IEC TR 21897:2022	Information technology — Data centres — Impact of the ISO 52000 series on energy performance of buildings	3
ISO/IEC TR 22417:2017	Information technology — Internet of things (IoT) use cases;	8
ISO/IEC TR 29119-13:2022	Software and systems engineering — Software testing — Part 13: Using the ISO/IEC/IEEE 29119 series in the testing of biometric systems	3
ISO/IEC/IEEE 15026-2:2022	Systems and software engineering — Systems and software assurance — Part 2: Assurance case	3
ISO/IEC/IEEE 24748-7000:2022	Systems and software engineering — Life cycle management — Part 7000: Standard model process for addressing ethical concerns during system design	3
ISO/IEC/IEEE 42010:2022	Software, systems and enterprise — Architecture description	3
ISO/PWI 17790	Development and utilization of management system standards for the minimization of food loss and waste across the food value chain	4
ISO/TR 20218-1:2018	Robotics — Safety design for industrial robot systems — Part 1: End-effectors	5
ISO/TR 23087:201	Automation systems and integration - the Big Picture of Standards	8
ISO/TR 23482-1:2020	Robotics — Application of ISO 13482 — Part 1: Safety-related test methods	5
ISO/TR 32220	Sustainable finance - Basic concepts and key initiatives	7
ISO/TR 4286:2021	Intelligent transport systems — Use cases for sharing of probe data	9
ISO/TR 4804:2020	Road vehicles — Safety and cybersecurity for automated driving systems — Design, verification and validation	5
ISO/TR 56004:2019	Innovation Management Assessment — Guidance	9
ISO/TR 8059:1986	Irrigation equipment — Automatic irrigation systems — Hydraulic control	5
ISO/TS 11356:2011	Crop protection equipment — Traceability — Spray parameter recording	5
ISO/TS 14812:2022	Intelligent transport systems - Vocabulary	6, 9
ISO/TS 15066:2016	Robots and robotic devices — Collaborative robots	5
ISO/TS 18625	Freight containers - Container Tracking and Monitoring Systems (CTMS): Requirements	7
ISO/TS 23016-1:2019	Fine bubble technology — Agricultural applications — Part 1: Test method for evaluating the growth promotion of hydroponically grown lettuce	1
ISO/TS 26030:2019	Social responsibility and sustainable development — Guidance on using ISO 26000:2010 in the food chain	7
ISO/IEC 27001:2013	Information technology — Security techniques — Information security management systems — Requirements	8
ISO/IEC 27002:2013	Information technology — Security techniques — Code of practice for information security controls	8
ISO/IEC 27017:2015	Information technology — Security techniques — Code of practice for information security controls based on ISO/IEC 27002 for cloud services	8

ISO/IEC 27018:2014	Information technology — Security techniques — Code of practice for protection of personally identifiable information (PII) in public clouds acting as PII processors	8
ISO/TS 34700:2016	Animal welfare management — General requirements and guidance for organizations in the food supply chain	2
ISO/TS22002-3:2011	Prerequisite programmes on food safety-Part 3: Farming	9
ISO/WD 23117-1	Agricultural and forestry machinery — Unmanned aerial spraying systems — Part 1: Environmental requirements	5

Annex E: Artifacts

The artifacts in this annex include:

- Scope items
- Stories
- Business Process Modeling Notation (BPMN) diagrams
- Personas and causal / relationship diagrams

E.1 Scope items

Table E.1 lists the scope items provided by members of the Core and Consultative groups of the SAG-SF in response to the question of what items they considered to be in scope of smart farming.

Table E.1 – Scope items proposed by the SAG-SF Core and Consultative groups, along with the subgroup each scope item was primarily assigned to.

No.	Scope Item	Primary Sub-Group
1	adaptive sprayers and the exchange of the environmental & context data needed to enable smart spraying	OEM
2	agricultural biotechnology	Crop production
3	agricultural biotechnology	Livestock
4	agricultural decision making	Data
5	agricultural information interoperability interfaces	Data
6	agricultural information management	Data
7	agricultural information markup language	Terminology
8	agricultural knowledge interoperability	Data
9	agricultural robotics	OEM
10	agricultural vehicle health	OEM
11	agro-AI/ML interfaces	Data
12	agroforestery	Climate & Environment
13	air	Climate & Environment
14	air quality	Climate & Environment
15	allow farmers to make a more efficient inputs use.	Climate & Environment
16	animal agriculture	Livestock
17	animal health	Livestock
18	animal welfare (in the food chain)	Livestock
19	animal welfare livestock	Livestock
20	aquaculture and precision aquaculture	Livestock
21	artificial intelligence and modelling	Data
22	autonomes field robotic	OEM
23	autonomous agricultural machinery	OEM
24	autonomous agriculture machinery	OEM
25	autonomous crop equipment	OEM
26	autonomous field robotics	OEM
27	autonomous harvesting	Crop production

28	autonomous harvesting	OEM
29	autonomous pesticide application	OEM
30	autonomous tractors and other self-propelled agricultural machinery.	OEM
31	biobased and clean products products	Climate & Environment
32	biodiversity	Climate & Environment
33	biodiversity	Climate & Environment
34	biodiversity data exchange	Terminology
35	blockchain elements for smart farming	Data
36	business continuity/contingency and crisis plans	Supply chain
37	carbon credit accounting	Climate & Environment
38	carbon credit accounting	Climate & Environment
39	carbon footprint computation and estimation	Climate & Environment
40	carbon marketing data collection standards	Climate & Environment
41	chain of custody	Supply chain
42	chain of custody	Supply chain
43	chain of custody	Supply chain
44	circular economy practices and processes	Climate & Environment
45	circular economy/ recycling, e.g. agricultural plastics	Climate & Environment
46	climate adaptation	Climate & Environment
47	climate adaption	Climate & Environment
48	climate adaption	Climate & Environment
49	climate and carbon resilient practices, techniques and technologies	Climate & Environment
50	climate change	Climate & Environment
51	climate change mitigation and adaptation	Climate & Environment
52	climate mitigation	Climate & Environment
53	coding and compression algorithms	Data
54	common controlled vocabularies / data semantics	Terminology
55	communication protocol for data exchange	Data
56	communication protocols for smart farming sensors communication protocols	Terminology
57	control systems for vertical farming	Urban farming
58	co-registration of different sources of position data	OEM
59	co-registration of navigation systems, to enable autonomous navigation	OEM
60	costs	?
61	creating an extensible controlled vocabulary of actors in smart farming, to support modeling, decision-support tools, automated reasoning, etc.	Data
62	crop and livestock protection management and solutions	Crop production
63	crop and livestock protection management and solutions	Livestock
64	crop input identification	Crop production
65	crop input identification	Terminology
66	cyber security	Data
67	cybercecurety	Data

68	cybersafety in smart farming	Data
69	cybersecurity	Data
70	cybersecurity	Data
71	data aggregation	Data
72	data carrier	Data
73	data convention	Data
74	data definitions	Data
75	data exchange regarding ag lab test results	Data
76	data formats	Data
77	data interoperability	Data
78	data interoperability throughout the farming	Data
79	data interoperability...	Data
80	data manager	Data
81	data mining	Data
82	data model for smart farming	Data
83	data movement	Data
84	data ownership	Data
85	data ownership	Data
86	data ownership and data rights delegation	Data
87	data privacy	Data
88	data sovereignty	Data
89	data standards	Data
90	data transfer	Data
91	deal with dust using smart farming	Climate & Environment
92	dealing with dust: data exchange for prevention and for mitigation	Climate & Environment
93	developing and emerging markets	Supply chain
94	documenting production practices	Social aspects
95	documenting production practices	Supply chain
96	drone and robot information for agriculture	Crop production
97	drone and robot information for agriculture	Livestock
98	drones for remote sensing	OEM
99	drones in application of pesticides	Crop production
100	effective collaboration between government and primary industry at country scale	Supply chain
101	effective land use strategies	Climate & Environment
102	energy efficiency and alternative resources	Climate & Environment
103	energy sources and storage	Climate & Environment
104	energy use efficiency and monitoring	Climate & Environment
105	environmental /biodiversity monitoring (remote)	Climate & Environment
106	equipment compatibility	OEM
107	error estimates in data	Data
108	ethical claims, e.g. about sustainability	Climate & Environment
109	farm waste management	Supply chain
110	farming against climate change	Climate & Environment
111	fertilizer	Crop production

112	field boundary precision and quality of measurement	Terminology
113	field crops	Crop production
114	field data collection equipment metadata	Crop production
115	field operations data exchange in production agriculture	Crop production
116	field operations processes	Crop production
117	field operations processes	Crop production
118	field sanitation	Crop production
119	finance	?
120	fine bubble control technology	Crop production
121	fine bubble control technology	Crop production
122	fine bubble technology for smart farming	?
123	fisheries	Livestock
124	food , environmental, and occupational safety	Supply chain
125	food loss and food waste	Supply chain
126	food loss and waste	Supply chain
127	food safety	Supply chain
128	food safety & traceability across the value chain	Supply chain
129	food security	Supply chain
130	food supply chain	Supply chain
131	food traceability	Supply chain
132	food waste	Supply chain
133	food waste in the consumption process at home	Supply chain
134	format harmonization	Data
135	gene editing and other tools for genomic selection	Crop production
136	gene editing and other tools for genomic selection	Livestock
137	genetic technologies (or genomics) for livestock and grains	Crop production
138	genetic technologies (or genomics) for livestock and grains	Livestock
139	genome engineering (genome editing)	Crop production
140	genome engineering (genome editing)	Crop production
141	genome engineering (genome editing)	Livestock
142	genome engineering (genome editing)	Livestock
143	GMO crops	Crop production
144	grain contract settlements	Crop production
145	grain contracts	Crop production
146	grain contracts	Crop production
147	greenhouse gas emissions (co2e) / unit of production	Climate & Environment
148	guiding through points of attention,	?
149	harvest-to-food-processor processes	Supply chain
150	how best to find and share country-level efforts going into interoperability and similar work that is valuable but is being undertaken in isolation	Social aspects
151	how equipment can be used to communicate with suppliers and processors in the next step of the production chain.	Supply chain
152	ICT as enabling technologies, including AI, cloud computing, barcode, RFID, software and so on	Data
153	image resources	Data

154	imaging	Crop production
155	in support of decision making	Data
156	input supply chain processes	Supply chain
157	input supply chain processes	Supply chain
158	integrated cropping-livestock systems	Crop production
159	integration of distributed energy (wind, solar, biomass) with in agricultural systems	Climate & Environment
160	integration of environmental data into autonomous control systems	Crop production
161	integration of smart farming with smart energy generation, smart grids and water management	Climate & Environment
162	integration of solar pv projects with ag land use	Climate & Environment
163	internet connectivity	Data
164	internet of things	Data
165	interoperability	Data
166	interoperability of field boundary data	Crop production
167	intersection of supply chain and field operations	Supply chain
168	inventory reporting	OEM
169	inventory reporting	Supply chain
170	irrigation	Crop production
171	irrigation (remote operation and sensing)	Crop production
172	irrigation management	Crop production
173	irrigation management	Crop production
174	irrigation system	Crop production
175	irrigation system data	Crop production
176	it is more than just smart farming if we want to take into account the entire value chain	?
177	just transitions	?
178	legislation and political protocols	?
179	lighting (wavelengths) control	Crop production
180	lighting (wavelengths) control	Livestock
181	livestock welfare monitoring (may apply to aquaculture too)	Livestock
182	livestock welfare monitoring (may apply to aquaculture too)	Livestock
183	logistics in the interface between supply chain and field operations	Supply chain
184	machine-to-cloud data transfer	Data
185	machine-to-cloud data transfer	OEM
186	machine-to-machine data transfer	OEM
187	management of agricultural waste	Supply chain
188	management system	Supply chain
189	market data	Data
190	markup language	Terminology
191	materials used in intensive indoor/vertical farming systems in relation to food safety	Urban farming
192	maximizing irrigation efficiency	Crop production
193	metadata	Data

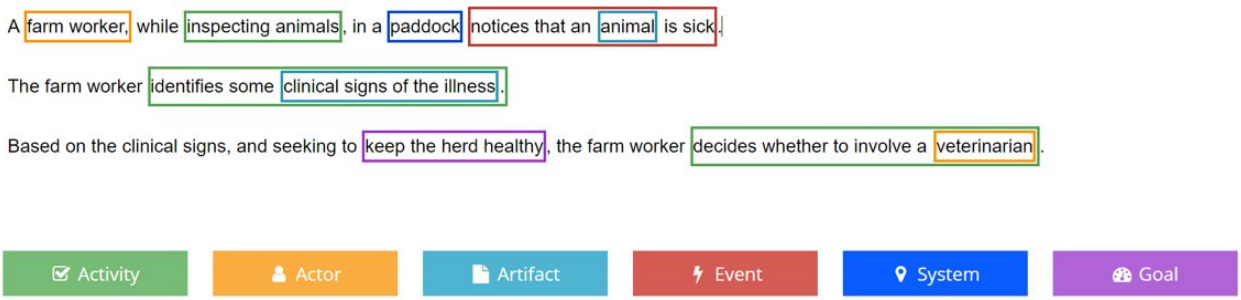
194	metadata	Data
195	metadata and controls to support managing/communicating what data is open and what data is restricted to certain parties	Data
196	methods and models for using ontologies to facilitate interoperability	Data
197	methods/practices of capturing resource usage (land, water, crop inputs, people) both manual and automated.	Climate & Environment
198	nutrient management plans (and subsequent nutrient management policies)	Crop production
199	ontologies for interoperability	Terminology
200	ontology	Terminology
201	packaging materials	Supply chain
202	performance indicators , monitoring and benchmarking for smart farm systems and techniques	Terminology
203	pesticide use	Crop production
204	phenotyping metadata (to enable exchanging plant trial data)	Terminology
205	plant diseases and pest control	Crop production
206	post-harvest processing and value addition in spices	Supply chain
207	postharvest and management of crop loss	Supply chain
208	precision agriculture	Crop production
209	precision livestock	Livestock
210	principal coordinate analysis	Social aspects
211	processes and means for traceability	Supply chain
212	processes involving crop protection products, seed, crop nutrition products	Crop production
213	product makeup data interoperability (active ingredients, their concentrations, target pests, labeled crops, etc.)	Supply chain
214	product quality to include nutrient-rich produce	Terminology
215	production equipment and sustainable agriculture inputs and output	OEM
216	productivity enhancement	Supply chain
217	provenance	Terminology
218	QR codes, blockchain, etc.?	Supply chain
219	quality certificates (i.e., grades)	Terminology
220	quality certificates (i.e., grades)	Terminology
221	quality of soil (meaning concentration of nutrients as well as contaminants, mobility of compounds from soil to water, plants, animals (e.g. earthworms))	Crop production
222	records, verification, etc.	Terminology
223	reduce conflicts between farmers and society, making agriculture more transparent.	Social aspects
224	reference architecture for smart farming	Data
225	reference data management	Data
226	reference data management (e.g., code lists; controlled vocabularies)	Terminology
227	reference data model	Data

228	related data management	Data
229	remote irrigation operation	Crop production
230	remoting sensing	Crop production
231	resource (e.g., seeds, crop protection products) identification in the field	Crop production
232	Retail	Supply chain
233	risk assessment framework and methodology	Terminology
234	robotics and automation equipment	OEM
235	Scale	?
237	SDG indicators related to farming that do not have metrics for yet	Terminology
238	security in smart farming	Data
239	Seed	Crop production
240	seed source	Crop production
241	sensor communication protocols	Data
242	sensors and dosing / fertigation / fertilisation	Crop production
243	sensors, IoT and AI	OEM
244	settlements	?
245	simple, common aggregations & analytics	Data
246	single-function data mountains aggregated by suppliers or buyers making core data difficult to access by producers	Data
247	smart animal rearing	Livestock
248	smart data tillage	Crop production
249	smart farming use cases	Social aspects
250	smart irrigation	Crop production
251	smart irrigation	Crop production
252	smart logistics for agriculture, including production, processing, distribution taking location into account	Supply chain
253	smart pesticide application	OEM
254	smart planters	Crop production
255	smart planters	OEM
256	smart sprayers	Crop production
257	smart tillage	Crop production
258	smart weed management	Crop production
259	software development	Data
260	soil testing	Crop production
261	soil testing	Crop production
262	spatiotemporal resolution of data	Crop production
263	spatiotemporal resolution of data	Data
264	special crops	Crop production
265	specialty crops	Crop production
266	standardizing smart greenhouse technology	Urban farming
267	structure to data	Data
268	supply chain management	Supply chain
269	support different units of measure	Terminology
270	support for a variety of units of measure	Terminology

271	support for business processes of smallholders	Social aspects
272	support for business processes of smallholders	Supply chain
273	sustainability	Climate & Environment
274	sustainability claims	Climate & Environment
275	sustainability metrics	Climate & Environment
276	sustainability metrics	Terminology
277	sustainability reporting data standards	Terminology
278	sustainable food chain	Supply chain
279	systems integration for irrigation hardware and components (especially control and sensing systems)	Crop production
280	technologies to create value added products	Supply chain
281	technologies to enhance cross country collaboration with regards to growing - production- distribution	Supply chain
282	terminology	Terminology
283	testing laboratory integration	Supply chain
284	traceability	Supply chain
285	traceability	Supply chain
286	trade agreements	Crop production
287	transport chains	Supply chain
288	uniform language	Terminology
289	uniform protocol and communication	Data
290	uniformity and availability knowledge and information	Social aspects
291	unify sensor data interpretation	OEM
292	unmanned aerial vehicles for remote sensing	OEM
293	urban farming (vertical-, aquaponic, *in vitro*)	Urban farming
294	use of drones, interoperability and data management	OEM
295	use of models and validation data	Data
296	use of waste from sources external to the farm as resources	Climate & Environment
297	vertical (indoor) farming	Urban farming
298	virtual herding technologies	Livestock
299	water quality	Crop production
300	water reduction utilization and water recycling.	Climate & Environment
301	water testing	Crop production
302	water testing	Terminology
303	water use efficiency	Crop production
304	weight certificates	Livestock
305	where do we as the SAG-SF consider human engagement and skills development	Social aspects

E.2 Stories

Members of the SAG SF used the Trisotech Discovery Accelerator to create stories to identify the actors, activities, artifacts, etc. that are involved in Smart Farming processes. The Discovery Accelerator allowed subgroup members to answer the Who, What, When, Where, How and Why questions for any given process. These became the basis for generating the BPMN diagrams.



In the stories, an **Activity** denotes *how* things get done; the **Actor** identifies *who* is involved in getting things done; the **Artifact** denotes *what* is involved in getting things done; the **Event** is *when* are things getting done; the **System** is *where* getting things done takes place; and the **GOAL** is *why* things are getting done. The stories led directly to the development of Business Process Management Notation (BPMN) diagrams shown in the section following.

Story: Expert or crop monitoring services

Expert receives an order from the farmer to inspect one or several fields.

Expert arranges a date to visit the field.

Expert alone or in company of the farmer visits the fields and decide what needs to be done and sends the data of what they determine is required to the farmer's FMIS (fertilizer, plant protection product, machines to be used, application rates etc.).

Crop monitoring data are sent regularly to the farmer as text message or are directly pushed to the FMIS of the farmer.

Story: Application of fertilizer and crop protection products

Farmer consults experts to get an application map for fertilizer and plant protection products application

Farmer defines an application map for the fertilizer and plant protection products in his FMIS.

The FMIS connects to a cloud database with relevant data about the crop protection products that are allowed to be used for this specific crop, in this specific time of the year and in this specific region.

Farmer contacts an online forecast service to check the weather.

Farmer exports the application map from the FMIS to the machine terminal.

Farmer identifies the fertilizer or plant protection products when filling the fertilizing or spraying machine by scanning the QR-code on the product label.

Farmer applies the fertilizer or plant protection products on the field based on the application map.

Machine terminal logs data by the machine (e.g. time, geolocalisation, used machine, used product, application rate, temperature, air humidity, crop images etc.) during work.

Farmer imports the logged data of the field work (e.g. machinery used, amount and type of seeds, fertilizer, plant protection product amount and dosage, etc.) into the FMIS.

Used fertilizer or plant protection products are automatically booked out of the FMIS (farm storage).

Story: Supply industry (machinery, fertilizer, plant protection products)

Plant protection product, fertilizer and seed industries produce plant protection products, fertilizers and seeds.

The suppliers deliver the identification data for the different products (e.g. active substances, concentrations, nutrient content etc.) to a central database.

The suppliers send the ordered products to retailers.

Retailers deliver the ordered products to the farmers.

Comment: It needs to be defined as to what exactly has been produced: active substances, nutrient content etc. An ISO standard is needed for this.

Story: Setup and reference data field use

Note: This scenario involves data preparation work prior to the planning, preparation and execution of the field operation, but this work translates into a frictionless experience processing the data afterward.

farmer uses an FMIS for managing field operations

When field operation planning, the FMIS operator exports setup data ,reference data and configuration data

The FMIS operator sends the setup data, reference data and configuration data to the MICS

During field operation preparation, the machine operator allocates a-priori-identified resources to the field operation on the MICS (fields, products, crops, people, etc.)

The machine operator starts the task on the MICS

The MICS on the machine logs field operations data; i.e., field operation documentation

field operation execution: The machine operator performs the field operation with the machine

The machine operator ends the task on the MICS

The machine operator sends the data to the FMIS

The FMIS notifies the FMIS operator of inbound data, imports the inbound data into the FMIS

When importing the inbound data into the FMIS, the FMIS recognizes the resource identifiers it exported to the machine

The FMIS stores the field operations data

Story: Farmer orders product from retailer

Retailer receives order from farmer.

Order is recorded in retailers database.

Retailer orders products from the supplier.

Order is recorded in retailers database/system and suppliers database/system

Retailer delivers product to farmer.

Delivery is recorded in retailers database/system and logged in the farmer's FMIS.

Story: Application of fertilizer and crop protection products

Farmer contacts experts to get their advice for field operations.

Farmer sends field data to the expert.

Farmer and expert visit the field together and determines the need for pest or fertilizer treatments.

Farmer contacts an online forecast service to check the weather.

Farmer defines an application map for the fertilization and plant protection product in his FMIS or writes the application data on paper (or another medium).

The FMIS connects to a cloud database with relevant data about the crop protection products that are allowed to be used for this specific crop, in this specific time of the year and in this specific region. If needed, corrections need to be applied.

Farmer sends orders for services like tillage, fertilization, plant protection or harvest including all the needed products from a supplier.

Farmer executes the different field works (tillage, planting, fertilization, plant protection, irrigation, harvest, in case of perennial crops additional works like tree-cut, fruit thinning etc.).

Farmer loads the application map from the FMIS to the machine terminal.

Farmer determines the coupled machine and the settings of the machine.

When filling the fertilising or spraying machine, the QR-code on the product label is scanned and the product is identified.

Farmer defines the amount of product per field that he has to use in the tractor terminal using the instructions in the FMIS.

During the operations the data may be logged by the machine: time, geolocalisation, used machine, used product, application rate, temperature, air humidity, crop images etc.

If no data are logged, work data are simply registered on paper or typed into the smartphone FMIS app.

After the work the farmer writes the data for the field work (e.g., machinery used, amount and type of seeds, fertilizer, plant protection product amount and dosage, etc.) into the FMIS.

Data are pushed from the machine terminal to the FMIS *(ISO-standard of to be recorded parameters for different crops and operations?)*.

Used products are automatically booked out of the FMIS (farm storage).

Story: No-process-calculations and data transfer to third parties

Farmer calculates the nutrient balance of each single field (Nutrient import – Nutrient export of each single field based on national rules).

Farmer establishes the plant protection protocol of the fields according to the different standards of related organisations, national rules etc. (e.g. product identity, applied amount, time, exact location, weather conditions like wind speed)

Production data are checked by an expert to guarantee that the agreed production standards have been met.

In accordance with the different standards the farmer sends the production data for his fields to the wholesalers, label organisations and the government.

Farmer calculates the revenue and the costs of the different fields.

Farmer calculates the needed working hours of the different fields.

Story: Analytical laboratories

Analytical laboratories are regularly actualizing their identification codes.

Laboratories receive samples *(soil, plant, manure, water etc*.) from the farmer.

Laboratories analyse soil, plant, manure and water samples.

the standard test results :

for soil :chemical constituents & particle dispersion

for water : ph ,ec ,organic mater

for plant : dry mater ,microbiology, toxins & pesticides

Results are sent to the farm management information system FMIS that deals the payroll, machinery, products and workers, field and geographical information, and decision and task management will all be available to the farmer.

Story: Closed loop spray

The **farmer** or **contractor** **prepares the spraying operations** for **pest control in a crop** , using a **Farm Management Information System (FMIS).** The FMIS contains up-to-date and detailed information

about all the crop fields of the farm; field identifiers, types of crop, field boundaries, a record of all the operations that we carried out on this crop field, etc.

The FMIS connects to the cloud application with the actual and forecasted weather conditions. The FMIS connects to a cloud data base with relevant data about the crop protection products that are allowed be uses for this specific crop, in this specific time of the year and in this specific region.

All the information is used to generate a planned spray operation for the specified field. The planned operations is transferred as a 'work order' to the tractor or spraying machine.

When filling the spraying machine with water and the crop production product, the QR-code on the product label is scanned and the product is identified. A final check is done, connecting to the cloud database with crop protection reference data, verifying if the conditions are still met for carrying out the spray operation. The executed workorder is captured by the tractor or spraying machine and fed back to the FMIS to be used for compliance purposes and for agronomic analysis.

Story: Fertilizing

Note: This sub-process may include irrigation, fertilizer, soil amendments, or crop protection chemicals as indicated by the crop plan or the crop field observation report. Equipment associated with inputs should be suitable and calibrated as appropriate to ensure proper application.

Farmer starts tractor and smart farming platform (SFP), then enters username and password.

Farmer chooses offline/online mode in SFP, of which offline operations apply to fields with sufficient historical soil and crop yield information and online operations apply to fields without historical data and requiring in-season monitoring.

Farmer retrieves basal fertilization information for the fields in SFP.

Farmer operates SFP monitoring module online mode to acquire soil information and crop growth information.

Farmer chooses a fertilizer recommendation algorithm in SFP.

SFP determines required nutrition (N) and farmer chooses sensor-based or prescription map-based topdressing.

Farmer prepares the tractor for sensor-based or map-based variable-rate fertilizer application on the go by setting precisely:

fertilizer type (compound or straight, solid or liquid)

AND

flow control valve (amount of fertilizer, determined for a specific fertilizer type)

AND

run time for the fertilizer (duration of applying this amount of fertilizer).

Story: Monitoring crops health status and application of phytosanitary products

Satellite or unmanned aerial vehicle (UAV) images are taken measuring the health sensitive vegetation index (HVI) of the crops.

Afield is selected, and satellite or UAV images are taken periodically of it and the variation of the HVI of the crop is evaluated, analyzing the different parts of the field.

Sections of the field, whose HVI suffers unusual changes, are observed. An alert is triggered to the monitoring company, who go through the field and evaluate the situation in site.

If it is determined that the decrease in HVI is due to a disease or pest, an order is triggered to the plant protection products application company to apply fungicides through a specific mapping of the field, producing variable application of fungicides, carrying out the treatment only in the affected area.

Story: Image processing weed control

An autonomous weed control robot is used in the field to remove weed in a crop in order to maximise crop production.

Weed detection algorithms for autonomous weed control robots are developed and placed on a server in the cloud.

The weed control robot downloads on a regular base the most up-to-data and appropriate algorithm it can use to real time detect and remove in a chemical or mechanical way the weed in a specific crop.

During the operation the robot takes many images to detect the weed. The captured images are, enriched with meta data (timestamp, type of crop, weather conditions, angle of the camera, etc.),

uploaded to a cloud server where the images are available for improving the algorithm and for other purposes; e.g. for detect fungus infections in the crop.

Story: Weeding - selective sprays

A crop monitoring company is hired to make the monitoring of the plots of a field.

They determine the presence of patches of weeds in the field, but not enough to spray it massively, rather selective spraying is required.

An alert is triggered to the farmer, and he contacts the herbicide application company that has a sprayer with the selective application system.

This contractor has mounted on the boom of the sprayer, some infrared sensors that, when detecting weeds (by NDVI), produce the application of herbicides, making selective applications in the places where the weeds are located and not elsewhere, reducing the risk of contamination and producing a more profitable application.

Story: Proper harvest time

Adjust harvest timetable and schedule based on actual field, weather and crop conditions. This step is taken whenever adjustments are required to the harvest schedule. These actions ensure final timing and schedule meet contract and yield requirements.

Weather data (solar/soil temperature/rainwater) is sent daily from automatic weather stations (AWS) and collected on a cloud-based server.

An API request calls data from the cloud to the model.

The model analyses the new data and updates the harvest prediction date for each field.

Farmer opens the app (decision support system) and directs harvest teams to field in order of priority. In this way crop yield and quality are maximised and labour allocated more efficiently.

Story: Grain harvest

The farmer gives the contractor the order to harvest a field of wheat.

From the farm management system, the farmer transmits the order with position, field boundaries and obstacles, i.e., the position of a large stone in the field to the contractor.

The contractor uses the guidance system and the field boundaries to plan the tracks of the combine harvester.

The contractor transmits all data for the order to the driver and the combine. These are the job number, the arable crop, the position of the field, the position of the transport trailer at the edge of the field, the tracks and the position of the stone. The driver drives to the field using the position and a navigation system. Here he starts harvesting.

He sets the standard value for wheat on the combine's terminal according to the manufacturer's specifications. He drives along the tracks with the parallel drive system. The combine adjusts the driving speed according to the amount harvested. The moisture of the wheat and the yield are recorded via the sensors in the combine and documented with the position data on a map.

As it is already evening and the straw is getting wetter, the combine does not clean the short straw as well. The driver recognizes this via the sensors in the combine and the straw in the field. He then adjusts the standard settings for wheat on the combine and saves the new setting on the combine as an alternative setting for wheat in the combine. After he has finished, he completes the job.

All data is transferred to the contractor via the cloud. For the contractor, this is working time, machine utilization and fuel consumption. The contractor then sends the map with the yield and moisture measurements to the farmer's farm management system.

Story: Automatic operation of harvesting machines

Fruit harvester driver operates both a trunk and shaker system simultaneously.

When driver starts harvesting a fruit row, an artificial vision system detects trunk to grab with the trunk shakers arms. Simultaneously, canopy shaker is also self-adjusted through a pressure sensor to approach the tree canopy itself:

The purpose of the system is to assist fruit harvester driver to optimize fruit harvesting automatically in a specific fruit orchard. The fruit harvester driver should only select trunk-shaking time, different vibration events per tree and canopy shaking time to detach most of the fruits from each fruit orchard.

E.3 Business Process Modeling Notation (BPMN) diagrams

Members of the SAG used Business Process Management Notation (BPMN) diagrams to map out processes, identifying actors and data flow. These diagrams are shown in figures 19-32 below.

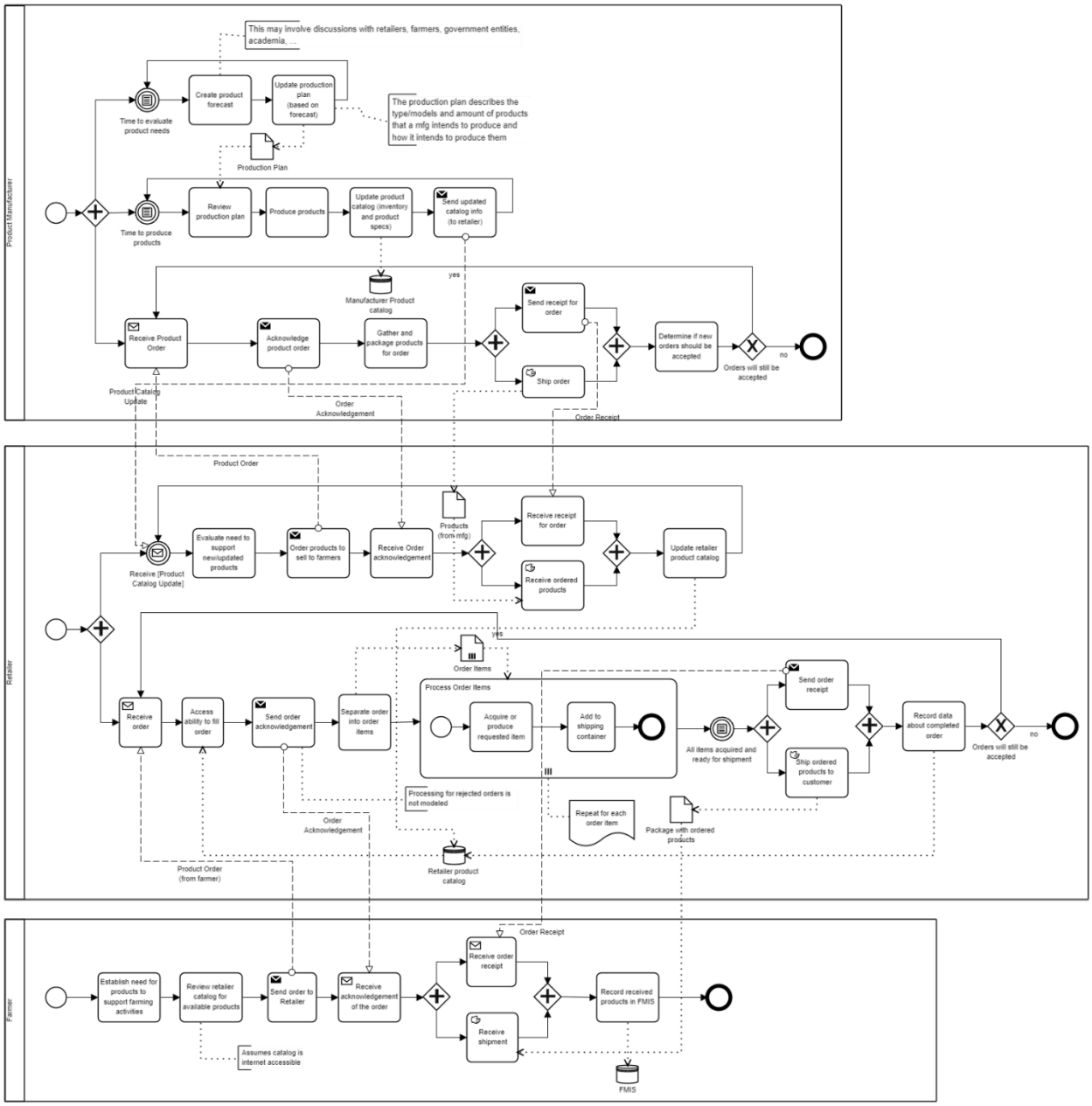


Figure 2: Supply Industry (machinery, fertilizer, plant protection products)

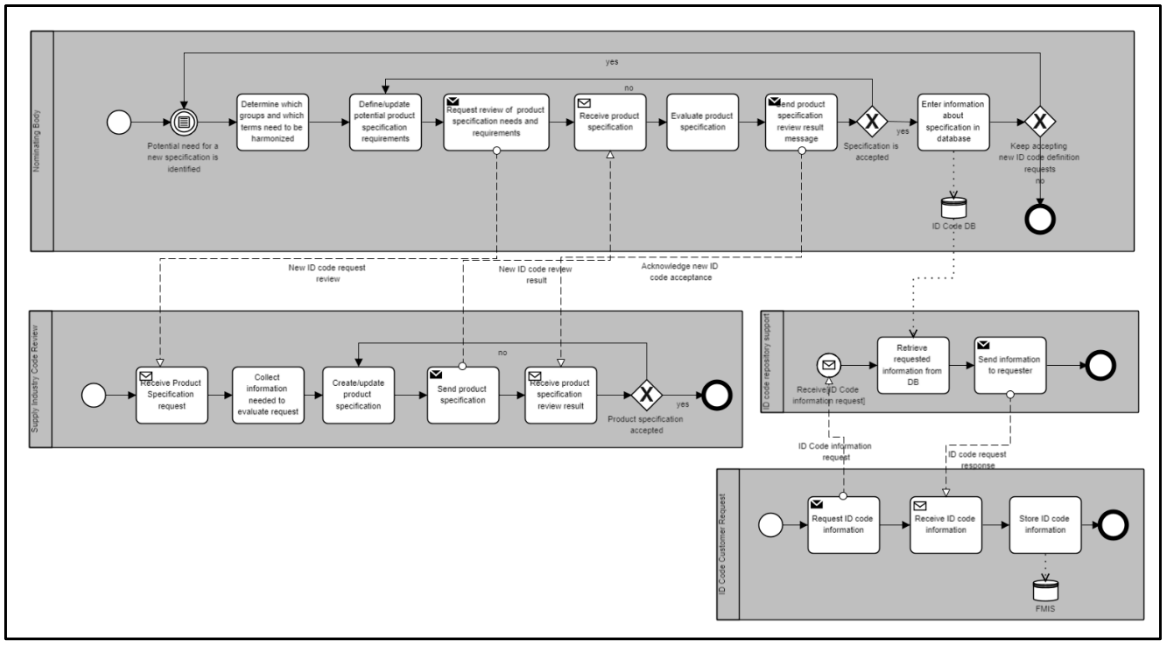


Figure 20: Supply Industry: Produce code development

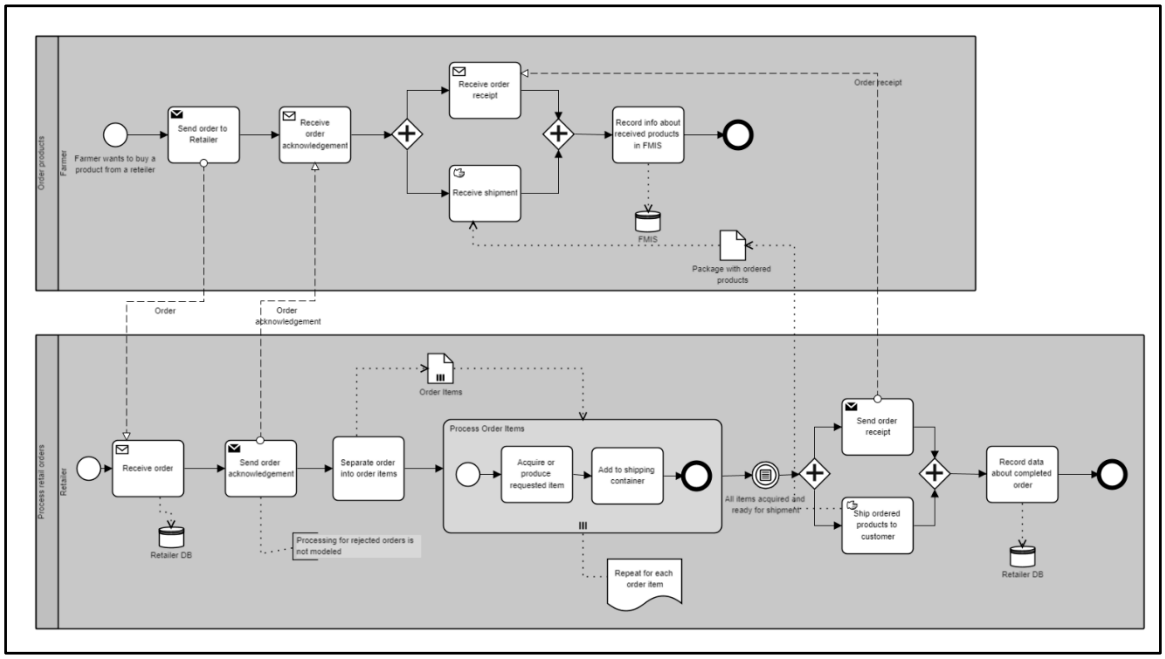


Figure 21: Agricultural Retailer

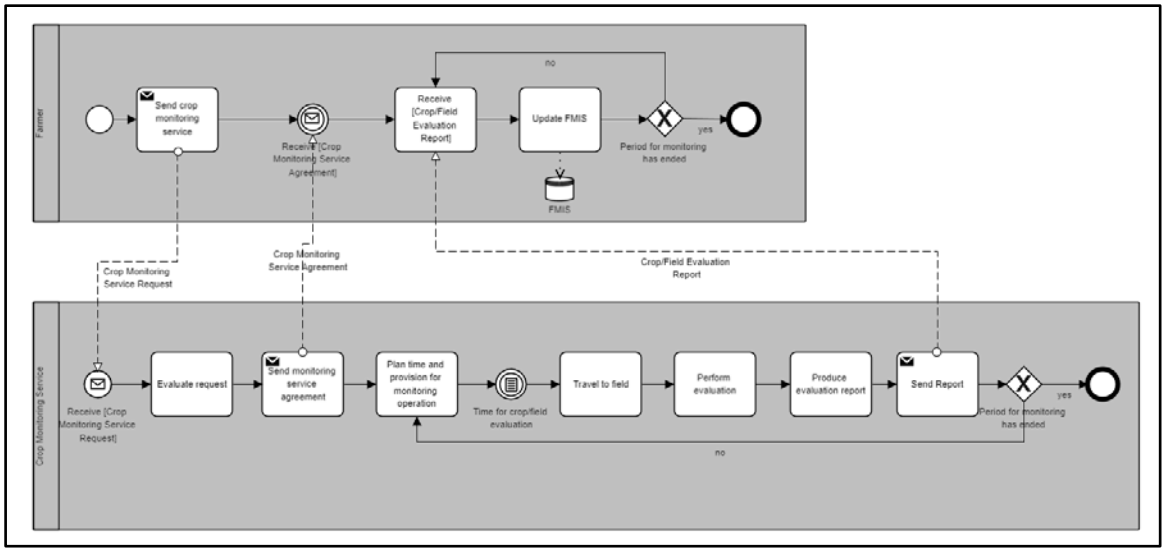


Figure 22: Crop Monitoring by Expert or Service

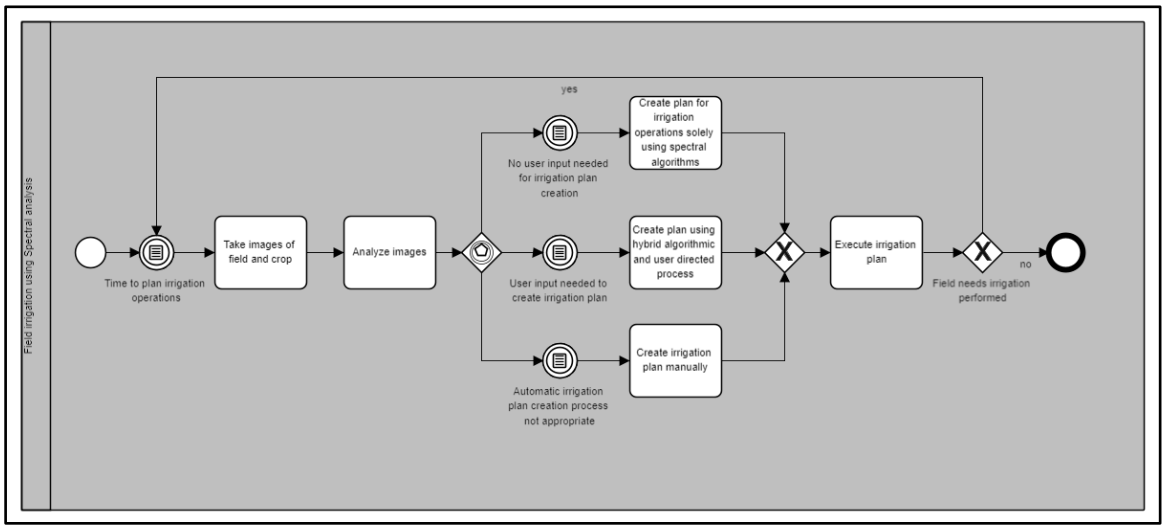


Figure 23: Irrigation using multi-spectral analysis

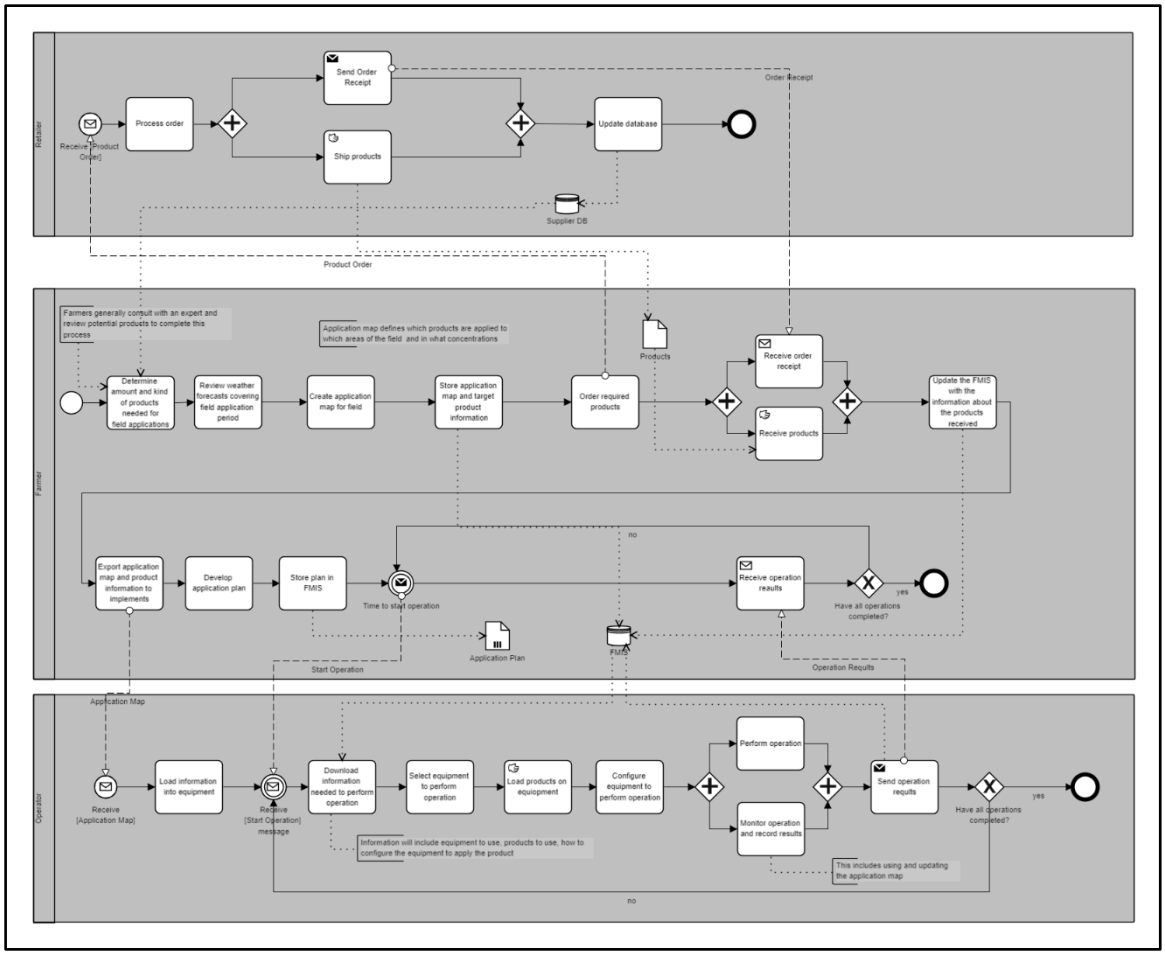


Figure 24: Application of fertilizer

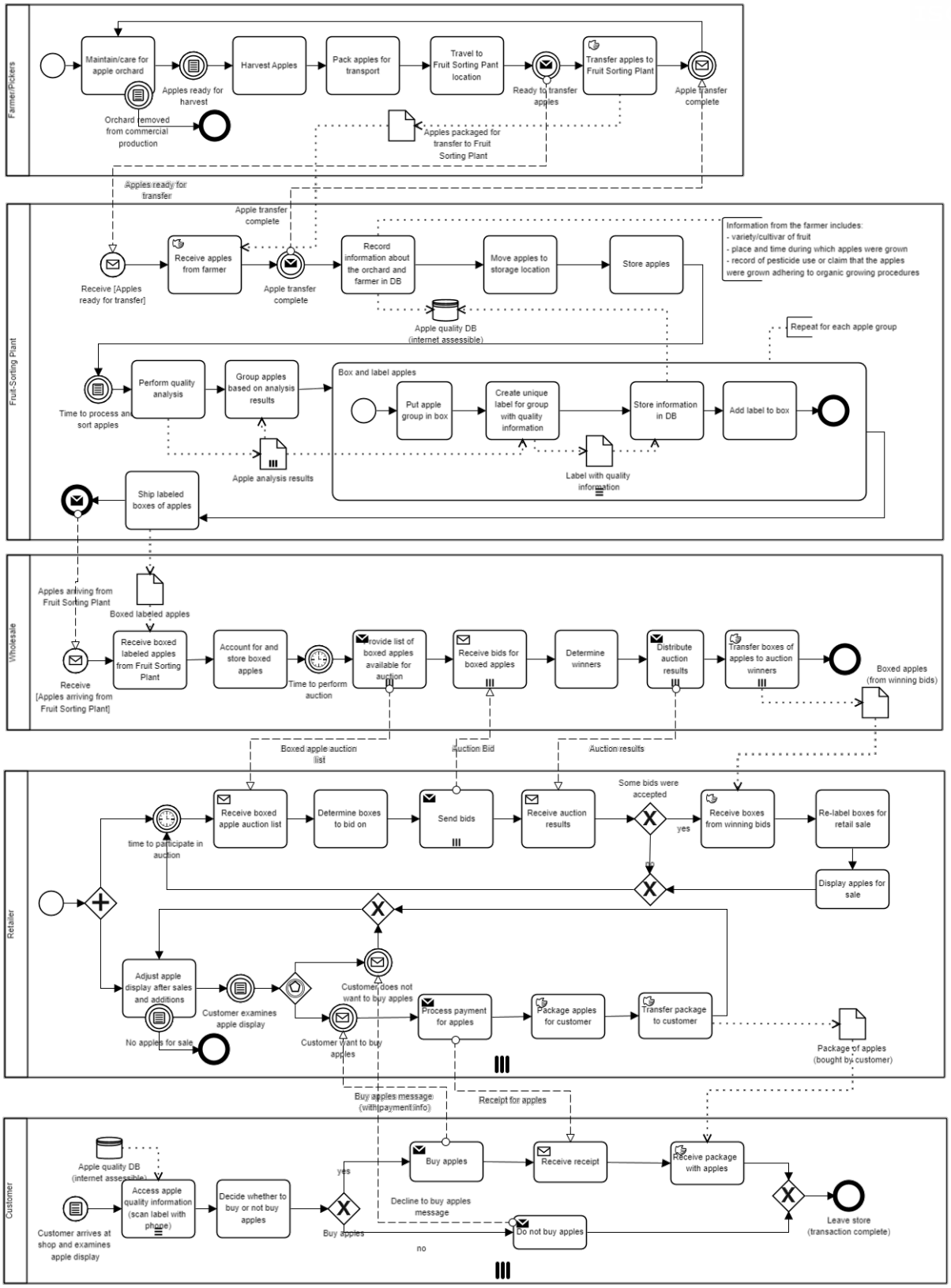


Figure 25: Apple Processing

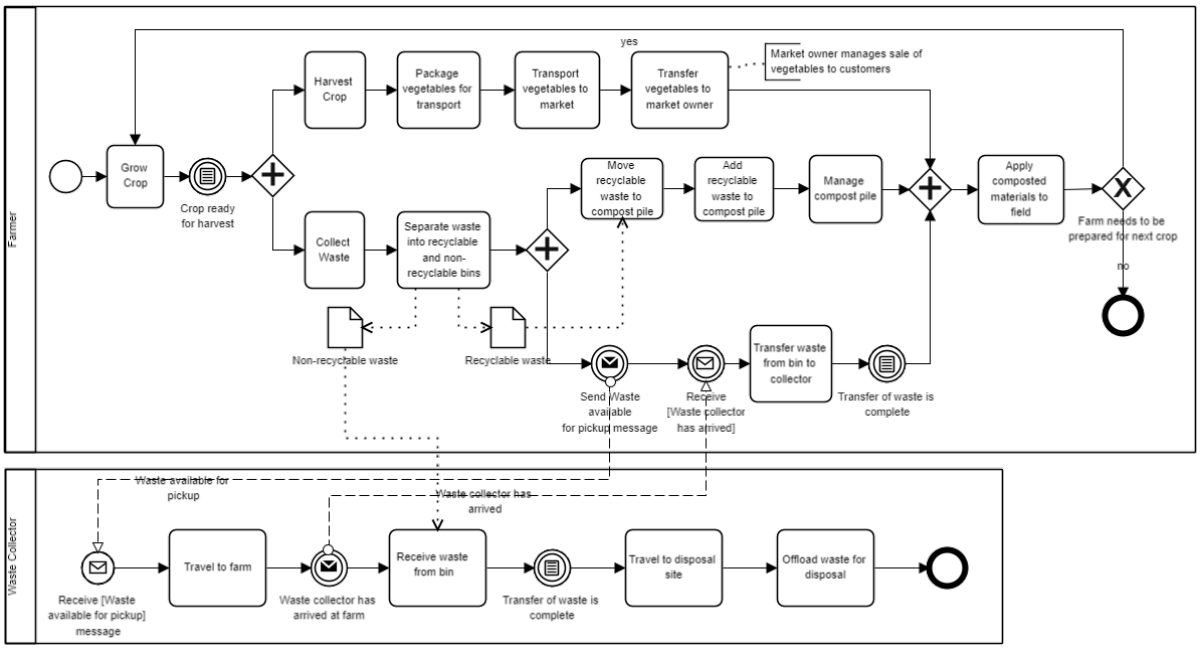


Figure 26: Farm Waste Management

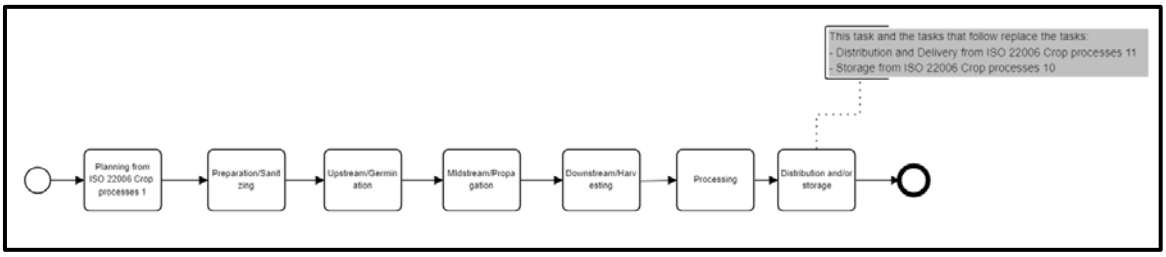


Figure 27: Urban Farming Hydroponics general process

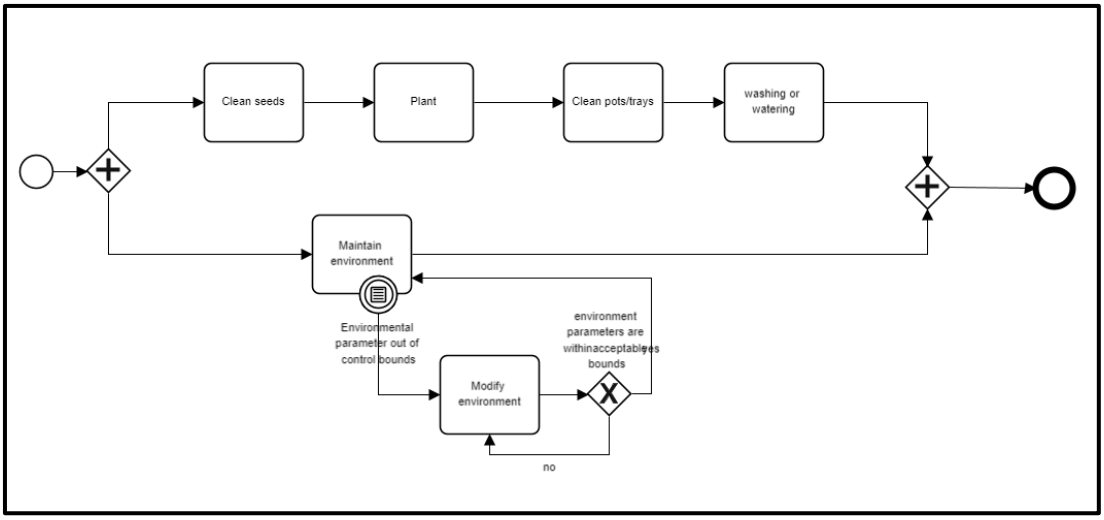


Figure 28: Hydroponics preparation and sanitizing

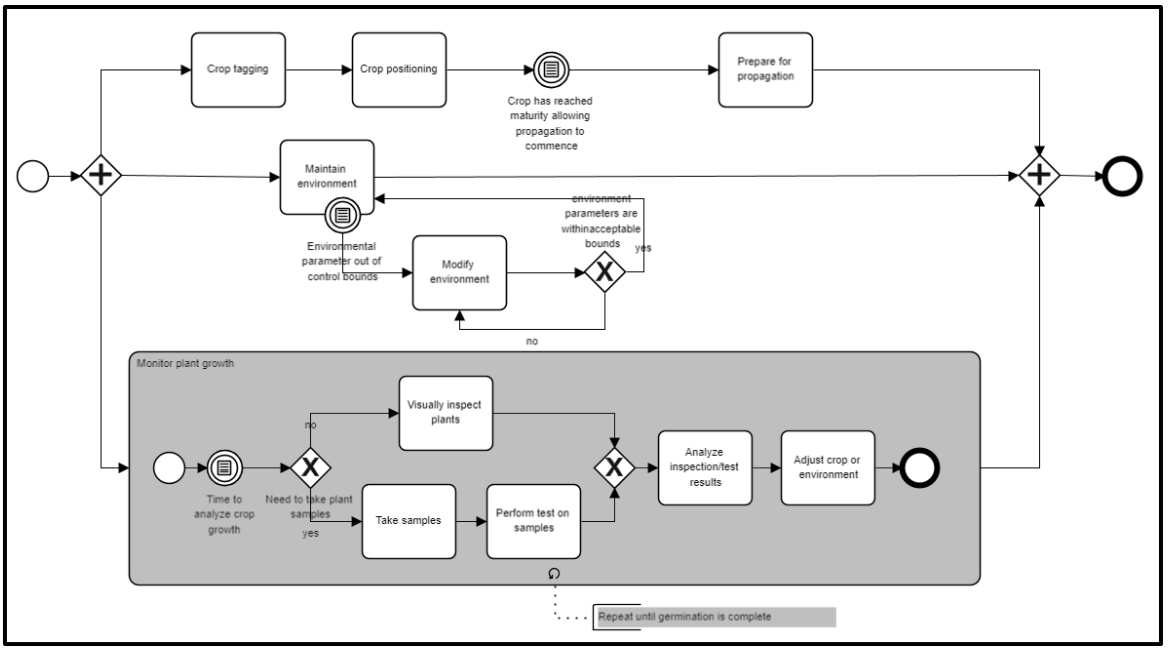


Figure 29: Hydroponics germination

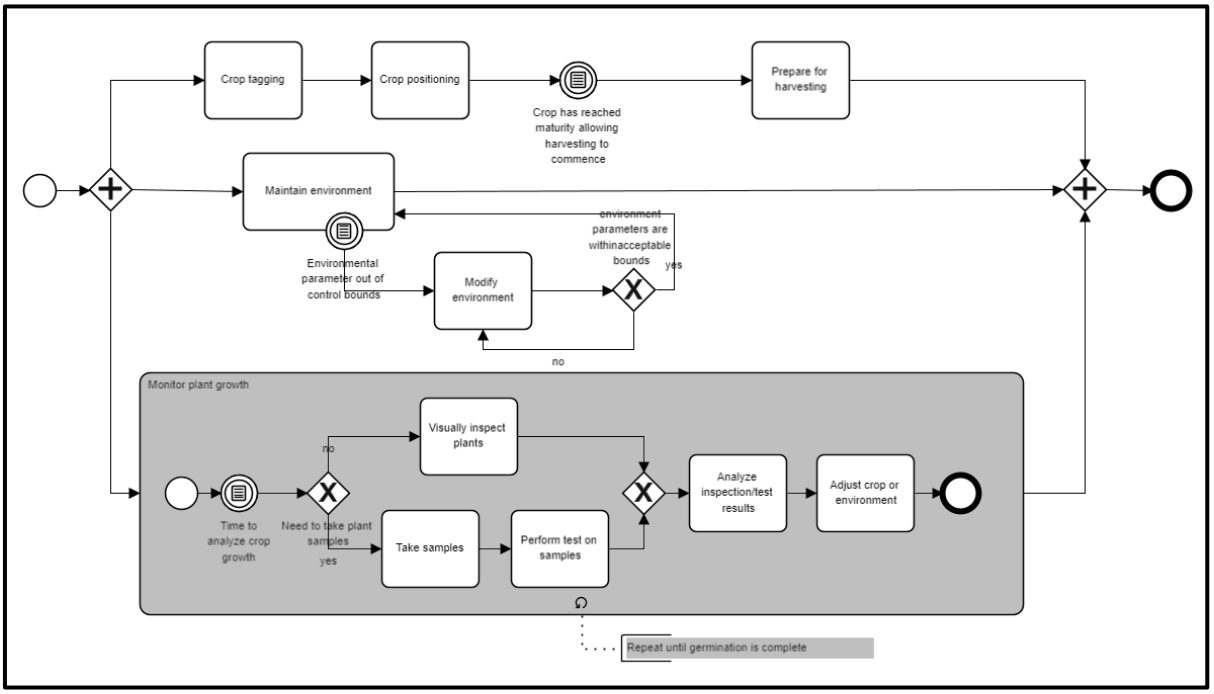


Figure 30: Hydroponics Propagation

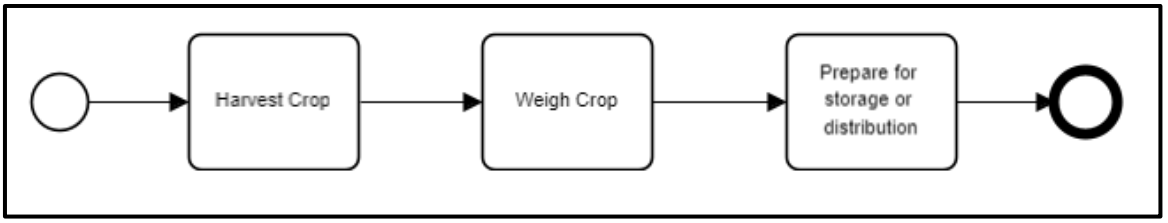


Figure 3: Hydroponics harvesting

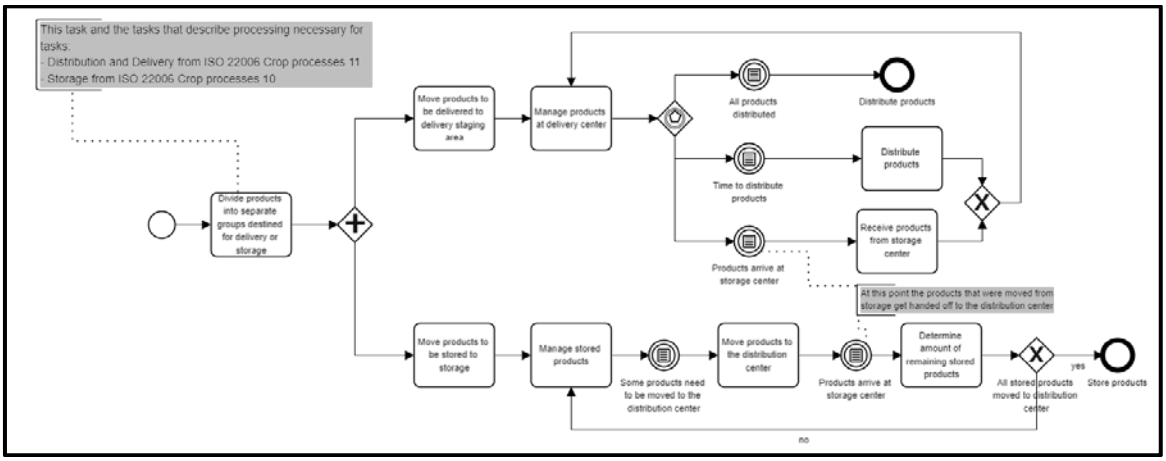


Figure 32: Hydroponics storage and distribution

E.4 Personas

The following personas and relationship diagrams were developed by the SG7 on Social Aspects to determine how the social forces impact their ability to practice smart farming.
Some of the personas are accompanied by causal diagrams, that express relationships between entities in the systems the personas are a part of.

Danial - Smallholder Farmer – non-mechanized in Fariman, Iran.

Product: Organic Saffron

Danial is concerned about the following Items:

- climate change and drought
- low speed of Internet
- high wages of labourers
- high costs of special fertilizer
- limited time for harvesting
- staying with limits of pesticide use
- guaranteed purchase contract of the product
- providing specialized training for harvest, post-harvest and planting the next product
- having specialized advice from experts at the production site
- assistance in the payment of financial aid before harvest
- specialized sales and supply of inputs and raw materials and, if necessary, deducting the amount from the final threshing place
- creating a virtual information and educational system for labourers
- creating an integrated system for the management of farms and cultivated areas
- preparing a comprehensive database of users
- getting assistance in water supply or implement a new irrigation system in saffron fields
- getting timely supply and cash purchase of products through payment by the bank

In-season, Danial will need to:

- prepare and disinfect corm for cultivation
- cultivation of saffron corm (end of June to end of September)
- control pests and weeds
- fertilize
- irrigate (First time Oct-Nov, second time: after harvest, third time: after Weeding and fertilizing, Last time: end of growth time April – May)
- transfer the standards and technical knowledge needed to produce products with higher added value (organic saffron, or products made from petals and other parts of saffron)

Harvest

- hire and supervise laborers for picking saffron flowers by hand, early in the morning
- separate stigma of saffron from flower as soon as possible in order to keep the high quality
- provide specialized and professional devices for drying saffron
- dry saffron stigma by oven, portable and special heater
- store saffron for use during the year

Post-Harvest

- pack and stock saffron in safe place and stock
- apply the and re new for organic certificate
- sample and test for organic certificate
- sell part of product to process factories or exporters
- participate in the final added value
- prepare the field for next crop

Data needs

- list of fertilize and suppliers
- limit of pesticides for organic saffron
- legalization of EU for certifying Organic Products
- list of buyers
- database for hiring laborers
- database of BDS (Business Developers)
- hygiene and health instructions

Information sources

- Agricultural Organisations
- Union of Saffron Growers
- Service Providers
- Saffron Exporters

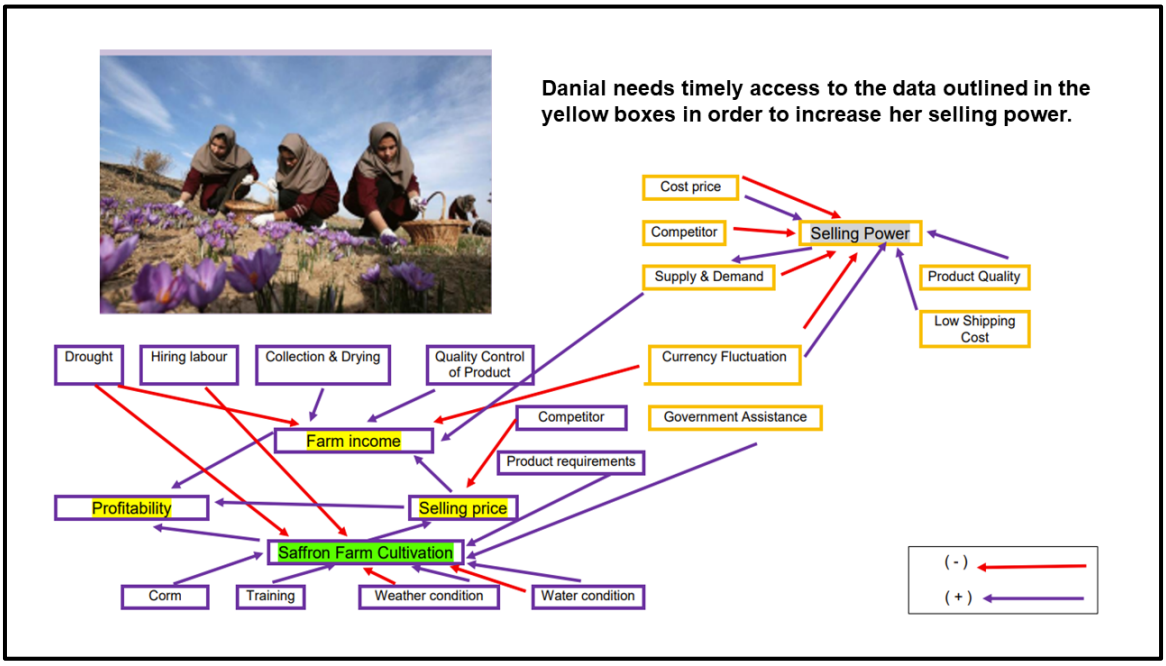


Figure 33: Danial data relationships

Dimitar: Fruit Picker

He is a Bulgarian citizen with a visa under the UK Seasonal Worker scheme.

He works six months of the year in the UK, Kent. He is not fluent in English.

Dimitar is concerned about these things:

- keeping his job
- earning enough money
- safety at work

He is dependent on his employer for:

- housing
- training
- knowledge of health and safety rules and procedures

Dimitar is preparing to go into the field to pick fruit. He needs to:

- understand his responsibilities
- pick fruit quickly and without damage
- ensure he works with the team to transport the fruit to designated parts of the field

While picking:

- he pays attention to ripe and unripe fruit
- he tries to keep hydrated but is dependent on management for break time
- his pace of picking is actively monitored by management
- he understands which part of the field he is responsible for
- he co-ordinates picking and transport logistics with the rest of his team

Souleymane: Agri-tech entrepreneur

Souleymane has a shop selling fertilizer, seed and pesticides in the market at Ouahigouya, Burkina Faso. Primary crops produced by his customers include sorghum, millet, and cowpeas. He would like to offer his customers a one-stop app that would help them diagnose plant disease, insect and other soil nutrient problems.

He has a bachelor's degree from the local lycée. He is literate in both French and Mooré. He has taken a coding class in school but has no practical experience in coding.

Souleymane is concerned about:

- building strong relations with his customers
- providing accurate diagnoses
- cyber security for his customers and his business
- He is often approached by NGOs and by companies with apps that they want him to use. Those apps are incompatible, too narrowly focused, untested, require too much memory space and require signing away data rights.

In planning for next season, Souleymane needs to:

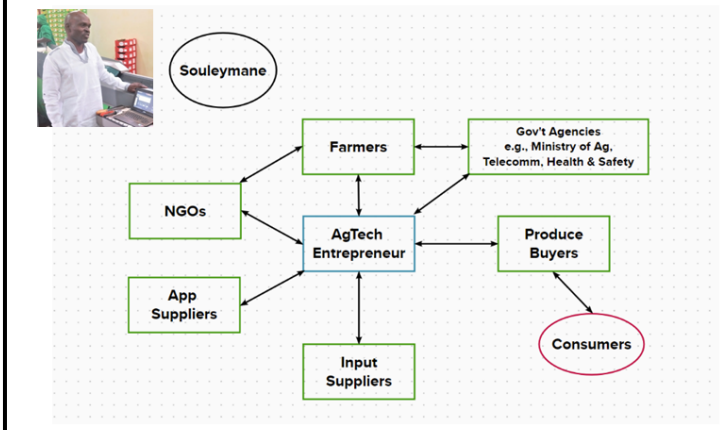
- understand which apps are available and their memory space requirements
- determine which apps are compatible with each other
- data privacy policies of each app developer

In-Season, Souleymane will need to:

- help his customers use the apps he recommends
- have the pesticides and fertilizers on hand which the apps are likely to recommend

Post-harvest, Souleymane, will need to:

- evaluate the apps used this crop season



Social Capabilities Needed:

- Match customer & consumer needs to products, apps, and services
- Build trust with customers
- Provide correct agronomic advice
- Understand Gov't regs and guidelines
- Communication

Potential Standards:

- Format and metadata rules to govern crop & livestock production descriptions
- Format and metadata for crop inputs (e.g., pesticides, seed, fertilizers, etc.)
- Data ownership standards
- Reliability standards for app based diagnostic tools.

Figure 34: Souleymane data relationships

Eve: Manager/owner, small family fruit farm in Hampshire, UK

Third generation owner of a small family fruit farm: strawberries, raspberries and blueberries. She is a UK citizen managing the farm with her husband. She hopes to pass it on to one or both of her two daughters. Eve has overall responsibility for:

- business management and planning
- recruitment and employment
- sales and customer relations

Eve is concerned about:

- providing good quality work with a need for fifty seasonal staff and five full-time staff.
- maintaining a thriving business.
- profit is important, but other values such as sustainability and family succession are vital

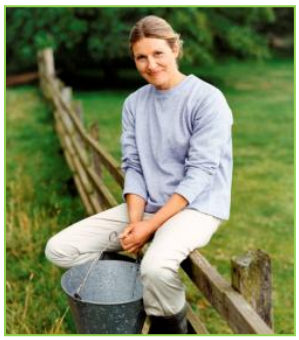
Eve is preparing the farm plan for the next year. She needs to:

- decide what to plant, where, and in what quantity
- predict and plan recruitment
- sustain relationships with customers

While planning, she pays attention to:

- she pays attention to costs and expected income
- tries to create good quality, well paid work
- tries to negotiate a good price for produce
- assesses all options to improve efficiency, including technology, variety, and husbandry
- consults business advisers, agronomists and her family
- engages the local community to discuss issues such as expansion of polytunnels in the local area

Sofia: Smallholder Farmer – non-mechanized; lives in the Rio Negro Province of Argentina



Her primary and most valuable crop is pears

She uses computers to run the farm business, but not much technology for orchard operations

Sofia is concerned about:

- increased drought due to climate change
- currency fluctuations
- speed of mobile internet is slow
- unexpected weather events (e.g., spring frost, followed by hailstorm)
- high international freight costs are squeezing margins

In planning, Sofia needs to:

- acquire market data
- have a soil analysis completed
- create a planting plan

In-season, Sofia will need to:

- drip irrigate and fertilize
- control pests and diseases
- prepare for, and respond to, to weather events

At harvest, Sofia will need to:

- hire and supervise laborers

For post-harvest, Sofia will need to:

- pack and prepare for shipping to Thailand
- reduce her exporting costs and/or or secure government funding

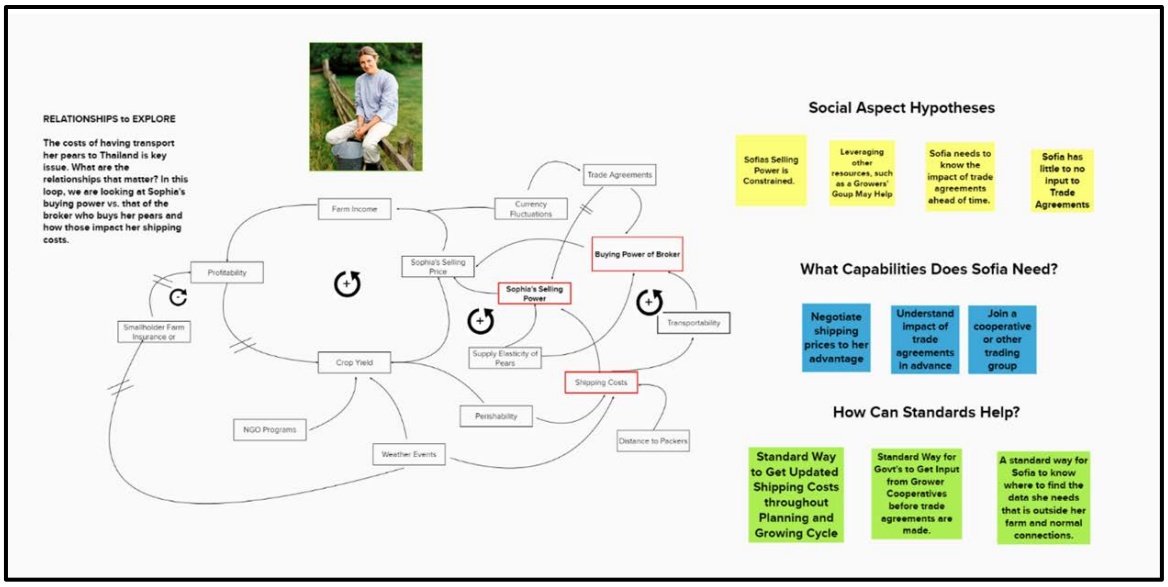


Figure 35: Sofia data relationships

Wolfgang: Smallholder farmer – mechanized; farms in Rotenburg, Germany

Wolfgang is very comfortable with technology; he uses computers, laser beams, drones, etc. He is changing his crop from rye to feed maize to take advantage of the biogas market.

Wolfgang is concerned about:

- downward price pressure from retailers
- inflation on parts and labor
- new restrictions on use of fertilizers and insecticides. He does not trust the official nitrate monitoring data.
- at the same time, he would like to support a bio-diverse environment

Wolfgang is preparing for the next season.

In Planning, he needs to:

- acquire the latest relevant data for the biogas market
- have a soil analysis completed
- create a planting plan

In-Season, Wolfgang will need to:

- irrigate and fertilize his crops
- control for pests and diseases
- respond to weather events

At Harvest, Wolfgang will need to:

- harvest and store maize
- record his yield
- report his use of nitrates and insecticides

Post-Harvest, Wolfgang will need to:

- arrange for transport to the biogas processor

Ian: IT worker and rambler; lives in Shrewsbury, Shropshire, UK

Ian is a British citizen of West Indian origin who grew up in London. He is a devoted rambler who spends at least one day a week year-round in the countryside for mental and physical health. He is a responsible rambler and is aware of the UK Countryside code; he stays on the path when it is clearly marked. While he loves the countryside, he has very little knowledge about agricultural practices, nor does he always understand the practices that he sees. He is concerned about personal safety while hiking.

Ian is planning his walks for the upcoming season. He will need to:

- obtain up-to-date maps of walking paths that are affected by farming operations
- sign up for path related text or email alerts from farmers and local councils
- create a walking plan

While walking, Ian will need to

- pay attention to signs
- monitor his cellphone for path condition alerts

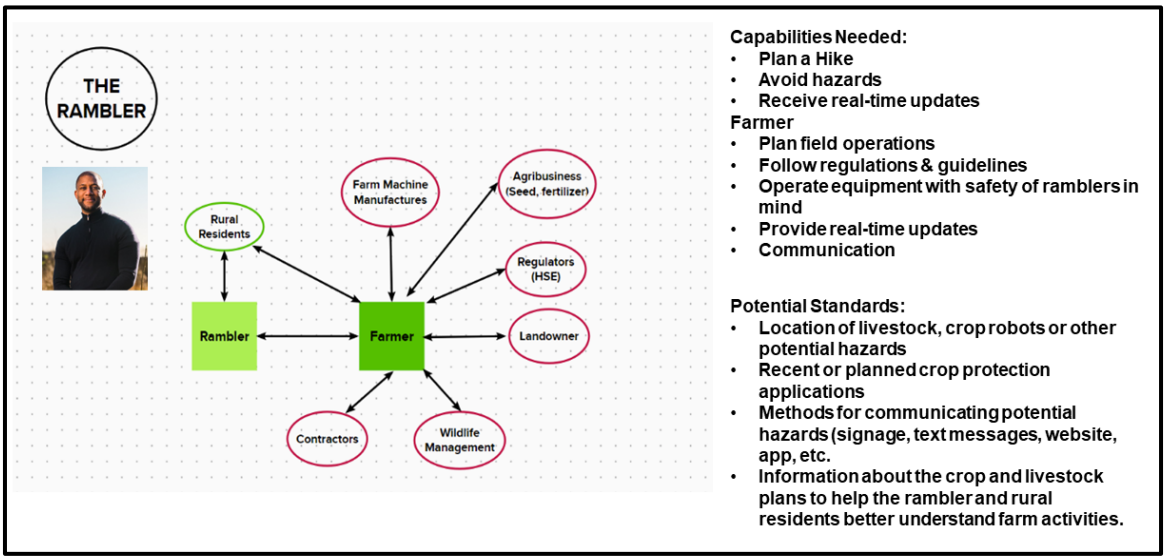


Figure 36: Ian data relationships

Stavros: Olive grower; lives in Greece

Stavros inherited an orchard from his father. He works another orchard that belongs to his brother who lives abroad.
May owe back taxes/increased taxes due to rural land reforms requiring all property to be surveyed using GPS coordinates

Concerned about these things:

- price of inputs (water, fertilizer, etc.)
- government taxation – does not trust government; is penalized with double tax rate for being more productive.
- disposal of agricultural waste.
- insurance coverage – does not trust government or private insurer
- wildfires

Needs to:

- maintain health of trees throughout the year
- source labor to harvest olives in the wintertime, typically crews of Serbians and Bulgarians
- dispose of agricultural waste without causing a widespread fire
- sell olives
    - some sold for cash locally
    - bulk sold to wholesalers (domestically and abroad)
- produce oil
    - some for personal use
    - some to sell for cash
    - some to sell to domestic wholesalers
    - some to sell to wholesalers abroad (typically send to Italy).

Colleen – Household consumer of organic produce; lives in Richmond, Virginia USA

Collen is solidly middle class. She

- has no scientific background
- has no tie to agriculture or farming
- is very health conscious
- environmentally conscious

When buying groceries, Colleen:

- will patronize farmer's market as a social activity, not as part of her regular shopping
- does not doubt claims that produce marketed as organic is indeed so.
- does not understand that organic does not necessarily mean pesticide- or fungicide-free
- is confused by competing labelling systems
- shifts burden of educating herself by purchasing organic products at retailers like Costco, Trader Joe's, and Whole Foods
- thinks there should be a scientific test to determine whether a fruit or vegetable is "organic" or not.

While shopping:

- Colleen does not consider where organic produce is sourced from (domestically versus internationally) and therefore does not consider CO_2 emissions from packaging and transport.
- Colleen does not know that produce are treated with fungicide to enable lengthy international travel
- Colleen is unaware of where organic produce is grown (greenhouses versus vertical farms versus fields) and who is doing the growing
- Colleen has no way of understanding what labor force is involved to pick and pack her produce and who is performing the labor and under what conditions.
- Is baffled that produce shipped from abroad is often cheaper than American-grown produce

National Farmers' Federation of Australia

The following set of personas was developed by, and included with permission from, the National Farmers' Federation of Australia.

Farmer 1: Paul, 64yrs old, sugar cane grower in QLD for 40 yrs. Employs 2 staff. Uses some technology on farm but only what's necessary. (Represents approx 60-80% of farmers)

Motivations
- Family, community, country lifestyle
- Cost effectiveness
- Good profit
- Sustainability

Jobs
- Grow produce
- Improve/upgrade equipment
- Employ staff
- Market produce
- Manage the farm business
- Manage production

Behaviours
- Purchase decisions based on relationships and word of mouth
- No time to look into data sharing issues
- Don't read software T&Cs because they are difficult to read
- Heard about data having value but doesn't understand how it applies to him
- Gets benchmarking reports from their RDC
- Assumes it is illegal for someone to share their data without permission
- Shares data with agronomist via an app

Pains
- Produce prices, export conditions
- Weather
- Time poor
- Can't negotiate software T&Cs, and can't get data out of his machines without accepting the T&Cs
- Reporting biosecurity data and audits
- Has had his email hacked once
- Can't get production data from the processing plant
- Has to provide financial data and production data to the bank
- Has to provide information about the farm to the insurance company or get charged a higher premium
- Has a lot of old paper records which are difficult to share
- Unsure whether providers manage data as they say they will

Farmer 2: Jude, 41 yrs old, cattle farmer in WA for 5 yrs. Employs 10 staff. Cautiously excited about AgTech, seeks innovation. (Represents approx 5-15% of farmers)

Motivations
- Family, community, country lifestyle
- Helping her industry grow
- Growing the business
- Health animals
- Sustainability
- Retaining control of her data

Jobs
- Raise cattle
- Improve/upgrade equipment
- Employ staff
- Market produce
- Manage the farm business
- Manage production

Behaviours
- Purchase decisions based on research
- Involved in several farmer groups
- Reads about new technology and goes to AgTech demos at field days
- Looks for software with good tech support
- Participates in research projects and AgTech pilots
- Aware about data sharing issues
- Shares her data with a benchmarking group
- Shares data with an advisor via an app
- Sees AgTech/precision agriculture as a way to reduce the risks inherent in farming; data helps you make better decisions
- Sells livestock at 20% premium because it has good data attached to it e.g. weight history, fertility history

Pains
- Produce prices, export conditions
- Weather
- Time poor
- Had her farm data accidentally shown in a demo at a field day
- Getting data from one software to another with limited technical skill
- Long and difficult to read software T&Cs, and no specific legal help available to read them
- Lost data due to a AgTech start-up closing down
- Ran out of feed one year due to incorrect information provided by software that was being piloted
- Research project contracts obscurely include data in IP clauses
- Research project results take long to get and are not always relevant

Jude, Cattle Farmer, relies on both onsite and external data to achieve profitability.

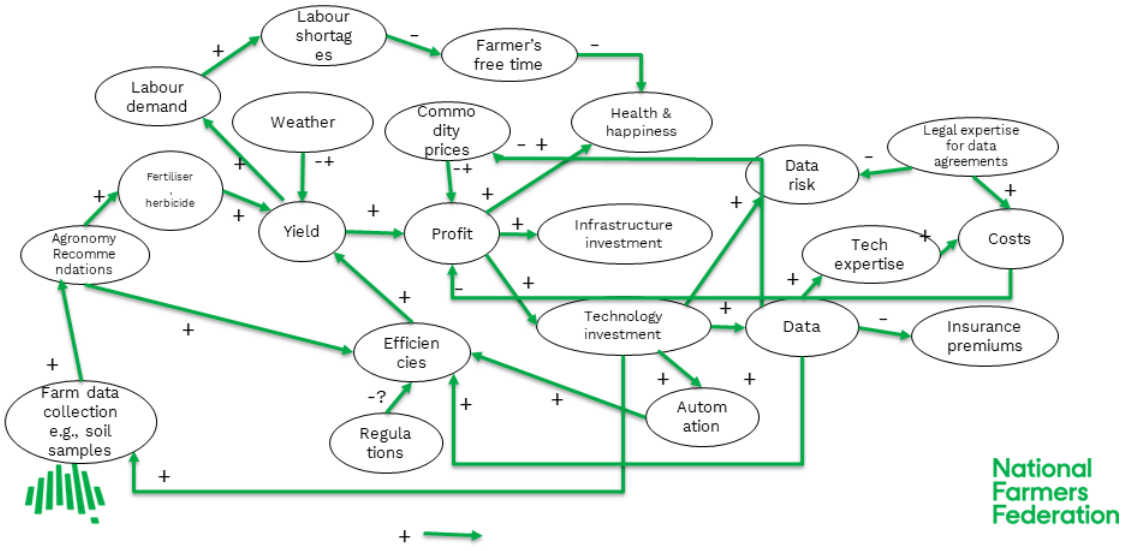
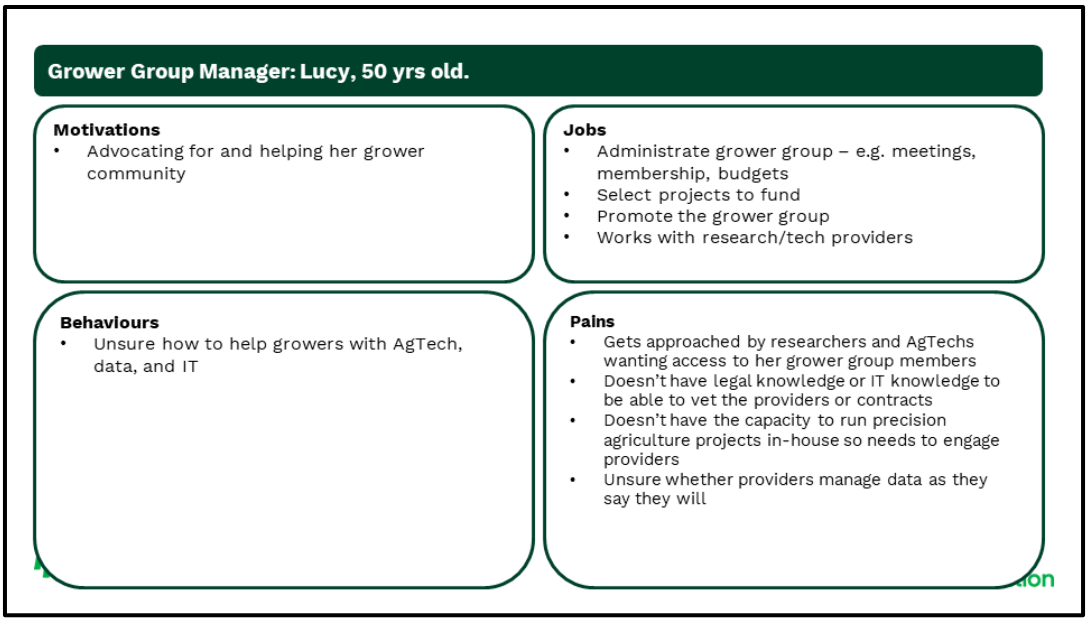
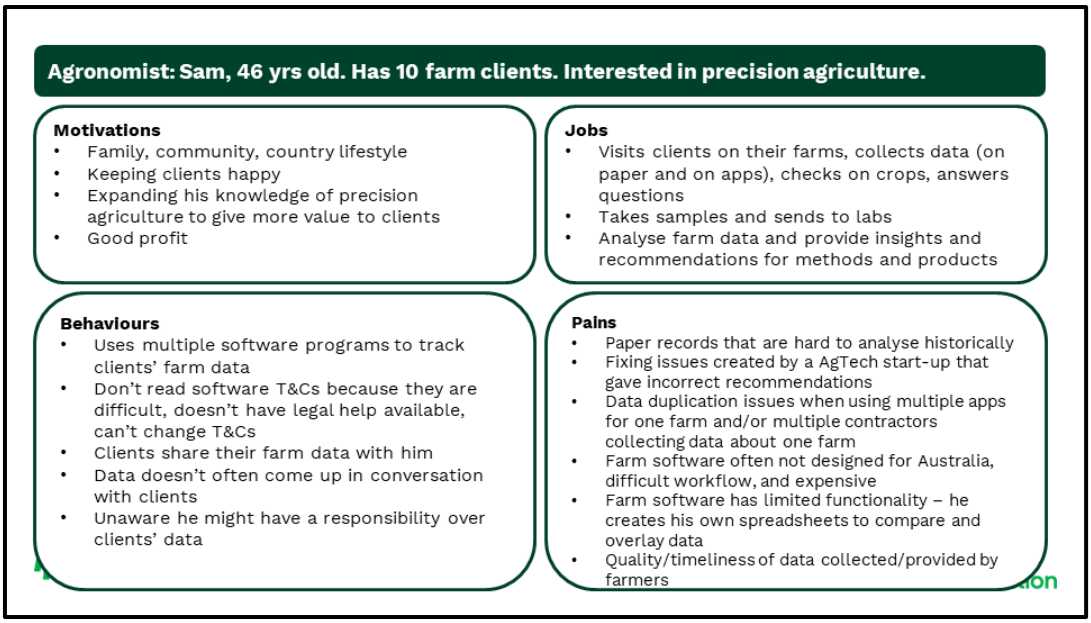


Figure 37: Jude Data Relationships


Grower Group Manager: Lucy, 50 yrs old.
Motivations
• Advocating for and helping her grower community
Jobs
• Administrate grower group – e.g. meetings, membership, budgets
• Select projects to fund
• Promote the grower group
• Works with research/tech providers
Behaviours
• Unsure how to help growers with AgTech, data, and IT
Pains
• Gets approached by researchers and AgTechs wanting access to her grower group members
• Doesn't have legal knowledge or IT knowledge to be able to vet the providers or contracts
• Doesn't have the capacity to run precision agriculture projects in-house so needs to engage providers
• Unsure whether providers manage data as they say they will


Agronomist: Sam, 46 yrs old. Has 10 farm clients. Interested in precision agriculture.
Motivations
• Family, community, country lifestyle
• Keeping clients happy
• Expanding his knowledge of precision agriculture to give more value to clients
• Good profit
Jobs
• Visits clients on their farms, collects data (on paper and on apps), checks on crops, answers questions
• Takes samples and sends to labs
• Analyse farm data and provide insights and recommendations for methods and products
Behaviours
• Uses multiple software programs to track clients' farm data
• Don't read software T&Cs because they are difficult, doesn't have legal help available, can't change T&Cs
• Clients share their farm data with him
• Data doesn't often come up in conversation with clients
• Unaware he might have a responsibility over clients' data
Pains
• Paper records that are hard to analyse historically
• Fixing issues created by a AgTech start-up that gave incorrect recommendations
• Data duplication issues when using multiple apps for one farm and/or multiple contractors collecting data about one farm
• Farm software often not designed for Australia, difficult workflow, and expensive
• Farm software has limited functionality – he creates his own spreadsheets to compare and overlay data
• Quality/timeliness of data collected/provided by farmers

AgTech company 1: small start up "WeGrow", 10 staff, 1 yr old. Product aggregates data and provides sowing recommendations.

Motivations
- Growing the company
- Increase revenue/investment
- Innovation

Jobs
- Product design and development
- Customer acquisition
- Public and investor relations
- Scaling processes and team

Behaviours
- Most staff are filling multiple roles and are stretched in many directions
- Assume that they own data they processed, aggregated, and derived
- Don't understand the potential negative consequences for the farmer of sensitive/identifying data being shared
- Business model is built on selling insights about farmers to third parties
- Use data to improve their products

Pains
- Cashflow is tight
- No company history - difficult to get customers to trust you
- Competing with established companies
- Australian agri market small – only 2% of global – can't make enough $ in Au to be viable
- Difficult to get investment funding in Australia
- Limited legal expertise, often use contract templates or write own contracts
- Slow cycles in agriculture – one harvest per year means product iteration and testing is slow
- Difficult to find data management standards
- Data quality and structure – it takes effort to make data usable
- Farm data difficult to completely de-identify
- Cyber-security threats
- Get approached by other organisations for access to farm data e.g. banks

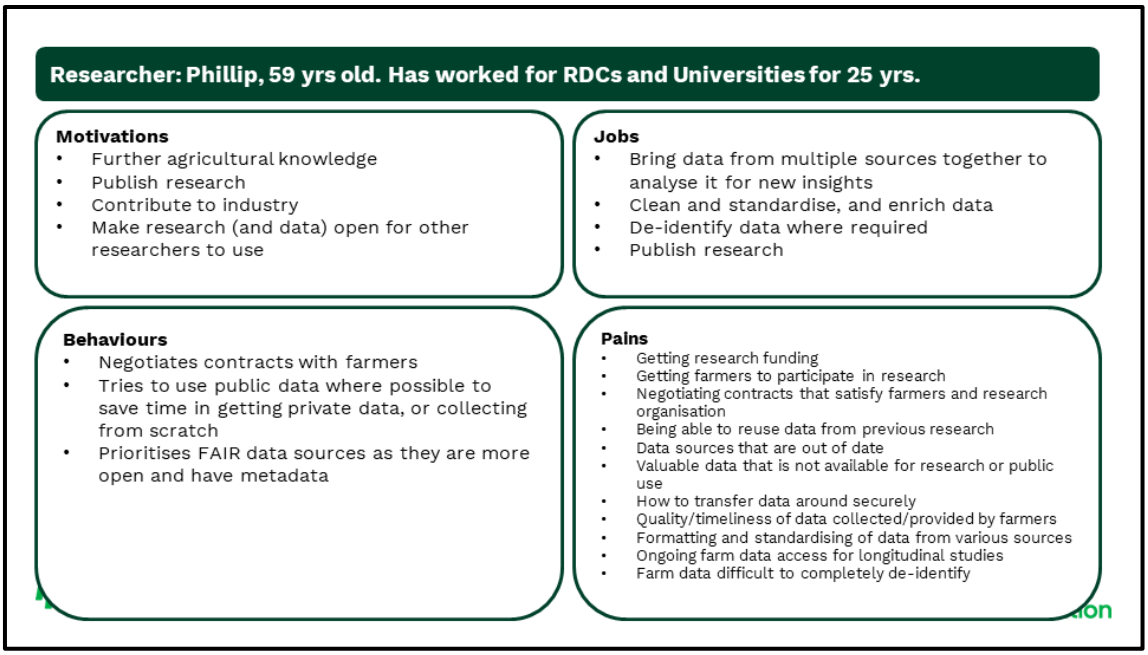
AgTech company 2: global company "AgriCo", 8000 staff, 25 yrs old. Product is rain and soil sensor device that provides land management recommendations.

Motivations
- Increase profit
- Increase market share
- Protecting reputation
- Limiting legal exposure

Jobs
- Product development and maintenance
- Customer management
- Public and investor relations

Behaviours
- Hierarchical structure with busy executives
- Assume that they own data they processed, aggregated, and derived
- Don't understand the potential negative consequences for the farmer of sensitive/identifying data being shared
- Has a large legal team that creates long contracts and T&Cs
- Does not negotiate on T&Cs with individual users
- Update T&Cs only every 6-12 months because they are onerous to draft and to get all users to accept
- Share users' farm data with subsidiaries that generate benchmarking reports
- Use data to improve their products

Pains
- Easy target for negative media, which creates distrust
- Farm data difficult to completely de-identify
- Data quality is challenging and not possible to correct as there is no process to talk to individual users


Researcher: Phillip, 59 yrs old. Has worked for RDCs and Universities for 25 yrs.
Motivations
Further agricultural knowledge
Publish research
Contribute to industry
Make research (and data) open for other researchers to use
Jobs
Bring data from multiple sources together to analyse it for new insights
Clean and standardise, and enrich data
De-identify data where required
Publish research
Behaviours
Negotiates contracts with farmers
Tries to use public data where possible to save time in getting private data, or collecting from scratch
Prioritises FAIR data sources as they are more open and have metadata
Pains
Getting research funding
Getting farmers to participate in research
Negotiating contracts that satisfy farmers and research organisation
Being able to reuse data from previous research
Data sources that are out of date
Valuable data that is not available for research or public use
How to transfer data around securely
Quality/timeliness of data collected/provided by farmers
Formatting and standardising of data from various sources
Ongoing farm data access for longitudinal studies
Farm data difficult to completely de-identify

Annex F: Glossary

The glossary that follows was constructed by the SAG-SF's Terminology and Semantics subgroup, with the intent to help the reader unambiguously interpret the text of this report. It is not meant to be used as a proposed glossary for the smart farming domain. That being said, wherever possible the definitions were taken from relevant ISO standards.

actor

Definition

An Actor specifies a role played by a user or any other system that interacts with the subject.

Notes

SG6 Semantics and terminology

actuator

Definition

device that provides a physical output in response to a input signal in a predetermined way

Notes

SG2: Livestock

agricultural domain

Definition

The realm encompassing the art and science of cultivating the soil, growing crops and raising livestock including the preparation of plant and animal products for people to use and their distribution to markets.

agricultural waste

Definition

Agricultural waste is waste produced as a result of various agricultural operations. It includes manure and other wastes from farms, poultry houses and slaughterhouses; harvest waste; fertilizer run- off from fields; pesticides that enter into water, air or soils; and salt and silt drained from fields.

Notes

SG9 Supply Chain

agrisemantics

Definition

Agrisemantics describes technologies, processes, and digital content that address an important problem in digital agriculture: the communication of meaning (semantics) among farm management information systems and equipment such as farm machinery, sensors, and other connected devices. Agrisemantics addresses developing, implementing and maintaining infrastructure to provide the agrifood industry with controlled vocabularies, variable-type registries and other tools and services seeking to enable the communication and preservation of the meaning of digital agriculture data as it is exchanged among various agriculture-related parties. This includes but is not limited to things like observations and measurement codes (codes to enable accurately expressing what is being measured or observed in operations like crop scouting, field instrumentation, and so forth; for example, mean daily air temperature, volumetric soil water content at 38 cm, and so forth), and representations (variables that are used in some systems to represent machine-logged data and other variables).

ajwa

Definition

Date paste used in traditional sweets in the Kingdom of Saudi Arabia.

Notes
SG9 Supply Chain

animal food

Definition
Single or multiple product(s), whether processed, semi-processed or raw, which is (are) intended to be fed to non-food-producing animals
Note 1 to entry: Distinctions are made in this document between the terms food(3.18), feed(3.16) and animal food(3.19):

- — food is intended for consumption by humans and animals, and includes feed and animal food**;**
- — feed is intended to be fed to food-producing animals;
- — animal food is intended to be fed to non-food-producing animals, such as pets.

[SOURCE: CAC/GL 81-2013, modified — The word “materials” has been changed to “products”, “non” has been added and “directly” has been deleted.]
ISO 22000:2018(en), 3.19
Notes
SG9 Supply Chain

application

Definition
⟨crop production⟩ treatment of the crop, soil or other medium with an input designed to aid in meeting requirements
EXAMPLE Treatments include fertilizers, insecticides, or fungicides.

artificial intelligence agent

Definition
automated entity that senses and responds to its environment and takes actions to achieve its goals
Notes
SG2: Livestock

audit

Definition
systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled
Notes
SG9 Supply Chain

auditor

Definition
person who conducts an audit
[SOURCE:ISO/IEC 17021-1:2015, 3.6]
Notes
SG2: Livestock

authorization

Definition
granting of rights, which includes granting of access based on access rights
Notes

SG2 Livestock

biodiversity conservation

Definition

active management of the ecosystem to ensure the survival of the maximum diversity of species and the maintenance of genetic variability within them

broker

Definition

entity that acts as a middleman or intermediary

Note 1 to entry: Such organizations take multiple orders from multiple sources and consolidate them into a single order for a provider or they take single orders from an originator and split them among multiple providers or they just pass orders through between originators and providers.

Notes

SG9 Supply Chain

butcher

Definition

a person who may slaughter animals, dress their flesh, sell their meat, or participate within any combination of these three tasks

Note: A butcher may prepare standard cuts of meat and poultry for sale in retail or wholesale food establishments. A butcher may be employed by supermarkets, grocery stores, butcher shops and fish markets, slaughter houses, or may be self-employed.

Notes

SG6 terminology and semantics

cadastral survey

Definition

topographic survey to determine and record the boundaries of properties

Note 1 to entry: The accuracy of the determination depends on the scale and purpose of the mapping.

Notes

SG2 LIVESTOCK

capability

Definition

measure of ability to perform and support a function

certification

Definition

issue of a statement by third party, based on a decision following a review, that fulfilment of specified requirements has been demonstrated

Notes

SG2 Livestock

chain of custody

Definition

process by which *inputs* and *outputs* and associated information are transferred, monitored and controlled as they move through each step in the relevant *supply chain*

Notes

Each organization active in the apparel chain of custody ensures that the minimum supply chain requirements for the segregated model are met. The specified characteristic in this example is 100 % recycled material, being input that has been recovered from post consumer use at some point.

climate change mitigation

Definition

human intervention to reduce GHG emissions or enhance GHG removals

[SOURCE:ISO 14080:2018, 3.1.2.1, modified — The preferred term “mitigation” has been added, and the words “to reduce the sources or enhance the sinks of greenhouse gases (GHGs)” have been replaced with “to reduce GHG emissions or enhance GHG removals” in the definition.]

Notes

SG2 Livestock

competent authority

Definition

1) organization or organizations which implement the requirements of legislation and regulate installations which must comply with the requirements of legislation

2) veterinary authority or other governmental authority of a country having the responsibility and competence for ensuring or supervising the implementation of animal health and welfare measures, international veterinary certification and other standards and recommendations in the OIE TAHC

[SOURCE:ISO/TS 34700:2016, 3.7]

Notes

SG2 Livestock

configuration data

Definition

Data that describe aspects of the state or context of one particular instance of a thing (for example, GPS offsets on a machine or implement)

conveyance

Definition

- means of transport
- vehicle or trailer used to transport from one place to another

Notes

SG2 Livestock

crop

Definition

1) plants cultivated collectively for an intended use or purpose

2) product of a particular kind or geographical location which is an element in the definition of the product

3) growing season or year which is an element in the definition of the product

4) wild harvest not formally planted or managed

Notes

SG9 Supply Chain

customer

Definition

1) individual or organization that purchases or receives a product

Note 1 to entry: The term customer includes but has a broader meaning than consumer.
2) ⟨crop production⟩ party that receives the output(s) of the product(s) [crop(s)] or services of farm operations
NOTE The customer can be internal or external to the farm operation and may include the end-user of the product(s) of farm operations. Other bodies, such as government or industry organizations, when they stipulate product or process requirements, can be considered to be customers.
Notes
SG2 Livestock

cybersecurity

Definition
safeguarding of people, society, organizations and nations from cyber risks
(ISO/IEC TS 27100:2020(en) Clause 3.2)
Notes
Note 1 to entry: Safeguarding means to keep cyber risks at a tolerable level.

data

Definition
reinterpretable representation of information in a formalized manner suitable for communication, interpretation, or processing (ISO/IEC 25024:2015 clause 4.5)
Note 1 to entry: Data can be processed by humans or by automatic means.
[SOURCE:ISO/TS 19104:2008, B.103]
Notes
SG2 Livestock

data dictionary

Definition
listing of data variables and their identifiers. (ISO 11783-10, clause 3.11)

data interoperability

Definition
the capacity to which data can be analyzed and/or merged with similar data. Data interoperability relies on data standards, data documentation, and metadata to indicate to researchers which data sets or variables are comparable.

data repository

Definition
- set of files, document(s) or databases combined with a storage placement system, a processing system and a retrieval system
- functional unit that stores and retrieves data
Notes
SG2 Livestock

data type

Definition
domain of values (ISO 10303-11:2004, clause 3.3.5)

data type definition

Definition

Machine-actionable record of the properties of a data type, such as its name, a unique ciode or identifier to designate it with, the data type its values can take (e.g., integer, real, etc.), the enumerated values in case of an enumerated data type, etc.

data type registry

Definition

information system for registering data types.

diffuse source pollution

Definition

pollution of surface or ground waters which arises not from a single point but rather in a widespread manner
EXAMPLE:
Leaching from the land

Notes

SG2 Livestock

digital farming

Definition

In the context of the SAG-SF, this was considered an evolution from the idea of precision farming, with a greater emphasis on using data to drive decision-making, and a greater use of farm management systems, scouting solutions. Its goal tends primarily (but not exclusively) toward maximizing profitability.

effluent

Definition

flow of waste material discharged into the environment

Notes

From ISO/TR 27912:2016(en), 3.28
SG2 Livestock

equipment reference data

Definition

Reference data describing all instances of a certain type of equipment; e.g., the operating parameters of a certain brand and model of equipment.

evapotranspiration

Definition

process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants

Notes

SG9 Supply Chain

event

Definition

1: noteworthy occurrence that happens at a point in time or during a temporal interval
2: A *message* sent from one *node* to another as defined by a *route*. *Events* signal external stimuli, changes to *field* values, and interactions between nodes. An event consists of a *timestamp* and a field value

Notes
SG2 Livestock

FAIR Principles

Definition
FAIR Principles: the 'FAIR Guiding Principles for scientific data management and stewardship' are a set of technical attributes published in *Scientific Data i*n 2016 to increase the Findability, Accessibility, Interoperability, and Reusability of data, emphasizing machine actionability due to our increasing reliance on computational systems when dealing with data.

- **Findable:** data and metadata are online and openly searchable with a persistent link that is uniquely attached to each specific dataset.
- **Accessible:** data and metadata are retrievable in machine-actionable form, with downloading options clearly described (including any needed authentication).
- **Interoperable:** data and metadata are consistently structured and described, both syntactically and semantically, so that algorithms can parse and ensure like data are accurately compared to like.
- **Reusable:** data and metadata are sufficiently annotated so machine and human users can determine fit-for-purpose in the context of their analysis.

farm

Definition
tract(s) of land or facilities under a farm management system devoted to agricultural or horticultural production

farm consultant

Definition
lives in a rural community and acts as a resource for farmers on a range of topics from agricultural technology to the issues facing the modern rural family

farm management

Definition
person or group of people that manage a farm on a day to day basis

farm management information system FMIS

Definition
office computer system used by a farmer or contractor that includes the software for farm management, such as book keeping, payroll, resource management for machines, products, workers, field management, geographical information system, decision support systems and task management
Notes
FMIS is an evolving technology, that has in broad terms gone through three generations:

- First-generation Farm Management Record Systems (FMRS) are simple computer or cloud repositories of farm records that otherwise would have been recorded in notebooks, diaries etc. A key concept is that FMRSs do not provide any information that farmers did not already know.
- Second generation: In addition to storing records uploaded by farmers, these systems also ingest data from IoT sensors and the like and make those data available to farmers and their advisors, on which they can make better informed decisions.
- Third generation Farm Management Decision Systems are FMISs with the added capability to ingest data and make decisions algorithmically, which can then be made available to farmers and growers

and their advisors, usually in three categories after the system reaches a decision, (a) the system alerts the farmer and awaits a response before action e.g. a predictive irrigation schedule is generated but nothing happens until the farmer approved the schedule (b) the system alerts the farmer advising an action will be implemented until cancelled e.g. stock water is low but daily water consent limits are about to be breached or (c) the system determines an action needs to be taken, and takes that action and advises the farmer accordingly e.g. a travelling effluent irrigator distributing effluent onto pasture has jammed and stopped moving and will imminently over-apply in one place in the field, thus breaching allowed application rate limits and leaching contaminants into the water table, so the system shuts off the effluent pump.

SG1 Crop Production
SG2 Livestock

farm operation

Definition

farm and the activities used by the farm to produce crops

Note 1 to entry: A farm operation refers to all of the management and physical activities related to the production of various crops.

farm worker

Definition

person engaged in agriculture, whether as a wage earner or a self employed person such as a tenant, sharecropper, or smallholder

Note 1 to entry: Agricultural workers are defined in ILO Convention 141[15].

Notes

SG2 Livestock

farmer

Definition

individual that manages a farm, irrespective of whether the individual is independent or part of an organization

farming plan

Definition

plan for crop production on a specified farm

Note 1 to entry: A farming plan is a set of instructions or activities to be implemented and intended to lead to the production of a crop. The farming plan normally defines the application of the components necessary to produce the crop, e.g. land use, resource management and application of best farm management practices. A farming plan may consist of procedures, flow diagrams, field maps, manuals or outlines.

feed

Definition

single or multiple product(s), whether processed, semi-processed or raw, which is (are) intended to be fed to food-producing animals

Notes

SG9 Supply Chain

feeding system

Definition

feed composition, delivery equipment, monitoring, automation and data exchange associated with livestock nutritional requirements.

Notes

SG2 Livestock

fertilizer

Definition

substance containing one or more recognized plant nutrient(s), designed for use or claimed to have value in promoting plant growth

Notes

SG2 Livestock

field observation

Definition

specialized type of field inspection

Notes

In the context of production agriculture, this term refers to a method of inspecting a field for pests or other production problems before or during the growing season. It is possible for farm management or farm people to perform this activity themselves or to hire a qualified individual to conduct field observation activities, depending upon the skills required and level of expertise available. Fields can be scouted several times during the growing season, or at specific times to identify pests or to assess crop conditions.

food

Definition

substance (ingredient), whether processed, semi-processed or raw, which is intended for consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of “food” but does not include cosmetics or tobacco or substances (ingredients) used only as drugs

Notes

SG9 Supply Chain

food business operator (FBO)

Definition

The entity responsible for operating a business at any step in the food chain

Notes

SG9 Supply Chain

food chain

Definition

sequence of the stages in the production, processing, distribution, storage and handling of a food and its ingredients, from primary production to consumption

Notes

SG9 Supply Chain

food grading

Definition

the inspection, assessment and sorting of various foods regarding quality, freshness, legal conformity and market value.

Notes

SG9 Supply Chain

food hygiene

Definition

All conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain.

Notes

SG9 Supply Chain

food hygiene system

Definition

Prerequisite programmes, supplemented with control measures at critical control points, as appropriate, that when taken as a whole, ensure that food is safe and suitable for its intended use

Notes

SG9 Supply Chain

food loss

Definition

decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers

Notes

SG9 Supply Chain

food safety

Definition

assurance that food will not cause an adverse health effect for the consumer when it is prepared and/or consumed in accordance with its intended use

Notes

SG9 Supply Chain

food waste

Definition

decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers

Notes

SG9 Supply Chain

forage

Definition

plants or plant parts other than separated grains that are fed to or grazed by domestic animals

Note 1 to entry: Forage may be fresh, dry or ensiled, e.g. pasture, green chop, hay, haylage.

Notes

SG2 Livestock

forage crops

Definition

Legumes, grasses (including all cereals), and other crops, either fresh or wilted.

Notes

SG2 Livestock

geographic information system (GIS)

Definition

computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations

Notes

SG1 Crop Production

global navigation satellite system (GNSS)

Definition

satellite based navigation system that provides autonomous global positioning of a receiving device
Note 1 to entry: Global positioning system (GPS), and global navigation satellite system (Glonass), Galileo and BeiDou are typical examples of global navigation satellite systems.

Notes

SG1 Crop Production

global positioning system (GPS)

Definition

The **Global Positioning System** (**GPS**), originally **Navstar GPS**,[2] is a satellite-based radionavigation system owned by the United States government and operated by the United States Space Force.[3] It is one of the global navigation satellite systems (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.[4] It does not require the user to transmit any data, and operates independently of any telephonic or Internet reception, though these technologies can enhance the usefulness of the GPS positioning information. It provides critical positioning capabilities to military, civil, and commercial users around the world. Although the United States government created, controls and maintains the GPS system, it is freely accessible to anyone with a GPS receiver.

Notes

SG1 Crop Production

good agricultural practice (GAP)

Definition

certification system for agriculture, specifying procedures (and attendant documentation) that must be implemented to create food for consumers or further processing that is safe and wholesome, using sustainable methods.

Notes

SG9 Supply Chain

GPS unit – reference Global Positioning System

Notes

SG2 Livestock

grade

Definition

reshaping the surface of land to planned grades for irrigation and subsequent drainage.

Notes

SG9 Supply Chain

greenhouse gas emissions

Definition

release of a GHG into the atmosphere

NOTE GHG is the gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds

Notes

SG2 Livestock

harvester

Definition

⟨crop production⟩ person involved in harvesting a crop

hazard and critical control point system HACCP

Definition

systematic methodology that recognizes and reviews the hazards throughout a process and identifies critical control points where preventative measures or set-points can be established and controlled to ensure product quality

Note 1 to entry: The main objective is to establish a monitoring program that can effectively manage the risks of each individual system in a process, and establish effective procedures to react to excursions of critical control points to ensure end-product quality.

Notes

SG9 Supply Chain

health sensitive vegetation index HVI

Definition

A satellite based determination derived from the normalized difference vegetation index (NDVI) for estimating weather impacts on vegetation, e.g., for example drought .

hydrology

Definition

study of the movement of water on and within the Earth's crust

Note 1 to entry: See also hydrogeology.

Note 2 to entry: For additional terms related to hydrology, see 3.12.

[SOURCE:BS 3618-5:1971, modified - Note 2 to entry added.]

identifier

Definition

data string or pointer that establishes the identity of an item, organization or person alone or in combination with other elements (ISO 5127:2017, clause 3.1.12.19))

indicator

Definition

Device, technology, biometric or sensor that uniquely identifies an animal in a data repository
Note: device which can change its state to give information

Notes

SG2 Livestock

infrastructure

Definition

⟨crop production⟩ system of facilities, equipment and services needed for the operation of a farm
NOTE This term includes, for example, equipment, facilities, agricultural land, buildings, vehicles, computers, communication systems, hand tools, production machinery, and utilities needed to produce a crop.

input

Definition

⟨crop production⟩ product or service used by crop production processes to achieve intended results
NOTE Inputs in crop production systems are the “ingredients” for the crop(s) produced. Soil amendments (fertilizers),
seed or rootstocks, crop protection chemicals, and fuel are examples of direct inputs into the crop production system.
Labour, custom work, and crop consultants, for example, can also be considered as inputs.

irrigator

Definition

assembly of pipes, components, and devices installed in the field for the purpose of irrigating a specific area

ISO/CASCO

Definition

CASCO is the ISO committee responsible for conformity assessment in ISO.

Notes

CASCO develops policy and publishes standards related to conformity assessment, but it does not perform conformity assessment activities.

ISO component organization

Definition

Refers to ISO Technical Committees and Subcommittees

ISO/DEVCO

Definition

The Committee on Developing Country Matters is an ISO committee that identifies the needs and requirements of members in developing countries; provides a forum for members to discuss standardization and related matters of interest to developing countries; recommends the ISO Action Plan for developing countries to Council for approval, and monitors its implementation; advises the ISO leadership on matters affecting members in developing countries relative to ISO governance and policy decisions, and provides guidance on issues of specific interest to developing countries.

ISO subcommittee (SC)

Definition

ISO sub group with a scope consistent with an existing technical committee established by the ISO technical management board where the development of ISO technical work takes place

ISO technical committee (TC)

Definition

ISO sub group established by the ISO technical management board where the development of ISO technical work takes place

khalal

Definition

of, relating to, or constituting the second of four recognized stages in the ripening of a date in which it reaches its full size ...

Notes

SG9 Supply Chain

land cover

Definition

observed (bio)physical cover on the Earth's surface

[SOURCE:UNFAO LCCS 2:2005]

Note 1 to entry: Land cover is distinct from land use(4.1.9).

Notes

SG2 Livestock

legislation

Definition

directives, acts, ordinances, and regulations

Notes

SG2 Livestock

livestock

Definition

domesticated animals, usually kept on a farm

Notes

SG2 Livestock

logistics

Definition

science and practice of interconnecting, and finding the best way of goal attainment, for bringing material objects or living beings in sufficient quantity to the right place in the right time

Notes

SG9 Supply Chain

loT

Definition

defined quantity of a products produced and/or processed and/or packaged essentially under the same conditions

Notes

SG9 Supply Chain

machine actionable

Definition

structuring data and content to make it possible for computational systems to find, access, interoperate, and reuse data without significant human intervention

machine readability

Definition

pertaining to data in a form that can be automatically generated by and input to a computer.

malaxate

Definition

to soften and incorporate (as plaster, clay, or drug ingredients of pills) by rubbing, kneading, or rolling, and simultaneously mixing with a thinner substance

management

Definition

direction, control, and coordination of work performed to develop a product or perform a service
[SOURCE: ISO/IEC/IEEE 24765:2017, 3.3064, modified — In the term, "process" has been removed.]

management software

Definition

computer program that is designed to streamline and automate management processes in order to lessen the complexity of large projects and tasks, as well as encourage or facilitate team cooperation, collaboration and proper project reporting.

Notes

SG2 Livestock

management system

Definition

set of interrelated or interacting elements of an organization to establish policies and objectives and process to achieve those objectives

Notes

SG9 Supply Chain

mathematical model

Definition

sets of equations that describe the behaviour of a physical system

Notes

SG2 Livestock

methane

Definition

comprises the contribution of greenhouse gas (GHG) emissions from ruminant production systems
Note: consists of enteric methane emissions

Notes

SG2 Livestock

normalized difference vegetation index (NDVI)

Definition

a dimensionless index that describes, in relative form, the difference between the near-infrared and red reflectance of land cover areas. It can be used to assess the vegetation cover over an area, because healthy vegetation has a high reflectance in the near-infrared band and low reflectance in the red band.

operational scenario

Definition

description of an imagined sequence of events or activities that includes the interaction of the product or service with its environment and users, as well as interaction among its product or service components when there is end-use significance

Note 1 to entry: Operational scenarios are used to evaluate the requirements and design of the system and to verify and validate the system.

Notes

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operator

Definition

person or organization having responsibility for the operation of the equipment

Notes

SG2 Livestock

organic fertilizer

Definition

material containing carbon or one or more elements other than hydrogen and oxygen mainly of plant and/or animal origin added either directly to the plant or to the soil

Notes

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organization

Definition

person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives

Notes

SG9 Supply Chain

organization perspective

paddock

Definition

a) A usually enclosed area used especially for pasturing or exercising animals

e.g., *led the sheep into the paddock*

especially **:** an enclosure where racehorses are saddled and paraded before a race

b) Australia and New Zealand **:** an often enclosed field

persona

Definition

model of a user with defined characteristics, based on research

ISO/IEC/IEEE 26515:2018(en), 3.12

pest

Definition

An organism that is detrimental to agricultural production.

plan

Definition

-account of intended future course of action aimed at achieving specific goal(s) or objective(s) within a specific timeframe - ISO 19156 Industrial automation systems and integration — Formal semantic models for the configuration of global production networks

- information item, that presents a systematic course of action for achieving a declared purpose, including when, how, and by whom specific activities are to be performed

post harvest

Definition

any handling activity that may be necessary for the delivery or sale of the product that does not alter the natural state of the crop

Notes

SG9 Supply Chain

precision agriculture

Definition

Precision agriculture (**PA**) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. First conceptual work on PA and practical applications go back in the late 1980s.[2] The goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources

precision farming

Definition

New set of enabling technologies.
Successes included auto-steer and fertility management based
on soil tests.

premises

Definition

physical location, buildings and supporting structures used to conduct receipt, storage, manufacturing, packaging, control and shipment of product, raw materials and packaging materials

Notes

SG2 Livestock

primary producer

Definition

person or persons carrying on a business of: a) cultivating or propagating plants, fungi or their products or parts (including seeds, spores, bulbs and similar things), in any physical environment; or b) maintaining animals for the purpose of selling them or their bodily produce (including natural increase); or c) manufacturing dairy produce from raw material that is produced; or d) conducting operations relating directly to taking or catching fish, turtles, dugong, bêche-de-mer, crustaceans or aquatic molluscs; or e) conducting operations relating directly to taking or culturing pearls or pearl shell; or f) planting or tending trees in a plantation or forest that are intended to be felled; or g) felling trees in a plantation or forest; or h)

transporting trees, or parts of trees, that are felled in a plantation or forest to the place: i) where they are first to be milled or processed; or ii) from which they are to be transported to the place where they are first to be milled or processed.

Notes

SG2 Livestock

primary production

Definition

Those steps in the food chain up to and including storage and, where appropriate, transport of outputs of farming. This would include growing crops, raising fish and animals, and the harvesting of plants, animals or animal products from a farm or their natural habitat

Notes

SG9 Supply Chain

process

process perspective

processor

Definition

An entity which through various manipulations converts livestock to packaged meat and meat by-products for consumption.

Notes

SG2 Livestock

procurement

Definition

activity of acquiring goods or services from suppliers

Note 1 to entry: The procurement process considers the whole cycle from identification of needs through to the end of a services contract or the end of the life of goods, including disposal.

Note 2 to entry: Sourcing is a part of the procurement process that includes planning, defining specifications and selecting suppliers.

product

Definition

⟨crop production⟩ end result of farm processes

product reference data

Definition

A form of reference data that describes properties of a crop input product (e.g., seeds, crop protection products, or fertilizers)

radio frequency identification RFID

Definition

wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object, for the purposes of automatic identification and tracking

Notes

SG2 Livestock

reference data

Definition

Data that describes all instances of a thing or idea.

resource

Definition

a thing that might be identified

scope item

Definition

One of a set of ideas the SAG-SF convenors requested from the experts of ISO SAG-SF Core and Consultative groups, regarding what these experts considered to be in/out of Scope of Smart farming. This was part of a time-saving constructionist alternative to formally defining Smart Farming a priori.
See Scope Item Perspective

scope item perspective

Definition

A methodology used within the SAG-SF, seeking to identify processes / sub-processes that are in the context of one or more scope items.

SDG indicator

Definition

A measurable representation of progress toward an SDG target.

SDG perspective

Definition

A methodology used within the SAG-SF, emphasizing how ISO standards support making, or measuring, progress toward the UN SDGs.

SDG target

Definition

Each goal typically has 8–12 targets, and each target has between one and four indicators used to measure progress toward reaching the targets. The targets are either "outcome" targets (circumstances to be attained) or "means of implementation" targets. The latter targets were introduced late in the process of negotiating the SDGs to address the concern of some Member States about how the SDGs were to be achieved. Goal 17 is wholly about how the SDGs will be achieved.
The numbering system of targets is as follows: "Outcome targets" use numbers, whereas "means of implementation targets" use lower case letters. For example, SDG 6 has a total of 8 targets. The first six are outcome targets and are labeled Targets 6.1 to 6.6. The final two targets are "means of implementation targets" and are labeled as Targets 6.a and 6.b.

segregation

Definition

separation of nonconforming products from products that conform to the customer's order
EXAMPLE Separation of different quality types or varieties.

sensors

Definition

device that observes and measures a physical property of a natural phenomenon or man-made process and converts that measurement into a signal
Note 1 to entry: Signal can be electrical, chemical, etc.

Notes

SG2 Livestock

setup data

Definition

Data that describe one particular instance of a thing or idea, but not including its state.

slurry tanker

Definition

thick, flowable mixture of solids and a liquid, usually water

Notes

SG2 Livestock

smart farming

Definition

Andres note: We need to harmonize (likely replace) this with the problems-centric (as opposed to technology-centric) definition being used by the SAG.

Smart farming is a management concept focused on providing the agricultural industry with the infrastructure to leverage advanced technology – including big data, the cloud, and the internet of things (IoT) – for tracking, monitoring, automating, and analyzing operations. Also known as precision agriculture, smart farming is software-managed and sensor-monitored. Smart farming is growing in importance due to the combination of the expanding global population, the increasing demand for higher crop yield, the need to use natural resources efficiently, the rising use and sophistication of information and communication technology, and the increasing need for climate-smart agriculture.

Notes

SG1 Crop Production

smart farming platform SFP

Definition

The *Smart Farming Platform* is an *integrated platform* providing a number of tools for disseminating and making easier the use of *Smart Farming* technologies.

soil map

Definition

two- or three-dimensional representation of soil or its properties for a geographic extent

Notes

SG2

Soxhlet extractor

Definition

piece of laboratory apparatus invented in 1879 by Franz von Soxhlet. It was originally designed for the extraction of a lipid from a solid material. Typically, Soxhlet extraction is used when the desired compound has a *limited* solubility in a solvent, and the impurity is insoluble in that solvent. It allows for unmonitored and unmanaged operation while efficiently recycling a small amount of solvent to dissolve a larger amount of material.

Notes
SG9 Supply Chain

spatial feature collection

Definition
feature collection that includes one or more features that have properties whose value is a geometry
[SOURCE:ISO 19168-1:2020, 3.1.4]
Notes
SG2 Livestock

standard

Definition
document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context
Note 1 to entry: Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits.
[SOURCE: ISO/IEC Guide 2:2004, 3.2]

standards domain

Definition
area of control or a sphere of knowledge covered by a standard
Notes
Andres work-in progress

standards perspective

Definition
A methodology used within the SAG-SF, emphasizing how ISO standards support stakeholder processes.

sub-process

Definition
a process that is included within another process.
Notes
In the context of BPMN, the sub-process can be in a collapsed view that hides its details. A sub-process can be in an expanded view that shows its details within the view of the process that it is contained in. A sub-process shares the same shape as the task, which is a rectangle that has rounded corners.

supplier

Definition
⟨crop production⟩ provider of inputs used in crop production
EXAMPLE Crop producers, those supplying seed and plant material, fertilizer, equipment, chemicals, and others
providing inputs or services (including consultants and advisors) to farm operations.

supply chain

Definition
linked set of resources and processes that upon placement of a purchase order begins with the sourcing of raw material and extends through the manufacturing, processing, handling and delivery of goods and related services to the purchaser

Note 1 to entry: The supply chain may include vendors, manufacturing facilities, logistics providers, internal distribution centres, distributors, wholesalers and other entities involved in the manufacturing, processing, handling and delivery of the goods and their related services.

Notes

The supply chain can be differentiated from the value chain using the Porter model.

SG9 Livestock

supply chain sustainability

Definition

supply chain sustainability refers to companies' efforts to consider the environmental and human impact of their products' journey through the supply chain, from raw materials sourcing to production, storage, delivery and every transportation link in between

The goal is to minimize environmental harm from factors like energy usage, water consumption and waste production while having a positive impact on the people and communities in and around their operations. These concerns are in addition to traditional corporate supply chain concerns around revenue and profit.

Notes

SG9 Supply Chain

sustainable development goal SDG

Definition

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The 17 SDGs are integrated—they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability. Countries have committed to prioritize progress for those who're furthest behind. The SDGs are designed to end poverty, hunger, AIDS, and discrimination against women and girls. The creativity, knowhow, technology and financial resources from all of society is necessary to achieve the SDGs in every context.

time-phased budget

Definition

allocation of the cost to accomplish the work over established periods of time or phases

Notes

SG2 Livestock

top management

Definition

⟨crop production⟩ single person or group of people who directs and controls farm operation or farm cooperative operations at the highest level

EXAMPLE Farm management, single owner, owners, proprietor, farm coop management board, partners, president,

chief executive officer, managing director, chairman, board of directors, executive directors, managing partner(s), or third

party advisors that provide high level control over the farm operation by establishing policy and setting objectives for the

farm operation.

NOTE In small organizations, farm management and top management may be the same person.

topography

Definition

topography

general configuration of a land surface or any part of the Earth's surface, including its relief and the position of its natural and manmade features

Note 1 to entry: The natural or physical surface features of a region, considered collectively as to form the features revealed by the contour lines of a map. In nongeologic usage, the term includes manmade features (such as are shown on a topographic map).

Note 2 to entry: For additional terms related to topography, see 3.6.

[SOURCE:Dictionary of Mining, Mineral and Related Terms, U.S. Bureau of Mines, 1996, modified - Note2 to entry added.]

Notes

SG2

traceability

Definition

ability to follow the history, application, movement and location of an object through specified stage(s) of production, processing and distribution

Notes

SG9 Supply Chain

transportation

Definition

movement of people and goods from one location to another performed by modes, such as air, rail, road, water, cable, pipeline and space and the field comprises the attributes of infrastructure, vehicles, and operations

travelling irrigation machine

Definition

irrigation machine designed to irrigate a field sequentially, strip by strip, while moving across the field

Notes

SG2

umanned aerial vehicle UAV

Definition

An **unmanned aerial vehicle** (**UAV**), commonly known as a **drone**, is an aircraft without any human pilot, crew, or passengers on board. UAVs are a component of an unmanned aircraft system (UAS), which includes adding a ground-based controller and a system of communications with the UAV. The flight of UAVs may operate under remote control by a human operator, as **remotely-piloted aircraft** (**RPA**), or with various degrees of autonomy, such as autopilot assistance, up to fully autonomous aircraft that have no provision for human intervention.

value chain

Definition

sequence of activities and operations leading to the delivery of a valuable product

Note 1 to entry: In the context of the guidance principles, the value chain covers the circular flow which starts with the disposal(3.7) of waste that containing recycleable or resuable material or collection of waste

and end-of-waste fractions that contain recycleable or reusable materials to the purchase of products made from recycled or reused materials by final consumers.
[SOURCE: ISO IWA 19:2017 modified; Porter, 1985,[39] modified]

Notes

SG9 Supply Chain

variety

Definition

unique and uniform member of a species of plant (except for hybrid species) that retains its characteristics from generation to generation through its natural mode of reproduction
Note 1 to entry: The concept of “cultivar” is essentially different from the concept of the botanical variety “varietas”, in that “cultivar” is an infraspecific division resulting from controlled selection, even if empirical; “varietas” is an infraspecific division resulting from natural selection. The terms “cultivar” and “variety” (in the sense of cultivated variety) are equivalent. In translations or adaptations of botanical nomenclature for particular uses, the terms “cultivar” or “variety” (or their equivalents in other languages) may be used in text.

Notes

SG9 Supply Chain

Verband Deutscher Maschinen- und Anlagenbau (VDMA)

Definition

German Mechanical Engineering Industry Association.

veterinarian

Definition

1) person designated by the relevant competent authority as suitably qualified for the responsibility delegated to him or her relating to ante- and post-mortem inspection of animals and/or relevant certification
Note 1 to entry: Under certain jurisdictions, it is a requirement that the veterinarian be a professionally qualified person in veterinary medicine.
Note 2 to entry: Under certain jurisdictions, the function of inspection and of certification can be carried out by different individuals. In such cases, the certificate can be signed by a person who is not designated by the competent authority. This function is covered in the quality management system of the medical device manufacturer.
2) a medical professional who is qualified to treat diseased or injured animals.
Veterinarians manage a wide range of health conditions and injuries in non-human animals. Along with this, vets also play vital role in animal reproduction, animal health management, conservation, husbandry and breeding and preventive medicine like animal nutrition, vaccination and parasitic control as well as bio security and zoonotic disease surveillance and prevention.

Notes

SG2 Livestock

water-soluble nutrient

Definition

nutrient completely soluble in water

Notes

SG2 Livestock

work environment

Definition

set of conditions under which work is performed

Notes

SG9 Supply Chain