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A Policy Proposal for Agricultural Data Governance

Ana Sofía Castellanos Santamaría
Portland State University

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by

Ana Sofía Castellanos Santamaría

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Dissertation Committee:
Bruce Gilley, Chair
Jennifer Allen
Mellie Pullman
Birol Yesilada

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Abstract

As the digital economy continues to grow and data becomes increasingly important, effective data governance is essential. A data governance framework enables the efficient management, sharing, and integration of data, resulting in better decision-making, increased productivity, and enhanced innovation across industries, including agriculture. However, the agricultural sector in the United States is lagging behind other industries in the adoption of effective data governance practices. Agricultural data governance presents a unique set of challenges due to the wide range of stakeholders involved and the ever-increasing volume of data generated by digital technologies in farming. One key challenge to achieving the benefits of effective agricultural data governance is the lack of a robust policy framework.

To address this issue, this doctoral dissertation utilizes a rigorous policy analysis methodology to examine the current data governance policy frameworks, identify gaps and areas for improvement, and propose a comprehensive policy framework for agricultural data governance. The proposed policy framework is informed by the policy analysis and designed to be adaptable and scalable to meet the changing needs of the digital economy and the agriculture sector. It addresses the challenges posed by the ever-increasing volume of agricultural data and aims to enhance the digital transformation of the agriculture sector.

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Introduction

In today's digital economy, data governance plays an increasingly vital role. A well-designed data governance framework facilitates efficient data management, sharing, and integration, leading to improved decision-making, increased productivity, and enhanced innovation across industries, including agriculture. However, compared to other industries, the agricultural sector in the United States has been slow to adopt effective data governance practices. This is due to the unique challenges presented by agricultural data governance, including a diverse range of stakeholders and the growing volume of data generated by digital farming technologies.

One of the primary barriers to realizing the benefits of effective data governance in agriculture is the lack of a robust policy framework. To address this issue, this doctoral research provides a policy analysis aimed at creating a comprehensive policy framework to enhance agricultural data governance in the United States. The goal of this study is to identify opportunities to improve agricultural policies for the digital transformation era.

Currently, digital technologies in farming range from satellite-guided tractors to seed-selecting algorithms and crops developed with gene-editing techniques (Bunge, 2021, p. 3). These new technologies are anticipated to increase productivity and drive a more sustainable and efficient agriculture industry. While digital technologies are an important component of the agricultural sector's digital transformation, relying solely on them is not sufficient for complete digitalization.

Every nozzle, pump, valve, tank, and motor are equipped with sensors that can collect large amounts of data as part of their regular operations (Featherstone, 2021, p. 1). For example, "…the amount of data generated per day by average farm exceeded 250 000 data points in 2015." (Kosior, 2019a, p. 4) and an increase in agricultural data generation is expected "to exceed 2 million data points per day by 2030." (Kosior, 2019, p. 5). Data can be combined from satellite maps, drone images, routine soil samples, and weather and climate reports.

Data generated from all these technologies play a crucial role. Effective governance of the large amounts of agricultural data and recognizing its value, is essential to enhance agriculture outcomes and maximize the sector's economic benefits. The digital transformation of agriculture involves boosting the sector's ability to not only produce and gather data, but also to exchange and utilize data in new and innovative ways. (Jouanjean et al., 2020, p. 6). Therefore, farmers and producers must view data as a potential strategic asset for their farms and the industry as a whole.

In the United States, there are various challenges to the digital transform the agriculture sector, and use agricultural data in smart agriculture[1]. For instance, Mr. Creighton's corn farm in Eleroy, Illinois (Bunge, 2021, p, 1) is representative of farms that faces challenges due to the rise of digital technologies and the vast amount of data they collect. As reported in the Wall Street Journal on August 22, 2021, one of the significant difficulties that U.S.

[1] "The digitalization of agriculture involves the development, adoption, and iteration of digital technologies in the agricultural sector; what has been referred to as both digital agriculture (preferred in Australia and New Zealand) or smart farming (preferred in the European Union) in different spatial contexts." (Fielke et al. 2020, p.3)

farms currently face is working with agricultural technology providers (ATPs)[2] to govern data.

In this case, Mr. Creighton signed a contract with provider Indigo Agriculture Inc. Indigo's original concept was to "reshape the agriculture industry" (Bunge, 2021, p.2) using cutting-edge technology and a data platform to connect farmers with buyers and get the best prices in the market. They also marketed special microbes to enhance seed productivity, and farmers had the option to sell their products at guaranteed premium prices through their program. Indigo's business strategy was to create a cluster of digital agricultural data platforms, from seeds, to an online marketplace, and transport logistics. However, Mr. Creighton faced difficulties, such as a large amount of paperwork, short response times to his requests and concerns, and payment delays. This led to growing mistrust of Indigo Inc. by Mr. Creighton.

Similar to Mr. Creighton, many farmers in the U.S. are encountering challenges with ATPs entering the business market and focusing on collecting agricultural data. One such company is Agrian Inc., based in California. Agrian Inc. provides farmers with the tools to comply with federal and state pesticide and chemical regulations and offers platforms for harvest, application, and planting maps. Growers utilize these services to create fertility recommendations or to aggregate data to address agronomic needs based on the maps. (Featherstone, 2021, p. 1) However, the ability to aggregate agricultural data has raised

[2] Agricultural Technology Providers (ATPs) could be categorized into nine main categories: farm management software, precision agriculture and predictive data analytics, sensors, animal data, robotics and drones, smart irrigation, next gen farms, marketplaces, plant data/analysis. Source of information CBInsights (2017) "The Ag tech market map: 100+ startups powering the future of farming and agribusiness" Research Briefs. Available at: https://www.cbinsights.com/research/agriculture-tech-market-map-company-list/

concerns among farmers about data ownership, privacy and security as well as the flows of data sharing.

Another challenge faced by U.S. farmers is the lack of accessible digital tools for repairing digital farming equipment. As noted at a small cattle farm in Cape Girardeau, Missouri, (O'Reilly, 2021), the farmer, Mr. Hovis struggled to find software tools needed to sync a new part to his tractor. The cost of acquiring the necessary technology for repairs was just as high as the farm itself. To address this issue, Mr. Hovis filed a right-to-repair bill in January 2021, and many other farmers across the United States are also pushing for "right to repair" laws that would require manufacturers to provide easy access to tools, software parts, and documentation. This effort is gaining support from state farm bureaus, farmers unions[3], and lawmakers from both parties in states like Florida, Montana, and Nebraska (O'Reilly, 2021).

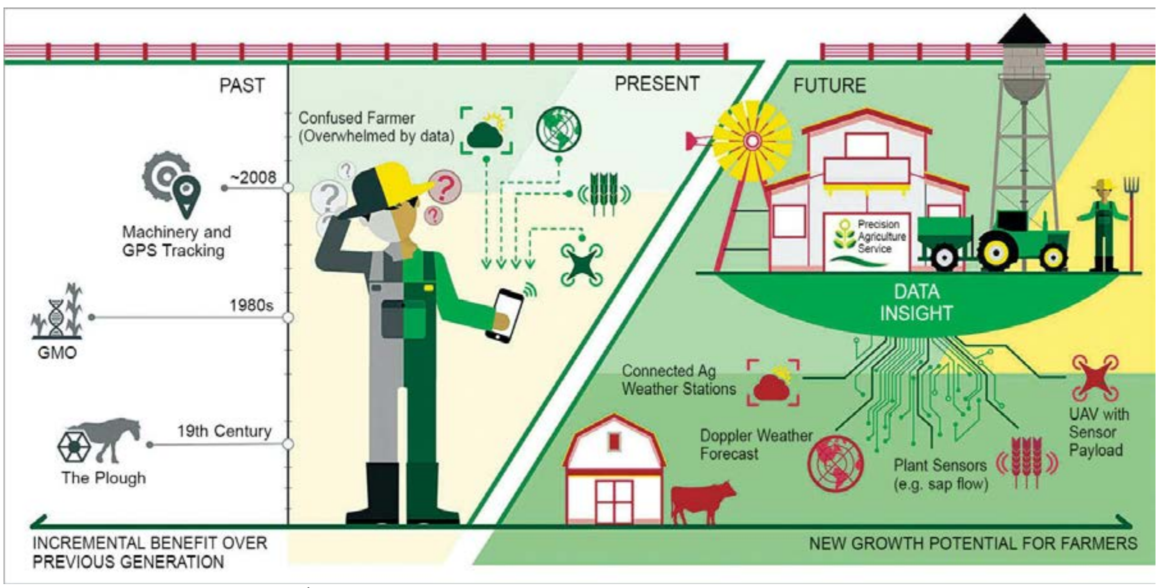
The challenges faced by farmers like Mr. Creighton and Mr. Hovis, highlight the difficulties that U.S. farmers encounter with technology and data in the modern agriculture industry. Despite the benefits of technology and data in improving farming efficiency, governing agricultural data remains a critical issue that needs to be addressed. The situation of Mr. Creighton with ATPs and Mr. Hovis with software tools demonstrate the need for

[3] On January 2023, the American Farm Bureau Federation (AFBF) and John Deere signed a memorandum of understanding that guarantees farmers' right to repair their own farm equipment (AFBF, 2023). This agreement was the result of years of discussions between the two organizations. The MOU outlines a plan to address farmers' concerns and John Deere promises to work with farmers and dealers to resolve any issues that arise, while also committing to bi-annual evaluations with the AFBF. The MOU grants farmers access to repair codes, manuals, product guides, and the ability to purchase diagnostic tools directly from John Deere. The manufacturer also offers assistance with ordering parts and products. This agreement could serve as a blueprint for other manufacturers, and AFBF has already initiated talks for the same. However, the John Deere - AFBF MOU is a non-binding agreement between one equipment manufacturer and one group representing farmers in the U.S. (National Farmers Union, 2023).

farmers to have more control over the technology they use and access to necessary information to repair their equipment. This reflects the ongoing tensions in the agriculture industry between the benefits of technology and the challenges of data governance and maintenance.

Figure 1 highlights the history of innovation in the agricultural sector and showcases the challenges faced by U.S. farms in adapting to the changing methods and technologies during the process of digital transformation.

Figure 1 Evolving Agricultural Methods and Technologies



Source:[4] Ayushee Sharma (2020). Industry 4.0 Driving Agricultural Revolution.

The Figure 1 demonstrates the ongoing trend of farmers embracing new technologies and techniques in an effort to improve their operations. From early innovations such as plows and irrigation systems to the most recent advances in precision agriculture, the

[4] Information and graphic available at: https://iot.electronicsforu.com/content/tech-trends/industry-4-driving-agricultural-revolution/

agricultural industry has always sought ways to make farming more efficient, sustainable, and profitable (OECD, 2019a, p. 21). The incorporation of digital technologies and data collection in the form of smart agriculture allows the sector to advance these efforts and overcome some of the challenges faced by farmers and producers. By embracing digital transformation, the industry can use data to make better decisions, increase productivity, reduce waste, and reduce negative environmental impacts. The key is to ensure that the data generated is effectively managed and that farmers and producers can access and use it in ways that benefit both themselves and the larger sector.

The FAO's Status Report on Digital Technologies in Agriculture and Rural Areas states that the growth of the market will be driven by the gradual integration of advanced and interconnected digital solutions, along with the rise of big data analytics (Trendov, et al. 2019, p.80). This highlights the fact that the implementation of smart or digital agriculture not only requires a significant investment in digital tools and technology but also a shift in thinking[5] to address the new challenges brought about by data and its usage.

Additionally, farmers are concerned about data ownership, privacy, and security, which highlights the need for clear and concise policies on data sharing and use in the agricultural sector. This is especially important in the context of the U.S., where there is a growing market of ATPs that aim to aggregate and use farm data. Farmers need to understand the

[5] The shift to digital agriculture requires not just the use of new technology such as drones, sensors, or mobile apps, but also an increase in farmers' data literacy. Farmers must learn to manage and govern their data to fully realize its potential benefits, including reducing risk and improving production efficiency. They must go beyond simply following technology recommendations and understand how the data collected can benefit their farming practices and the entire agricultural value chain. This shift involves a change in traditional farming methods and requires an investment in learning and understanding data and its use in agriculture.

flow of data and be confident that their data will not be misused or exploited. A well-designed policy framework will help to mitigate these concerns and ensure that the benefits of smart agriculture and digital technologies are effectively leveraged for the benefit of farmers and the overall agricultural sector.

Chapter 1: Research Question and Methods

The aim of this chapter is to identify the existing gaps in research and to investigate the role that a policy framework could play in enhancing the digitalization process of agriculture in the United States. The focus is on how a well-designed policy framework could contribute to the sustainable development of modernized farming practices through the use of digital technologies. The primary research question addressed in this study is:

> What is the most effective policy framework for governing agricultural data to promote sustainable farm modernization through digital transformation?

In this context, the term "sustainability" refers to not only the economic sustainability of farms (i.e., their ability to remain profitable and sustainable operations), but also the environmental and social sustainability of the agricultural sector as a whole. Although these various aspects of sustainability require different types of agricultural data, this research project assumes that high-quality data is required for each aspect's policy-making and social action. Because this project addresses the primary question of how to establish a data governance system, the question of how data can be applied to different aspects of sustainability is left to future research. Sustainability represents the long-term impact that agricultural data governance aims to achieve. However, this research focuses on the preceding outputs of interest, which are the production and sharing of high-quality data and the subsequent outcome of interest, which is the cost-effective digitization of the agricultural sector.

The primary research focus of this study is to examine the general issues related to data practices and contractual complexities in the agriculture sector at the national level in the

United States. The study also looks at cross-sector data governance practices and compares them with international approaches. Additionally, the research addresses the sub-question of what type of policy framework can effectively balance the interests of various stakeholders while addressing the benefits and risks of increased data access in the U.S. agricultural sector.

Research Gap

In recent years, there has been an exponential growth in the amount of data generated by agricultural activities in the United States. According to a report by the United States Department of Agriculture (USDA), the amount of data generated by precision agriculture technologies in the country is expected to grow by 20% per year, reaching a total of 4.1 million terabytes by 2050 (USDA, 2019). This represents a massive opportunity for the agriculture sector to improve its efficiency, productivity, and sustainability, as well as to create new business models and revenue streams. However, to fully realize the potential of this data, it is necessary to establish a governance framework that promotes data sharing, protects data privacy and security, and addresses the technical and legal challenges associated with the use of agricultural data.

This study recognizes that there is a lack of consensus in the U.S. regarding the mechanisms that can ensure the reliability and trustworthiness of the flow of agricultural data. Currently, there are no legally binding frameworks in place to govern the use and management of agricultural data, leading to a need for a comprehensive policy framework to address these issues.

Researchers such as Sanderson et al. (2018) and Wiseman (2019) have explored the use of codes of practice (COPs) as a means of addressing the legislative gaps in the regulation of agricultural data practices (Sanderson et al., 2018) in the U.S. and other countries where they are considered enforceable. However, despite the efforts of COPs to promote responsible data practices in the agriculture sector, there is a lack of evaluation of compliance with the core principles of these codes, which presents a significant challenge.

Not all agriculture service and technology providers, as well as farmers and producers, participate in the collective efforts to implement the codes of agricultural data practices. As a result, it is unclear whether these codes have been successful in promoting accountable data practices and trust between technology providers, farmers, and producers. The participation rate in these codes and its impact on the trust relationships between stakeholders is not well understood.

Additionally, the United States Department of Agriculture (USDA) is in the process of updating its agricultural data infrastructure systems (Ristino & Hart, 2022). Discussions are ongoing about the need for the USDA and its agencies to undergo institutional changes to support the digital transformation of agriculture. Implementing such changes would require a comprehensive understanding of data sharing, use, and reuse at a macro-level, and would necessitate collaboration from all stakeholders involved.

The situation presented above highlights the potential risks and benefits of policy decisions that could impact the digital transformation of the agriculture sector, and the lack of comprehensive analysis or proposals for a data governance framework specific to this sector. While COPs have been explored as a means of promoting responsible data practices in agriculture, the lack of evaluation of compliance and participation rates of stakeholders pose significant challenges.

As there is limited literature available on a public policy, legal, or regulatory framework for governing agricultural data practices, particularly in the United States, this research aims to fill this gap in the literature and in the fields of policy analysis and public policy. The goal is to facilitate meaningful changes that encourage and support efficient, secure, and accurate data sharing across stakeholders in the agriculture sector.

This research aims to provide a comprehensive policy framework for governing agricultural data practices by conducting a policy analysis and proposing policy alternatives that have the potential to significantly improve agricultural data practices. The focus is on establishing standards for data usage at the macro, meso, and micro levels to encourage efficient, secure, and accurate data sharing among agriculture sector stakeholders.

A comprehensive policy framework for governing agricultural data practices could lead to improved efficiency, reduced costs and a lower environmental impact in the agriculture sector. It can serve as a valuable resource for policymakers and stakeholders in considering options for improving the governance of agricultural data. However, it is important to note that the implementation of a prescriptive policy framework (Sanderson et al., 2018, p. 7) may face challenges such high costs, and difficulty in reaching agreement among all interested stakeholders, including government agencies, agriculture service and technology providers, farmers, and producers. Despite these limitations, this research aims to contribute to the sector and to public affairs by offering a valuable policy framework for governing agricultural data practices that would be acceptable and implementable by all interested parties in the agriculture sector.

The complexity of the task is compounded by the need to balance the competing concerns of different stakeholders and address the benefits and risks of enhanced access to data. The challenge of reaching agreement and implementing a comprehensive policy framework highlights the need for a collaborative and inclusive process that takes into account the perspectives and interests of all stakeholders.

Ontology

Adopting a structuralist analysis approach to govern agricultural data means acknowledging the power structures that shape incentives and constraints for different actors within the agricultural sector. This involves recognizing that the role of structures "[is to] exercise causal powers by providing an environment of incentives and prohibitions for various agents within a social system." (Little, 1991, p. 104). This approach seeks to ensure that the control, access, sharing, and use of agricultural data by all stakeholders leads to a fair and equitable outcome. By examining the various elements and components of the agricultural data governance process, the goal is to promote a system that is beneficial to all parties involved.

As stated by Little (1991, p. 105) the "incentives and constraints imposed by the social structure will have predictable consequences for the choices that individuals will make." It is therefore necessary for the state and its institutions to step in and implement trustworthy systems to govern agricultural data in the U.S.

Figure 2 illustrates Coleman's Boat (Coleman, 1986, p.1310) and provides a visual representation of the relationship between macro and micro foundational connections. It serves as a structural explanation and provides insight into the intention driving this research[6].

Figure 2 The Explanatory Cycle

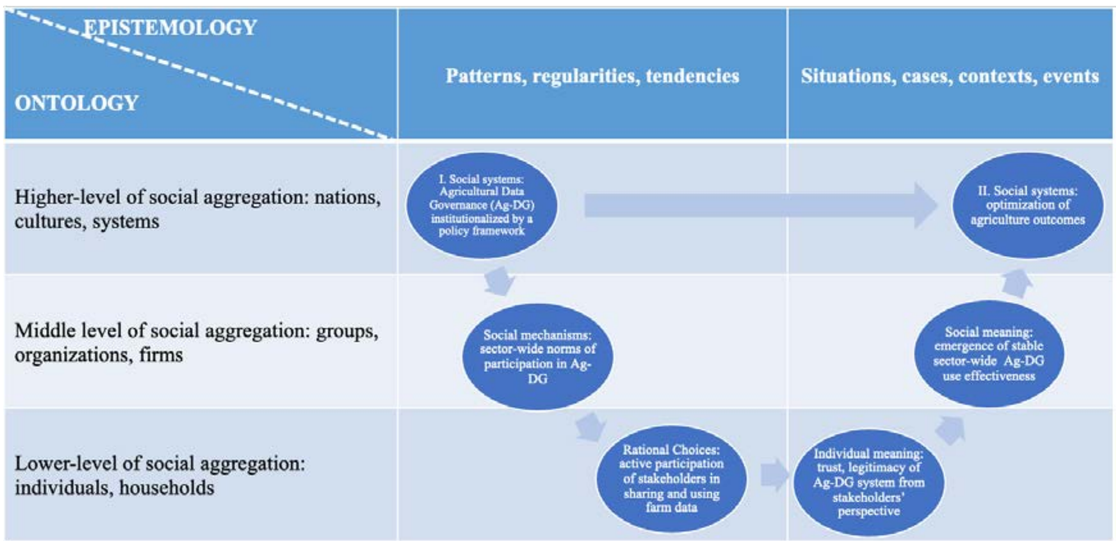


Diagram elaborated by the author

The social system of agricultural data governance (Ag-DG) is institutionalized as a policy framework, with norms for sector participation playing a crucial role at the meso level. Individual decisions to participate and share data within the framework are driven by trust, transparency, and legitimacy. This leads to a more stable and effective agricultural sector, resulting in improved products and services.

[6] In this research, the epistemological approach adopts inductive reasoning to create knowledge by observing, from a comparative perspective, particular case studies. Creating knowledge by induction might be open-ended and the appearance of new evidence can modify the initial conclusion. However, this could be also positive since it gives the possibility to feedback policy frameworks to adapt and incorporate changes and new knowledge.

Policy Science versus Social Science

Policy science, as elucidated by Goodin et al. (2006), endeavors to supply policy actors with useful information for the purpose of providing policy advice. The objective of policy studies is action-oriented and aimed at contributing to the improvement of life by offering political actors something that they can put into use (Goodin et al. 2006, p. 5). Policy science seeks to address questions regarding what ought to be done, as opposed to what it is. On the other hand, social science seeks to uncover laws and generalizations and provides political-institutional designs as instruments of collective values (Goodin et al. 2006). In contrast, policy science focuses on what can be achieved collectively through and within institutional frameworks.

In this research, the findings of policy analysis are not intended to be general statements about the theme under research, but specific prescriptions intended to assist policymakers. Therefore, the policy science approach does not take a deductive approach but rather an inductive one. Policy studies stress an aspiration toward relevance[7] along with the role of value premises[8] in policy choice (Goodin et al. 2006)[9]. This research design does not

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[7] Policy studies is a multidisciplinary field that investigates the decision-making processes involved in public policy. In this context, "relevance" refers to the importance of ensuring that policy decisions are based on evidence and are responsive to the needs and values of society. The idea is that policies should be grounded in the best available knowledge and research, and should be tailored to the specific needs of the people and communities affected by them.

[8] Value premises, on the other hand, refer to the underlying moral and ethical principles that shape policy decisions. These may include ideas about social justice, individual rights, environmental sustainability, and other ethical considerations that are important to policymakers and society as a whole.

[9] Goodin et al. (2006) argue that policy studies should take both relevance and value premises into account when analyzing policy choices. By doing so, policymakers can make more informed decisions that are grounded in evidence and aligned with the values and priorities of society. This approach recognizes that policy choices are not purely technical or objective, but are influenced by a range of social, cultural, and political factors, and by the values and beliefs of the people involved in making those choices.

address the general question of what kind of policy framework will tend to cause improvements in agricultural data governance and thus of agricultural outcomes but only the context-specific question of what kind of policy framework should be implemented as optimal for agricultural data governance in the United States.

In addition, this research seeks to gain an understanding of not only farmers' perspectives on the value and use of agricultural data, but also the perspectives of other stakeholders involved in the sector. The objective of conducting policy analysis is to assist decision-makers in determining the desired outcomes and the most feasible means of achieving those goals (Schneider, 1997, p. 9) through the implementation of public policy. Policy plays a mediating role in resolving conflicts and fostering compromise among conflicting interests. It endeavors to establish an optimal structure that would provide suitable incentives to stakeholders, thus overcoming challenges such as mistrust, lack of transparency, and information asymmetry risks.

This study specifically examines the relationship between stakeholders such as farmers, as data primary contributors, and third-party agriculture technology providers, with a focus on resolving the conflicts arising from agricultural data usage. The aim is to create a structure that facilitates collaboration and establishes a long-lasting and trustworthy relationship between farmers, producers, tech and service providers.

Research Design and Methods

As stated by Dunn (2018, p. 3), policy analysis is a comprehensive and interdisciplinary process aimed at the production, critical evaluation, and dissemination of policy-relevant knowledge. The methods of policy analysis are designed to address the intricate nature of the policy-making process. This study proposes a multi-method strategy (Peters & Fontaine, 2020, p. 14) that aims to understand the problem at hand through the examination of tangible and verifiable facts and information.

This research utilizes policy analysis methods to structure the problem, design policy options, and forecast policy proposals. These methods are considered as tools for creating and transforming knowledge (Dunn, 2018, p. 8). Table 1 presents an overview of the policy analysis methods selected for this research.

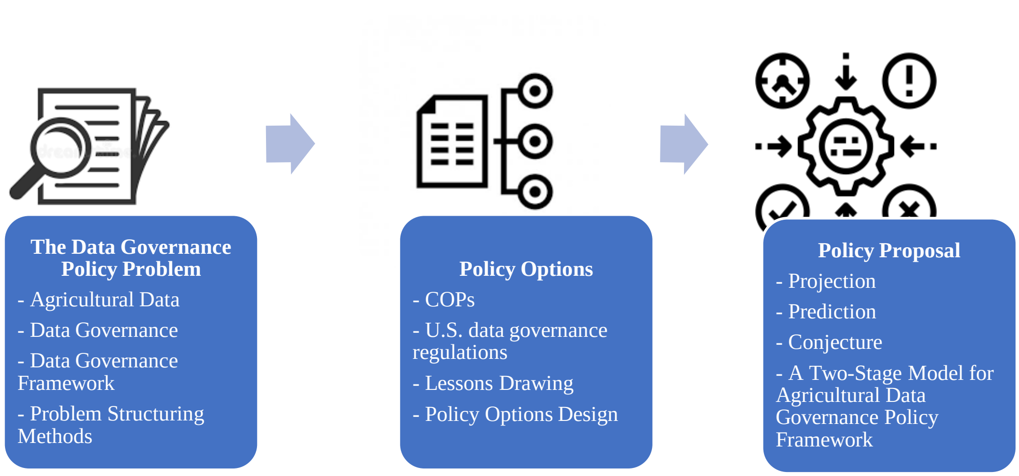
Table 1 Methods of Policy Analysis

Policy Stage	Description	Application
Problem Structuring	Developing a definition of the key elements of the problem; structuring the right problem to propose the right solution.	What are the key elements of the problem of creating an agricultural data governance framework in the U.S.?
Policy Options	Developing policy alternatives and forecasting their effects; discussion of different approaches taken in other countries (lesson drawing, benchmarking, best practices, policy diffusion).	What are the main options for creating an agricultural data governance framework in the U.S.?
Policy Proposal	Choosing a preferred policy option using criteria of effectiveness (productivity, innovation, sustainability) cost-effectiveness, political feasibility, technical feasibility, legitimacy, security, cost-benefit analysis.	What agricultural data governance framework would work best for the U.S.?

Adapted from Dunn, 2018.

A roadmap is presented in this doctoral dissertation to guide the progression of the analysis, providing a clear and structured approach for conducting the policy analysis and developing a policy framework. This roadmap outlines the steps involved in the policy analysis process, from problem structuring and option design to policy proposal. By following this roadmap, the resulting policy framework will be well-informed, evidence-based, and effective in improving agricultural data practices. The research content is presented in a roadmap format in Figure 3, outlining the sequence of the study.

Figure 3 Policy Analysis Process for Agriculture Data Governance Policy Framework



The steps illustrated in Figure 3 are as follows:

Chapter 2: The Data Governance Policy Problem: This chapter provides an in-depth analysis of the current data governance landscape in the U.S. agricultural sector. It examines existing data governance frameworks, with a particular focus on identifying the safeguards and enabling mechanisms that ensure the secure flow of data among stakeholders. The objective is to gain a better understanding of the key elements of the problem and structure it in a way that facilitates proposing the right solution.

Chapter 3: Policy Options: The goal of this chapter is to analyze publicly available policy documents related to data governance from a comparative perspective in order to identify valuable lessons and best practices. This chapter discusses the different approaches taken in the U.S. and other countries to solve the agricultural data governance problem. These existing data governance policies serve as the basis for developing three policy alternatives. This step includes consolidating the gathered information to provide a comprehensive analysis and designing policy options to solve the agricultural data governance problem in the U.S.

Chapter 4: Policy Proposal: In this chapter, this research then proceeds to project the feasibility and effectiveness of these three policy options in the context of the U.S., and propose a two-stage solution, that moves from minimal to moderate models. The chapter then evaluates the policy options using criteria such as cost-effectiveness, political feasibility, and costs and benefits analysis to choose a preferred policy option.

In conclusion, policy analysis methods serve as effective means of evaluating and proposing "potential solutions to practical problems" (Dunn, 2018, p. 3), including those related to agricultural data governance. These methods aid in accurately defining the policy problem. This research draws on a comparative policy lesson-drawing approach to identify viable options for designing the three most appropriate policy alternatives. The evidence from comparative cases is used to project the feasibility and effectiveness of each model in the U.S. context while balancing the competing demands of various stakeholders.

Chapter 2: The Policy Problem

This chapter will address the nature and scope of the agricultural data governance policy problem. It will build on the previous chapter by presenting a detailed and well-structured model of the policy problem. To achieve this, this research uses three methods of problem structuring. The chapter concludes with a preferred model of the policy problem. This model will serve as the basis for formulating policy options in Chapter 3. This chapter also includes the description of the context covering agricultural data and the data governance framework, which serves as background information to structure the problem in the agriculture sector in the U.S.

Agricultural Data and Data Governance

- **Agricultural Data**

Data can be understood as a representation of factual information in various formats, including numerical, textual, visual, or audio forms (Abraham et al. 2019). On many occasions, data has been described as a valuable commodity, similar to oil, that can contribute to economic growth and development (Benfeldt Nielsen, 2017, p. 120). Unlike oil, however, data is a renewable resource that can be continuously used and leveraged for multiple purposes.

To realize the full potential of data, it is crucial to understand the contextual information that provides value to the data. According to DAMA-DMBOK (2015), context refers to the data's representational system. For instance, in the agricultural sector, data has the potential to drive better decision making, increase farm profitability, and promote sustainability by aggregating and analyzing various data sources, such as seed yields, input rates, and product pricing (Séronie, 2020).

Agricultural data classification encompasses a wide range of categories, including livestock data, land data, agronomic data, climate data, and equipment data, among others. In some cases, this type of data may be linked to personal information about farmers. Land data, for example, may include information such as the farmer's name, address, and financial information such as bank loans (Wiseman & Sanderson, 2019). It is critical to distinguish between data streams in the agri-food chain[10], depending on whether they are related to pre-planting or consumption activities.

One of the difficulties in determining the origin of agricultural data is determining whether it is generated on-farm or off-farm, especially when it is generated on-farm through a third party, such as an agriculture technology provider (ATP). This lack of clear distinction may lead to confusion regarding the ownership and control of this type of data.

The classification criteria for agricultural data also include how and why the data is generated (Jouanjean et al., 2020). In this regard, Jouanjean et al. (2020) classified how agricultural data is generated into three categories: process-mediated, machine-generated, and human-sourced. Traditional business data generated as a result of processes that monitor and record business events of interest falls under the purview of process-mediated

[10] This distinction is important because different types of data may require different levels of protection or regulation. For example, data related to pre-planting activities, such as land data, may be more sensitive and require more protection because they can be linked to personal information about farmers. On the other hand, data related to consumption activities, such as nutritional information, may require more transparency and regulation to ensure food safety and consumer protection. Therefore, understanding the different types of data in the agri-food chain and their associated risks and benefits is crucial for developing effective policies and regulations for agricultural data governance.

data (Jouanjean et al. 2020). Machine-generated data, on the other hand, is generated automatically by computer-based digital devices, tools, and applications that have grown in importance with the rise of precision farming[11]. Finally, human-sourced data refers to human-created records, such as those found in books, photographs, audio, and video (Jouanjean et al. 2020).

The second criterion for classifying agricultural data is based on its primary reason why (purpose), which is to assist farmers in making informed decisions. For instance, agriculture data is used by the private sector to develop and support new services and activities, while agricultural data is used by public institutions to inform their innovation policies and activities (Jouanjean et al. 2020).

In the agriculture sector of the U.S., data is used in two contexts: public and private big data. On the one hand, public-level big data, according to Stubbs (2016), refers to records collected, maintained, and analyzed through publicly funded sources and federal agencies, such as farm program participant records and weather data. Private big data, on the other hand, includes records generated at the production level by farmers and agriculture technology providers, such as yield data, soil analysis, irrigation levels, livestock movement, and grazing rates. Both public and private big data are useful in agriculture. They provide a more accurate picture of agricultural operations, making them a better decision-making tool.

[11] The increased in data generation that could provide insights for making informed-farming decisions, need specialized regulation considerations.

This study uses the agricultural data taxonomy proposed by Jouanjean et al. (2020), which focuses on what data is generated and how it is collected. Jouanjean et al. (2020) classify and categorize agricultural data, dividing it into three broad typologies: farm business operations and management data, farm production process tracking data, and data collected to provide general agricultural services.

This research incorporates Stubbs' (2016) distinction between private and public data, which relates to the why of data generation. This analysis identifies key agricultural data that farmers and other stakeholders should be aware of. Table 2 summarizes the various types of agricultural data, and Figure 4 shows how they interact.

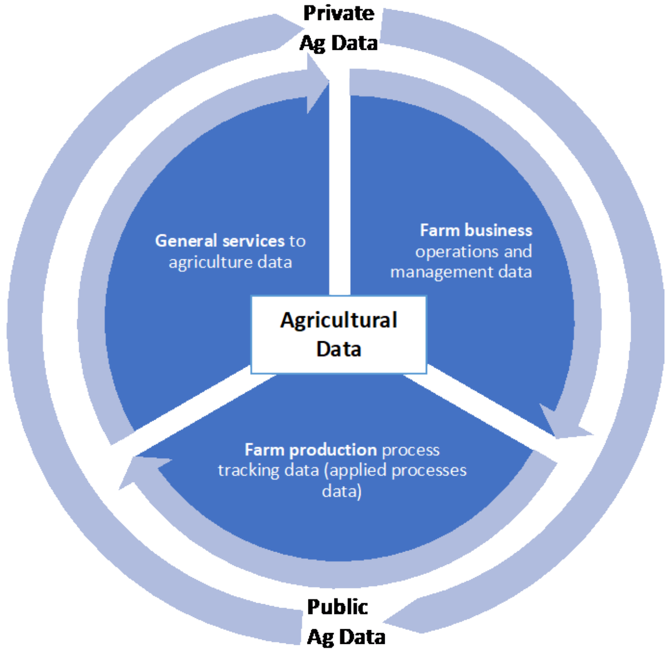
Table 2 Agricultural Data Taxonomy

	Description of the type of data
Farm business operations and management data	• Financial • Tax • Human resource • Contracts • Supply chain (partnerships, customer, and supplier information) • Rolling and fixed assets data • Machine operations data (fuel consumption, equipment function, reference) • Reporting and compliance data (government policies, certification schemes)

	Description of the type of data
Farm production process: machine-generated data, tracking data (applied processes data)	• Crop seed • Dates of operations • Water management • Disease and pest management (type of herbicides, insecticide, fungicide used, and dates and location applied) • Yield data • Land data (Soil and fertility data, watershed, drainage, tillage practice) • GIS, GPS, and field boundary data • Livestock data (breed, genetics, feed, production)
General services to agriculture data	• Climate and weather data • Environmental and ecological data • Commodity prices and market information

Adapted from Jouanjean et al. (2020, p.30)

Figure 4 Cycle of Agricultural Data



Adapted from Jouanjean, M. et al (2020) and Stubbs (2016)

According to Stubbs (2016), there are two types of public agricultural data sets in the United States: traditional data and administrative data. Traditional data includes information gathered, managed, and analyzed using traditional methods such as surveys. These data sets are generated in the agriculture industry, particularly the United States Department of Agriculture (USDA) to fulfill the mandates of this agency (Stubbs, 2016, pp. 3-5). Table 3 displays the most important agriculture sector agencies in the United States, as well as their involvement in agricultural data.

Table 3 The U.S. Agriculture Agencies

U.S Agency in the Agriculture Sector	**Data Activities**
National Agricultural Statistics Service (NASS)	Collects, manages, and analyzes survey data through the Census of Agriculture;

Economic Research Service (ERS)	Collects, manages, and uses resource, production, and financial data through the Agricultural Resource Management (ARM) survey;
Agricultural Research Service (ARS)	Collects, manages, and uses scientific data related to agriculture through its mission of research and information access;
Natural Resources Conservation Service (NRCS)	Collects, manages, and uses soil, water, and geospatial data through the Soil Survey program;
Agricultural Marketing Service (AMS)	Collects, manages, and uses price and sales information through its market news programs;
World Agricultural Outlook Board (WAOB)	Analyzes commodity and market data to develop the World Agricultural Supply and Demand Estimates (WASDE) report.

Adapted from Stubbs (2016)

Administrative data, on the other hand, is a less commonly used source of agricultural information derived from the administration of agriculture programs mandated by law and based on the goals of an agriculture sector agency. These organizations are not typically thought of as big data collectors, and this type of data is not made public. Administrative data is subject to statutory restrictions that limit its availability to the public. Despite these constraints, these data can still be used to improve the efficiency and quality of federal farm program and activity decision-making (Stubbs, 2016, p. 4), as well as to investigate other aspects of the agriculture sector. Table 4 lists the relevant agriculture sector agencies in the U.S.

Table 4 Other U.S Agencies in the Agriculture Sector

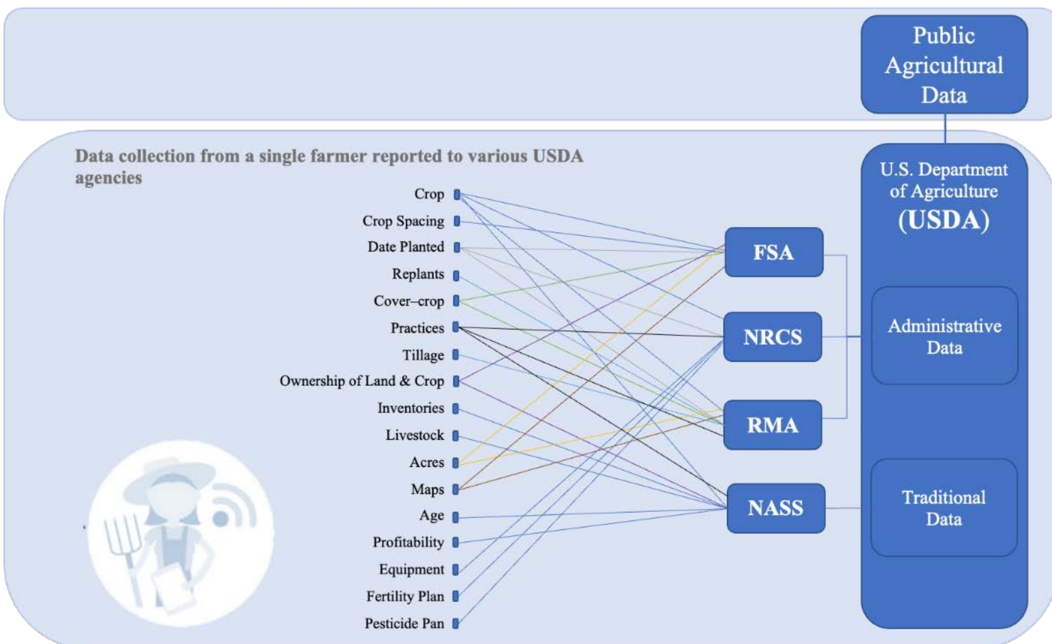
Other U.S Agency in the Agriculture Sector	Data Activities
Risk Management Agency (RMA)	Collects, manages, and uses individual yield and loss information to administer the Federal Crop Insurance program;
Farm Service Agency (FSA)	Collects and manages individual producers' farm record data, federal payments, and loan information used in administering various farm programs;
Natural Resources Conservation Service (NRCS)	Collects and manages conservation plans, geospatial data, and conservation program activities and payments;

Adapted from Stubbs (2016)

In the United States, the collection and use of public agricultural data is governed by a number of statutes and guidance documents that establish not only data quality standards but also privacy protection requirements. When collecting data, the USDA and its affiliated agencies generally prioritize confidentiality, transparency, and public access. However, as Stubbs (2016, p. 5) points out, one of the major challenges for public agricultural big data is a constrained federal budget, reduced staffing levels, and a lag in the adoption of new technologies. These factors have all had an impact on federal agriculture agencies' ability to collect, govern and manage data effectively.

The collection, sharing, and use of agricultural data present various challenges for the USDA, as noted by Ristino and Hart (2022, p. 3). These challenges include the absence of open data standards, inconsistent system interoperability, misaligned incentives for farmers to provide data, leadership and governance gaps, and inconsistent legal authority and interpretation within the agency. Figure 5 depicts the various USDA agencies[12] that require farmers to report their data in order to participate in programs like soil conservation. However, the current reporting requirements impose a burden on farmers, as they are required to report their data to multiple USDA agencies (Sanderson et al., 2018), and this issue has yet to be resolved.

Figure 5 A visual representation of the information that one farmer reports to various USDA agencies



Adapted from (Ristino & Hart, 2022)

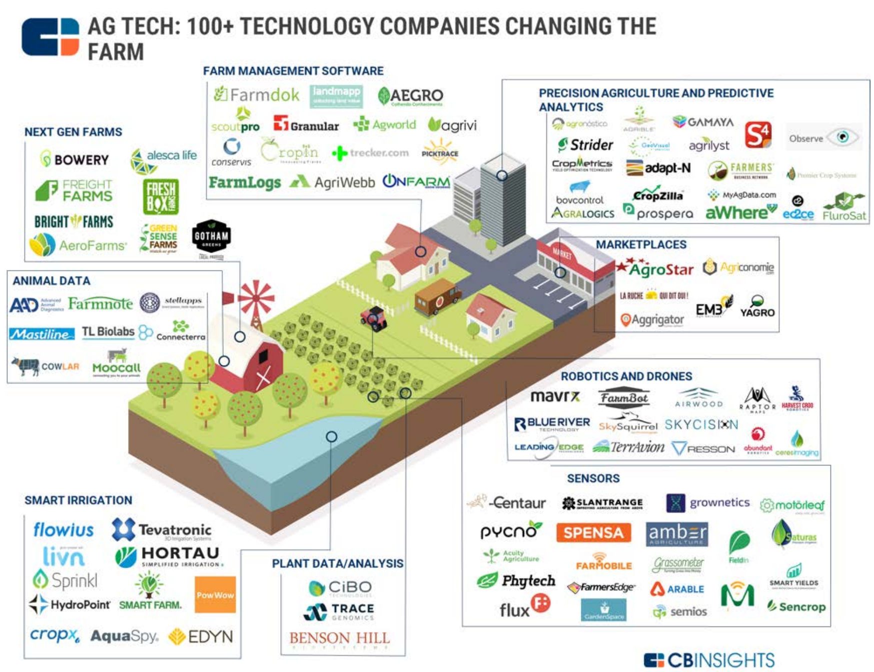
Private data, as defined in this study, refers to data sets generated by the agricultural producer on the farm[13] and used to improve farm or agriculture sector operations (Stubbs, 2016, p. 7). The participation of various key stakeholders in the agricultural industry is

[12] USDA agencies such as the Farm Service Agency (FSA), Natural Resources Conservation Services (NRCS), Risk Management Agency (RMA), and the National Agricultural Statistics Service (NASS).

[13] The author explains that for the purposes of her report, private agricultural data sets are farm-level data without aggregating with other farms because it is an issue frequently discuss in the agriculture community.

critical in facilitating private agricultural data collection, management (which includes processing, sharing, integration, and analysis), and use. Farmers and agricultural producers are among the most experienced in utilizing private data effectively. Privately analyzed data can be used to develop recommendations for a variety of farming practices, including seed and fertilizer application rates, soil analysis, and weather forecasts, among others. Figure 6 depicts more than 100 technology firms that are digitally transforming farming practices.

Figure 6 Technology companies digitally transforming farming



Source[14] CBInsights (2017)

The use of private data in agriculture is increasing, and its benefits are becoming more apparent. The improved outcomes in production, such as higher yields, lower costs, and

[14] More information is available at CBInsights (2017) "The Ag Tech Market Map: 100+ Startups Powering the future of Farming and Agribusiness" Agriculture. Retrieved from: https://www.cbinsights.com/research/agriculture-tech-market-map-company-list/

reduced farming risks, are just a few examples. There are also environmental benefits associated with this, including improved soil quality and more efficient use of water resources. The ability to collect, process, and analyze agricultural data in real time provides additional benefits as well as new business opportunities.

According to Stubbs (2016), the use of these advanced technologies has created an ever-changing landscape of information sources and stakeholders. However, the complexity of the data collection process, as well as the involvement of numerous private players, pose significant challenges in the private agricultural data sector.

Data standardization, interoperability, accuracy, and privacy concerns are just a few of the key challenges. According to Stubbs (2016, p. 11), one of the most pressing challenges confronting the private agricultural data sector is data privacy, and producers must ensure that their data is secure and protected from unauthorized access. Furthermore, data standardization is an important issue because it ensures that the data gathered can be accurately compared and analyzed across multiple sources and stakeholders.

The network that facilitates communication among the technologies involved is another critical aspect of data collection. This network is commonly referred to as the "Internet of Things" (IoT), which refers to a network of interconnected objects that communicate with one another and with computers via the Internet (Stubbs, 2016, p.8). This area is subject to continuous development and evolution due to the dynamic nature of the technologies involved in the data collection stage.

Furthermore, the use of cloud computing to store and process data has grown in popularity because it provides a cost-effective solution for data storage and management

(Stubbs (2016, p. 8). With the rise of cloud computing, producers have gained greater control over their data collection, management, and analysis. They can also share their data with other farmers and agricultural industry stakeholders. However, this presents challenges, such as ensuring data security, privacy, and data ownership. The rapidly changing landscape of the data collection stage in private agriculture big data highlights the importance of a comprehensive and adaptable policy framework that ensures responsible data collection and use in the agriculture sector. The table 5 lists data collection important players in the agriculture industry in the U.S.

Table 5 Players in the agriculture industry in the United States

Important stakeholders	**Technologies for Data Collection**
Equipment Manufacturers	Manufacturers of traditional farm equipment (e.g., tractors) are well positioned to expand into data collection technologies. In many cases, technology is an extension of the equipment already in use.
Chemical Companies and Applicators	Chemical companies are playing an increasing role in the research and development of data collection tools and methods to improve application use of nutrients and pesticides.
Multi-Use Technologies	Technologies used by other industries. For example, some farmers in the dairy industry are exploring the use of radio frequency identification (RFID), commonly used in the shipping and transportation industries, to track movement, production, feed, and disease outbreaks in herds.

Adapted from Stubbs (2016, p.8)

Private agricultural big data management encompasses the processes of organizing, administering, and governing large amounts of data (Stubbs, 2016, p. 9). The goal of data management is to ensure high-quality data that is easily accessible to end users. This stage of the agriculture industry is rapidly growing, with an increasing number of actors providing flexible solutions for mid-sized and small-scale farmers/producers. These actors either collect and organize data for a fee or serve as data brokers, trading and selling data (Stubbs, 2016, p. 9). Table 6 summarizes some of the most common data management practices and providers.

Table 6 Data Practices and Providers

Important stakeholders	**Data management practices**
Producers	Producers are the primary data generators in the agricultural sector. They have traditionally stored their data locally, either on their own computers or on physical data storage devices. However, some are now beginning to explore cloud-based storage options that offer greater convenience and accessibility. Producers are also increasingly interested in data analytics and using data to improve their farming practices.
Data Collectors	Data collection and management companies offer a variety of services to producers, including data collection, storage, and analysis. Many of these companies are affiliated with other agricultural products such as equipment, seed, or chemicals. Data collectors often provide value-added services such as benchmarking and predictive analytics.

Independent Agricultural Data Banks	These are private companies that specialize in data management and analysis for the agricultural sector. They offer a range of services, including data storage, analysis, and reporting. Data banks generally operate on a subscription or fee-for-service basis, and their clients include both producers and other agricultural stakeholders.
Data Cooperatives	These are producer-owned organizations that pool members' data to create economies of scale and generate additional value and negotiating power. Data cooperatives offer a variety of services, including data storage, management, and analysis. They also provide members with access to benchmarking data and other industry insights. Many data cooperatives anonymize data before selling it to interested parties in order to protect members' privacy.

Adapted from Stubbs (2016, p.9)

The final stage of the process is the use of private agricultural data. In this stage, the value of the data for producers is realized. Typically, data sets are analyzed and packaged in a usable and understandable format. Stubbs (2016, p.10) distinguishes three types of analytical products: descriptive, prescriptive, and predictive data products. Table 7 lists the primary users of these data products.

Table 7 Users of Agricultural Data

Important stakeholders	**Uses/users of private ag data**
Farmers and Ranchers	Producers who own the data can benefit from big data products that offer improved production such as lower costs, increased yields, or reduced inputs.

Retailers	Retailers create big data products by analyzing data, packaging it into a usable and timely product, and selling it to the producer.
Industry Groups	National commodity and agricultural industry groups provide guidance on licensing language and data contracts, especially related to producer concerns regarding privacy, security, and ownership.
Environmental Interests	The use of private agricultural big data can result in positive environmental effects such as reduced inputs (e.g., fertilizer, pesticides, and water) and increased efficiencies (e.g., reduced air emissions through reduced tillage overlap).

Adapted from Stubbs (2016, p.10)

Consequently, private corporations are leveraging the use of meteorological, soil, and field-based information to assist farmers in determining crop yield-limiting conditions and making production-related decisions. Furthermore, certain entities are using cutting-edge microbiology and technology to improve crop robustness and accelerate the growth of carbon markets (Ristino & Hart, 2022). Moreover, agricultural machinery manufacturers have embraced new technologies and integrated the most recent tractors and harvesters into cloud systems, allowing for the collection of real-time data from the field for future use. However, it has been noted that the USDA's efforts to collect, integrate, and use data to improve farmer outcomes and agricultural program performance have been hampered

(Ristino & Hart, 2022), and that much of the large amounts of data collected to address various agriculture-related missions remains unused[15] (Ristino & Hart, 2022).

To summarize, the use of private agricultural data is becoming more common, and the benefits are becoming more apparent. Private agricultural data has the potential to revolutionize the way farmers make production decisions, from increased yields and lower costs to improved soil quality and water availability. However, challenges remain, such as data ownership and privacy concerns, high costs of precision tools and equipment, and market competition. Despite these obstacles, private companies are using cutting-edge technologies such as IoT, drones, and sensors to collect, manage, and analyze data in order to provide solutions to farmers. Furthermore, while the USDA's data collection efforts have been limited, private companies are stepping up to fill the void, providing innovative solutions that can improve farmer outcomes and performance. Figure 7 shows the distribution of agricultural data in the United States and highlights the key players involved. The figure illustrates the absence of governance data infrastructures tools or

[15] There is no single source of data that provides a comprehensive view of how much agricultural data in the U.S. is being used. However, there have been various studies and reports that suggest that while there is a significant amount of agricultural data being collected, much of it is not being fully utilized or shared. For example, a 2018 report by the USDA found that while the majority of farmers were collecting data on their operations, many were not using it to make management decisions. Similarly, a 2019 survey by the American Farm Bureau Federation found that while most farmers were using some type of precision agriculture technology, many were not fully utilizing the data collected by these technologies. Overall, these studies suggest that while there is a significant amount of agricultural data being collected, there may be untapped potential for its use in improving agricultural productivity and sustainability. USDA Economic Research Service. (2018). Agricultural Resources and Environmental Indicators, 2018. Retrieved from https://www.ers.usda.gov/webdocs/publications/93026/eib-208.pdf. American Farm Bureau Federation. (2019). Farmers and Ranchers' Views on the Adoption of Ag Tech. Retrieved from https://www.fb.org/market-intel/farmers-growing-reliance-on-technology-highlights-need-for-robust-digital-toolbox

aggregate platforms in the country's public sector and highlights the importance of considering the reuse of public agricultural administrative data.

Figure 7 Main-actors in public and private ag data in the U.S.

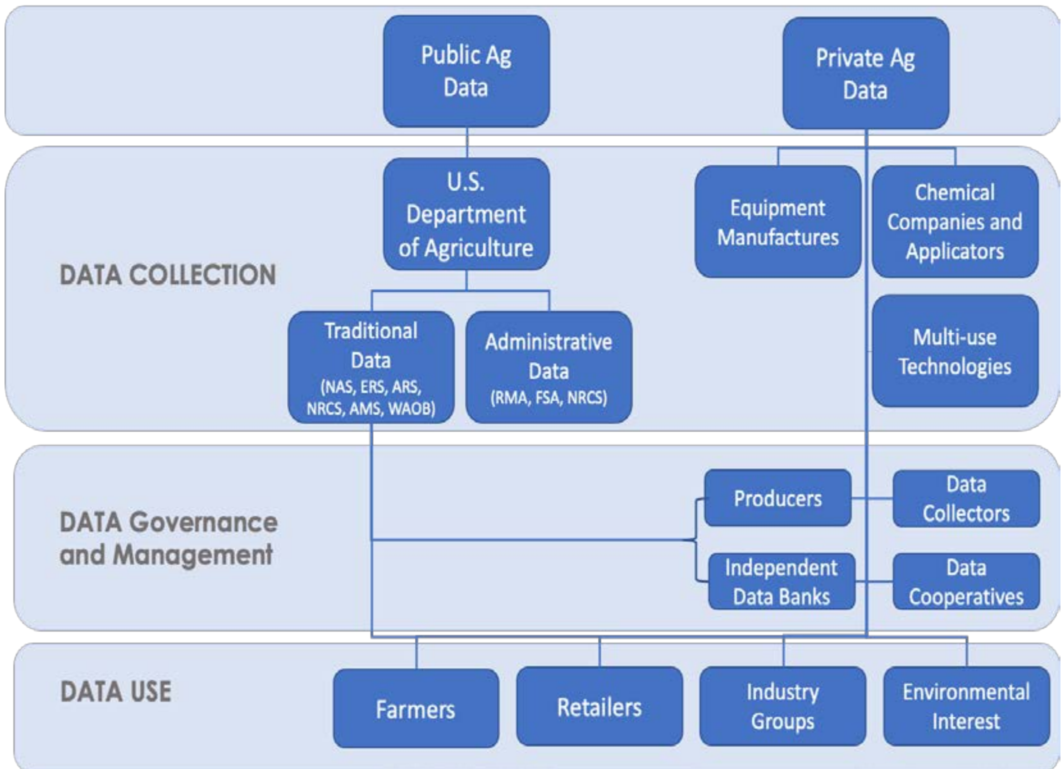


Diagram elaborated by the author

In the context of analyzing agricultural data in the United States, it is necessary to describe the data value chain. The term "value chain" refers to the steps taken to incrementally add value and produce a final product or outcome (Brown, 2020, p. 4). A data value chain describes the information flow from raw data to valuable insights in the context of big data systems (Cavanillas et al., 2021, p. 29). This concept can be used to organize data activities and transform processes into a series of steps that add value to data. The definition of an agricultural data value chain will aid in addressing challenges in agricultural data governance in the context of agriculture's digital transformation. It entails managing and coordinating data in a continuous flow from data generators to decision-makers[16], which will aid in agricultural data governance (Miller & Mork, 2013, p. 57). Figure 8 presents a data value chain adapted for the purposes of this research, which encompasses six stages that can be grouped into phases and potentially divided into sub-phases.

Figure 8 A Data Value Chain

Adapted from Kosior (2019)

The utilization of a data value chain in agriculture plays a crucial role in optimizing the transformation of raw data into valuable information. This process of transforming data into smart data involves the incremental addition of value at various stages of data input activities, data processing and transformation, and finally the generation of high-quality and accurate data products (Brown, 2020, p.4). Currently, the governance of agricultural data value chains in the United States is primarily governed by private contracts and agreements (Fisher & Streinz, 2021, p. 73), which are complex in nature and provide data producers or farmers with limited negotiation power.

[16] Given this data cycle conceptual framework, in the current digital and technological global context, the economic dynamic is becoming more data-driven when it comes to make decisions. This is what known as data economy. One of the main challenges "the data economy faces today is the insufficient level of data sharing between public and private actors." (Carballa, 2019, p. 222)

- **Data Governance**

Data governance is defined by DAMA International (2015, p. 67) as the “exercise of authority and control (planning, monitoring, and enforcement) over the management of data assets.” The concept of governing data refers to the decision-making processes involved in data management, as well as the expected data-related behaviors and responses of individuals and processes (DAMA 2015, p. 68). Data governance thus entails the creation of a systematic decision-making framework that outlines the various roles and responsibilities associated with data access. The goal is achieving organizational or sectoral objectives such as improving operational efficiency, mitigating risks, and gaining market advantages (Benfeldt et al., 2020, p. 301).

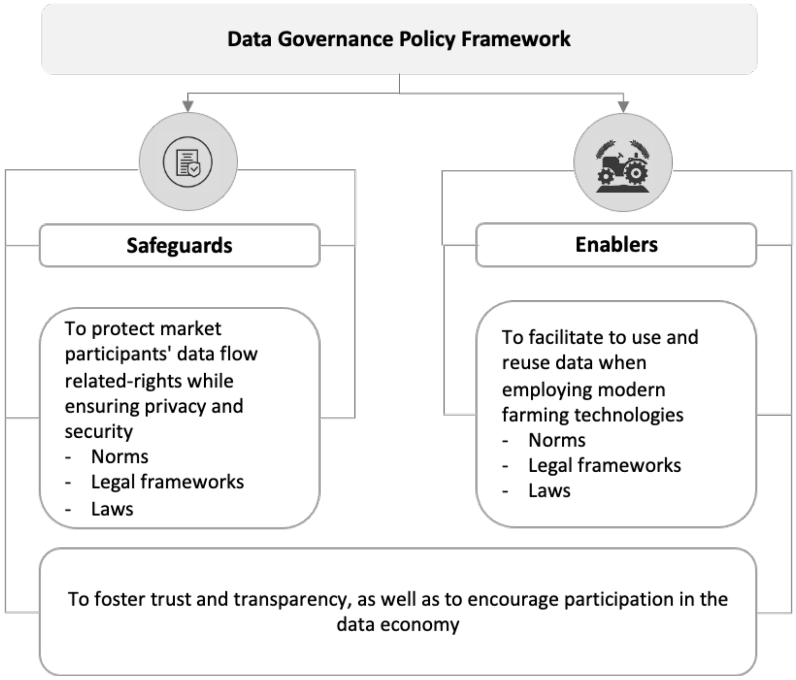
Furthermore, data governance is frequently described as a comprehensive system that includes fundamental attributes or characteristics. According to the Data Governance Institute (DGI), as cited in Al-Ruithe et al. (2019, p. 840), data governance is defined by decision rights and responsibilities regarding information-related procedures that are carried out in accordance with established models that specify who is authorized to execute specific actions with specific data, when, under what conditions, and using what methods.

For the purposes of this doctoral dissertation, data governance is defined as a comprehensive system that includes decision-making authority and accountability for managing data assets, with a focus on controlling the flow of data by regulating its access, usability, quality, and security. This definition includes the roles and responsibilities of network members, rules and processes, principles or standards that facilitate data practice coordination, and common goals. In this dissertation, the overarching goal of data governance is to ensure that data is managed effectively as a valuable asset.

- **Data Governance Policy Framework**

The World Bank's World Development Report 2021: Data for Better Lives (WDR21) (World Bank, 2021) presents a data governance framework that outlines the legal and normative safeguards and enablers required to promote trust and foster the growth of a data-driven economy. WDR21 and Chen (2021) define safeguards as “norms and legal frameworks that aim to protect the rights of individuals and entities participating in the data economy by addressing misuse of data or data breaches” (Chen, 2021, p. 4). And enablers are defined as “norms and laws that facilitate the use and reuse of data, such as data portability mechanisms and open data legislation, (Chen, 2021, p. 4). Figure 9 illustrates these two pillars as critical components in creating an efficient data governance environment and regulatory framework, as well as describing the overall data governance objectives.

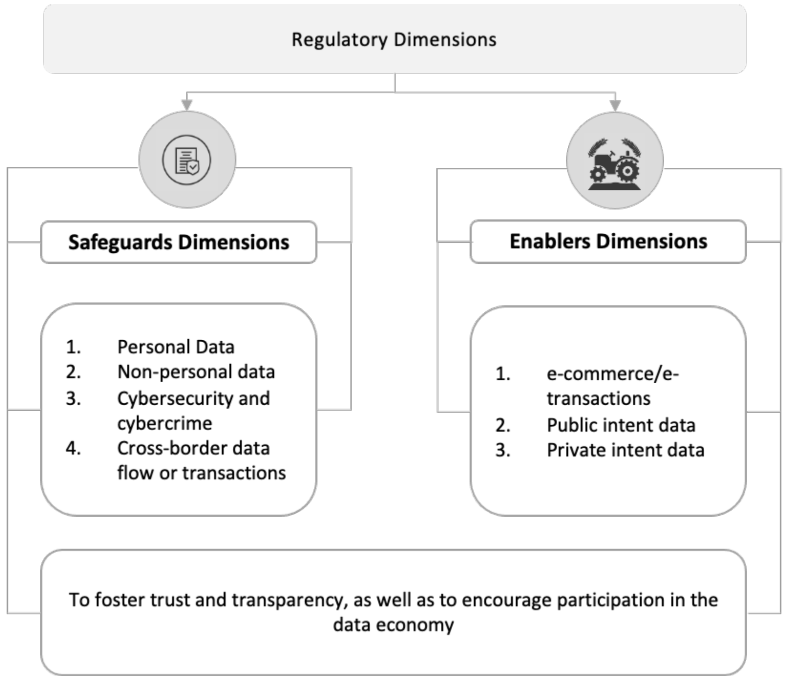
Figure 9 Data Governance Policy Framework



Adapted from Chen (2021)

The two pillars of the data governance framework proposed by WDR21 and Chen (2021) include multiple dimensions that address various issues related to data governance and necessarily require corresponding regulations. Figure 10 of the report illustrates these dimensions. This study will adapt these dimensions to specifically address agricultural data governance.

Figure 10 Data Governance Safeguards and Enablers Regulatory Dimensions



Adapted from Chen (2021)

These dimensions allow the Global Data Regulation Diagnostic report (Chen, 2021) to identify data components from other data governance regulations. Personal data includes not only "data directly provided by an individual, but also personally identifiable information and machine-generated information that can readily be linked to an individual (such as mobile phone data)" (World Bank, 2021, p. 190). Non-personal data recognizes "intellectual property rights (IPRs) over non-personal data." Regarding enabler dimensions, e-commerce/e-transactions refer to electronic communications (or e-communications) and digital ID systems (e.g., e-signatures) for accessing services (e.g., e-government services) (Chen, 2021, p. 19). Public intent data "refers to data collected for public purposes, regardless of the collection instrument or the entity that manages the data" (e.g., censuses and home surveys) (Chen, 2021, p. 21). Private intent data "refers to data collected with the original intent of pursuing commercial purposes" (e.g., consumer data)

(Chen, 2021, p. 22). Table 8 organizes the safeguards and enablers, as well as the seven dimensions of data governance, each with its own set of regulatory concerns that must be carefully considered when developing a legally binding instrument. The table will be used as a tool to guide the analysis and evaluation of regulatory frameworks and policies related to agricultural data governance in this study.

Table 8 Data Governance Safeguards and Enablers, and the 7 Dimensions and Regulatory Issues

Data Governance Pillars	**Dimensions**	**Regulatory issues to be addressed**
Safeguards	Personal data	• Personal data protection (e.g., an individual's health or financial information) • Data rights, such as the right to object to data usage, file complaints, and seek redress • Implementation of data subject rights, such as redress. • Use of personal data, as well as restrictions on sharing with third parties. • Requirements for data minimization, purpose limitation, and data storage limitation.
	Non-personal data	• Intellectual property rights protection • Protection of third-party rights in nonpersonal government data, such

Data Governance Pillars	Dimensions	Regulatory issues to be addressed
		as company registers or business data underlying official statistics.
	Cybersecurity and cybercrime	• Adoption of provisions prohibiting the criminalization of unauthorized or illegal access to or use of infrastructure, systems, and data.
	Cross-border data transfer	• Conditions under which personal data can be transferred abroad. • Adequacy and accountability approaches, including documentation of the specific conditions that allow data transfer. • Mutual agreements with foreign countries or multinational entities, as well as schemes to require, permit, or limit cross-border transfers of personal data.
Enablers	Public intent data	• Open data laws, • Interoperability of government data exchange platforms, • Data classification policy and its mandatory use for government data, • Access to information (ATI) • Adoption by governments of an open licensing regime.
	Private intent data	• Creating incentives and removing barriers to facilitate voluntary data

Data Governance Pillars	Dimensions	Regulatory issues to be addressed
		sharing involving private sector actors • Granting data portability rights to individuals to legally obtain and reuse their personal data across services
	E-commerce/e-transactions	• Adaptable e-commerce law to fast-evolving technologies. • Legal recognition of e-signatures. • Adoption of principles of technological neutrality of e-communications. • Implementation of a digital ID system so users can access e-government services.

Adapted from Abraham et al. 2019; DAMA – DMBOK 2017, and from Chen, 2021

It is important to recognize that data governance is a continuous process that involves people[17], processes, and technology. The primary goal of data governance is to enhance the value of data while minimizing the associated costs and risks (Abraham et al., 2019, p. 424). This highlights the ongoing effort required to effectively manage data, as well as the importance of effective data governance practices.

[17] People is involved in generating, governing, and using data. These are data generators, users, policy makers. Retrieved from: Laney (2001), UN Global Pulse (2018), Oracle, UN Women. https://cgspace.cgiar.org/bitstream/handle/10568/108205/Fairfood_Infosheet_SmallFarmer_BigData.pdf?sequence=1

Introducing data governance into the agricultural sector can help to ensure data quality while also ensuring its secure and open use. As the agricultural sector continues to digitalize its farming practices, agricultural data governance becomes more important as it promotes desirable and responsible agricultural data practices. The sector can ensure that data is managed responsibly and that its value is maximized while potential risks are minimized by implementing effective data governance practices.

Until now, contractual agreements have primarily governed the management of agricultural data. Contractual agreements define the conditions under which data can be collected, shared, and used by farmers, producers, and digital technology providers. These agreements define the parameters for data use and the extent to which data can be shared with third-party service providers, as well as the consequences of data misuse or unauthorized access. These contracts, according to Casalini and Gray (2020), determine data sharing permissions and data ownership following contract termination. According to Micheli et al. (2019), power imbalances and power relations can have an impact on governance processes and value creation.

These scholars argue that civic society and public bodies play an important role in democratizing data governance and redistributing value through data. This implies that, in addition to addressing technical aspects of data governance, it is also necessary to consider the roles and responsibilities of various stakeholders, as well as how power dynamics and information asymmetries between them can affect data governance in agriculture.

According to Micheli et al. (2019), agricultural data governance requires an examination of stakeholders' roles and responsibilities, as well as the processes and mechanisms used as data strategies to access, share, and use data. Thus, effective data governance in agriculture needs not only addressing software, digital applications, or data platforms, but also power dynamics and information asymmetries between farmers and agricultural technology service providers.

The Sense of Problem

In the United States, the governance of agricultural data is currently an unstructured problem, meaning that it is a recently explored and discussed issue with various key actors still deliberating ideas. The issue of contractual agreements is a particular challenge, resulting in low trust and tensions between farmers, industry professionals, and agribusiness (Cue et al., 2021). Furthermore, challenges associated with the transition from analog to digital and smart farming, as well as the generation of large amounts of agricultural data, present additional difficulties.

The problem situation at hand is the digitalization of agriculture[18], which involves the adoption of innovative digital technologies like artificial intelligence (AI), sensors, drones, and robotics to optimize agricultural production systems, value chains, and food systems. However, the growing reliance on digital tools in agriculture has resulted in disagreements and tensions between farmers and agriculture technology providers, particularly regarding agricultural data monetization (Cue et al., 2021, p. 11). This issue has yet to be fully structured, as agricultural data governance is a relatively new concept being explored and debated by key actors in this field.

[18] The adoption, use, and adaptation of digital farming technologies in agriculture daily practices.

In the United States, the Code of Practice (COP) and its fundamental principles represent an initial move towards establishing reliable systems for the flow of agricultural data that safeguard privacy and security. Nonetheless, due to its voluntary and non-binding regulatory nature, as well as the lack of evidence demonstrating its impact and outcomes in promoting beneficial data practices for all stakeholders in this sector, the it proves insufficient to govern data in the agricultural industry.

There is a growing concern among farmers regarding the ambiguous use of data that arises from the implementation of digital farming technologies. The various stakeholders involved, including farmers, agriculture tech providers, and other agribusinesses, hold different perspectives on the value of data and its potential benefits.

Farmers' associations in the United States, for example, have created data cooperative platforms, while agribusinesses provide mobile application services for data analysis. The Agriculture Network Information Collaborative (AgNIC)[19] is an example of an institution cooperating voluntarily in the field of agricultural information and data management. Additionally, there are private business companies that deal with the storage and analysis of agricultural data, including but not limited[20] to the Agriculture Data Coalition (ADC), Farmers Business Network (FBN), Growers Information Services Coop. (GiSC), Open Ag

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[19] AgNIC webpage: agnic.org

[20] Others, such as the National Coalition for Food and Agricultural Research (NCFAR) (www.ncfar.org), a nonpartisan, consensus-based, and customer-led coalition or the Agricultural Research Data Network (ARDN) (https://agmip.github.io/ARDN/). The goal of ARDN is to build a distributed network for harmonized crop system research data and make it available through existing data portals like the USDA's Ag Data Commons. It provides researchers with tools and protocols that allow them to not only share their data, but also make it interoperable and reusable.

Data Alliance, the National Agricultural Producers Data Cooperative (NAPDC), and Ag Transparent.

Agricultural data issues have been recognized as a public concern in the United States and have been incorporated into legislative policy-making agendas. Senators Amy Klobuchar and John Thune introduced the Agricultural Data Act (Ag-Data Act) (115th Congress, 2017-2018) as an example of how senators began to address agricultural data in 2018. Senator Klobuchar proposed that by using appropriate data collection, review, and analysis methods, knowledge of how conservation practices impact farm and ranch profitability, such as crop yields, soil health, and other risk-reducing factors, could be expanded (Thune et al., 2017). Nonetheless, the Agricultural Data Act Bill makes no mention of the different types of data practices that exist in agricultural data contracts (Janzen, 2018b). It is difficult to evaluate or "determine the precise information that will be collected, how the USDA will obtain it, and who will have access to, use, or share it" (Janzen, 2018a).

The absence of legal regulations to govern data sharing and usage in the U.S. agricultural sector has raised concerns among farmers from specific agricultural industries (Cue et al., 2021). For example, in response, farmers from the dairy industry, are calling for the introduction of legislation, proposing a "Farmers Bill of Rights" to ensure fair and transparent dairy data governance within an ecosystem comprising farmers and industry companies (Cue et al., 2021, p. 6). To support this legislative proposal, Cue et al. (2021) conducted a survey as part of the Dairy Brain project at the University of Wisconsin-Madison in 2021. The findings showed that 59% of farmers reported not having signed a data sharing agreement in the past five years, while 22% were unsure if they had signed one (unpublished data). Despite this, all farmers eventually share their data in some way. Hence, these concerns are considered significant worldwide (Cue et al., 2021, p. 4).

According to Jouanjean et al. (2020), farmers are uncertain whether the data collected belongs to them or to third parties who provide technological tools. Additionally, Kosior (2019a, p. 6) notes that the current network of organizations managing and utilizing agricultural data operates under an outdated and fragmented regulatory framework. The absence of specific legal and regulatory frameworks for smart farming data leads to mistrust in the farming community and inhibits farmers' willingness to share their data. Political economic factors, such as a lack of a data-sharing culture in government and inadequate coordination among government entities (Cue et al., 2021, p. 11), can further hinder the exchange of public sector agricultural data. The value of agricultural data that has not been used to its full potential is nil.

In the World Development Report 2021: Data for Better Lives, the World Bank (World Bank, 2021, p. 190) states that several factors have the potential to undermine trust in the flow and use of data. These include the lack of a legal framework, an inadequate implementation of laws, institutions and law enforcement that are weak, or the absence of effective ways for parties to enforce their rights (World Bank, 2021, p. 190). Additionally, practices that provide unfair advantages to certain actors, incentives that are skewed or unbalanced, and poor or insecure infrastructure are also contributing factors.

In addition to distrust in agreements with ATPs, the OECD (2019a, p. 25) report entitled “Digital Opportunities for Better Agricultural Policies” notes that farmers frequently lack the necessary tools and skills to effectively utilize data for decision-making. This includes tools for data management and governance, which enable data sharing, integration, and linkage across various intelligent systems (OECD, 2019a, p. 25). Intelligent systems rely on big data analytics, cloud computing, machine-to-machine communication, and the Internet of Things (IoT) (OECD, 2019b, p. 27) to generate new and valuable information. Without context, trends, or causal references, individual data points are meaningless. The OECD report argues that combining different types and sources of data can provide actionable insights not only for farmers but also for regulators and policymakers, significantly increasing the value of the data (OECD, 2019a, p. 26).

Globally, several organizations are working towards advocating policy solutions for enhancing equitable agricultural data practices. Some of these key organizations include the Organization for Economic Cooperation and Development (OECD), the World Bank, Global Open Data for Agriculture and Nutrition (GODAN), Global Forum on Agricultural Research and Innovation (GFAR), and the Centre for Agriculture and Bioscience International (CABI), among others. While these organizations emphasize different but interconnected facets of agricultural data governance, they promote varied and disjointed solutions to the issue.

While digital technologies like drones have shown promise in providing efficient solutions for farmers, the potential of the data they generate is often underutilized. In an article by Smith Thomas (2022), John Church, an associate professor at Thompson Rivers University in British Columbia and the Regional Innovation Chair in cattle industry sustainability, describes how drones are useful in monitoring cattle, from checking calving pastures to determining if an animal is sick or has an elevated body temperature. Despite these specific uses, it is unclear how the data generated by drones can be effectively governed and utilized to contribute to the sustainability of the agricultural sector and its subsectors.

CABI's Director of Data Policy and Practice highlights the importance of addressing the institutional context and the roles of various actors involved in agricultural data governance, including farmers, industry and government statistical organizations, technology businesses, and research institutions. According to the Director, achieving real change in agricultural data practices requires an improved data culture where trust in data is earned and built over time, and where sustainable data access is integrated into platforms from the outset. The Director emphasizes the need to address data sharing and mitigate risks during the development of interventions, rather than treating them as an afterthought. This approach presents an opportunity to promote responsible data practices and to enhance the sustainability of the agricultural sector and subsectors. (GFAR Blog, 2022, p.3)

Problem Structuring Methods

In the realm of public policy, problem structuring is an approach that aims to integrate multiple alternative perspectives or views regarding a particular problem situation (Rosenhead, 1996). From a social stage perspective, structuring a policy problem requires two distinct actions. The first is identifying the problem situation, while the second is identifying multiple representations or interpretations of the situation (Hoppe, 2018, p. 14) from the diverse perspectives of various stakeholders. These representations must highlight the elements and factors that are contributing to the policy problem.

These methods help to identify the characteristics of the problem, its type, and the stages required to structure it. The focus is on understanding the problem situation within the conditions that lead to conflicts or dissatisfaction. According to Dunn (2018, p.69), the nature of a policy problem should be defined in terms of needs, values, or opportunities for improving or optimizing outcomes. For example, the need to govern agricultural data, the values that underpin the agricultural sector, and the opportunities that can be seized to do so must be clearly defined as a first step before proposing any public policy alternatives.

In the case of agricultural data governance, farmers are concerned about their contracts with ATPs, lack of trust and transparency in accessing, sharing, and using agricultural data, as well as doubts about the benefits of using this data (Casalini & Gray, 2020). Additionally, the external conditions that contribute to the problem, such as power asymmetries and data politics among agri-businesses, ATPs, and farmers, need to be defined, classified, and evaluated (Dunn, 2018, p.72). Understanding the context is essential to comprehend the dynamics involved in current agricultural data practices.

When approaching the problem of structuring agricultural data governance, it is essential to assess how stakeholders define the problem. The goal is to accurately define the problem in order to identify the appropriate solution and avoid what Dunn (2018, p. 80) refers to as the error of the third type[21]. To this end, there are several methods that can be employed, including the problem structuring methods summarized in Table 9.

Table 9 Characteristics of Three Methods of Problem Structuring

Method	Aim	Procedure	Source of Knowledge
Content Analysis	Critical and analytical thinking	Stakeholder identification, assumption	Agriculture sector stakeholders: scholars, farmers,

[21] An error of the third type is formulating and solving the wrong problem.

Method	Aim	Procedure	Source of Knowledge
		surfacing, challenging, and synthesis	farmer-led associations, public, and non-profit sector organizations
Key Item Mapping	Creative synthesis of assumptions and key items using a software tool	Mapping analysis of key items	Agriculture sector stakeholders: scholars, farmers, farmer-led associations, public, and non-profit sector organizations
Boundary Analysis	Ensuring that the problem estimation is as accurate as possible	Boundary estimation (Pareto chart)	Agriculture sector stakeholders: scholars, farmers, farmer-led associations, public, and non-profit sector organizations

Adapted from Dunn, 2018

These three problem-structuring methods aim to identify the essential elements that constitute a problem, including the conditions that lead to stakeholder concerns, mistrust, dissatisfactions, conflicts, or tensions, as well as external factors. The selected problem structuring methods aim to capture diverse perspectives on the problem situation to facilitate consensus building on the problem definition. Taken together, these methods offer a rigorous and comprehensive approach to structuring the policy problem of agricultural data governance, providing valuable insights that enhance the credibility, transferability, and reliability of this qualitative research.

In order to avoid the error of formulating and solving the wrong policy problem (Dunn, 2018, p.80), this research has selected a total of 57 documents for analysis. These documents include a range of sources such as scholarly papers, policy papers, discussion papers, industry newspapers, research reports from international organizations, and webinars' content, all of which are focused on agricultural data practices. By using multiple text-data points[22], the research benefits from a large number of sources, which reduces the reliability problem that may arise from a heavy dependence on a smaller set of sources. Moreover, the larger sample size of 57 text-data sources used in this research reduces the likelihood of random error. As a result, the possibility of Type III error, which refers to defining the wrong problem, is significantly minimized.

Additionally, the probability of Type II error, which results from structuring the problem too narrowly, is also reduced because the high number of sampled text-data sources tends to bring forth a greater number of problem elements during analysis. However, the possibility of defining the problem too broadly, Type I error, is increased by these problem structuring methods. This outcome is due to the only stopping rule being the accumulation of new problem elements. As such, it is important to reassess the scope of the structured problem at the policy formulation stage to identify whether any elements are marginal or unnecessary. Such elements may not contribute to the target problem that solutions seek to resolve.

[22] "Text-data points" refer to individual pieces of text-based information that are used in research or analysis. By incorporating multiple text-data points from a variety of sources, this research is better able to account for a range of perspectives and reduce the risk of bias or inaccuracies.

- **Content Analysis**

Content analysis is a widely used method in qualitative research for studying various phenomena. Its main objective is to uncover the implicit meaning of textual data by quantifying the significance of written language. It examines data present in messages and communication as opposed to observable events or individual characteristics. In this study, content analysis is defined as a "method for investigating social reality, which involves deducing the attributes of a non-apparent context [or phenomenon] from the characteristics of an apparent text" (Krippendorff, 2004, p. 25).

Krippendorff's (2004) definition of content analysis emphasizes the importance of context in analyzing text. By using content analysis to uncover the underlying meaning of text, this research can gain a more nuanced understanding of the complex policy problem of agricultural data governance in the U.S. context. Furthermore, this approach allows for the identification of the key elements of the problem, which can inform the subsequent use of network-based maps and boundary analysis to structure the problem and identify potential solutions.

The process consists of several steps to ensure the scientific rigor of the content analysis method in this research. The first step involves defining the research question and the scope of the analysis. This is followed by selecting the documents that will be analyzed from various sources, including academic literature, policy papers, reports, newsletters and newspaper, and webinars' content. The next step involves pre-processing the data to ensure that it was suitable for analysis.

Pre-processing the data for this qualitative content analysis involves data cleaning[23], coding, and categorization based on relevant themes, concepts, or categories, which are designed to organize and analyze the text-data effectively. In this research, the qualitative content analysis involves manual coding, which is a widely used method for analyzing textual data. Manual coding entails identifying and labeling relevant text segments using predetermined categories to identify patterns and themes within the selected qualitative data. This process helps to uncover key insights and themes and provides a more in-depth understanding of stakeholders' perspectives.

Finally, the next step in the process involves analyzing the coded data to generate insights and develop a problem structure that accurately captured the underlying issues and challenges related to agricultural data governance. This process ensures the validity, reliability, and replicability of the content analysis method and provides a clear and transparent framework for conducting the analysis.

Findings from Content Analysis

The content analysis conducted in this research was delimited to 57 text documents published between October 2020 and May 2022. The selection of this time frame was based on pertinent events related to text publications. Specifically, the report titled "Issues around data governance in the digital transformation of agriculture: The farmers' perspective" by Jouanjean et al. (2020) published by the Organisation for Economic Cooperation and Development, and the report by Ristino and Hart (2022) titled "Modernizing Agriculture

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[23] Data cleaning involves removing irrelevant or extraneous information and ensuring that the data is consistent and accurate. This may involve checking for inconsistencies, correcting errors, and removing duplicates

Data Infrastructure to Improve Economic and Ecological Outcomes" published by the Data Foundation. The literature search query was crafted as follows: "agricultural data" or "farm data" or "agricultural data and data governance" or "digital technology and agricultural data" or "agricultural data and regulations or legal." Nonetheless, a few documents dated from 2017, 2018, and 2019 were included in the analysis due to their relevance to the research theme and the scarcity of documents addressing the governance of agricultural data. The search was conducted based on the criterion that each document addresses the use of digital technologies and agricultural data.

An initial inventory of themes was developed through an inductive thematic analysis of the text data set, with the aim of openly codifying text data into interrelated information categories (Creswell, 2007). To group codes into a category set, Dey (1993: 100) suggests interpreting the data to analyze it. This step requires a comprehensive understanding of the text to isolate features that may lead to the identification of policy problems related to agricultural data.

Moreover, creating categories involves grouping related data. The process of grouping data or establishing relationships creates categories that are conceptually and empirically grounded. That is, categories must be grounded in "relevant empirical [text] material and relate to an appropriate analytic context" (Dey, 1993: 102). Table 10 presents the key themes identified in the text data set, including subthemes, keywords, and descriptions.

Table 10 Key Agricultural Data Problems

Key Problem Themes	Subthemes	Keywords	Description
Data Sharing (Data Governance)	Agricultural Data	Farm data, Code of conduct, big data, Open data, Management, Law	The use and sharing of data generated and collected in farms, and the issues related to secondary use and access to such data. This theme is related to questions of governance and control of agricultural data.
Data Privacy and Security	Risks, Cybersecurity	Access, Control, Law and Regulations, Data Storage, Data Collection	The risks related to the disclosure or exposure of data without farmers' consent, and concerns about cybersecurity and data privacy.
Data Ownership	Ownership Rights	Digital farming, Digital farming technologies, Agriculture 4.0, Agribusiness, Tech companies, Agriculture industry	Farmers' concerns about who owns the data generated or collected in farms through digital farming technologies.
Smart Farming or Smart Agriculture	Digital agriculture, Digital farming, Agriculture 4.0	Digitalization, Digital farming technologies, Agricultural technology providers, Agribusiness, Tech companies, Agriculture industry	The adoption of digital technologies, and the benefits and challenges of implementing "smart" farming systems.
Trust	Informed Consent, Benefits, Open Access, Standards	Contractual agreements, Agricultural tech and service providers	The lack of trust in informed consent and concerns about maintaining principles via contractual agreements with

Key Problem Themes	Subthemes	Keywords	Description
			agricultural tech and service providers.
Transparency	Terms and Conditions, Contract Agreements, Third Parties	Agribusiness, Farmers/producers	The lack of transparency in contractual agreements between agribusiness and farmers/producers, and the difficulties in understanding terms and conditions.
Others	Ethics, Asymmetries, Inequality, Inclusion, Voluntary Standards, Benefits, Data Monetization, Data Economy, Data Literacy, Ag tech services	Other concerns of farmers around agricultural data practices, including ethical considerations, asymmetries in power, and the potential for inequality or exclusion.	

Elaborated by the author

In this study, the selected texts were classified based on their sources, representing different stakeholders in U.S. agriculture. The first classification type includes scholars and their peer-reviewed articles. The second stakeholder is the media that covers agriculture and digital technologies. The third stakeholder is farm association publications and news, and the final stakeholder is represented by reports and publications from international organizations.

- **VOS-Viewer Software Analysis**

The second method used in this study was the VOSviewer software[24], which was used as a tool to create and visualize maps based on network[25] data (van Eck & Waltman, 2021, p. 3). This software utilizes text data from reference manager files to create the maps (van Eck & Waltman, 2021, pp. 26–27). The input data for VOSviewer was imported from the reference repository created in Zotero. The "network visualization" option was selected from among the visualization options provided by the software to visualize the problem of agricultural data.

To refine the settings and create the map, this research used the objects of interest or items[26] (van Eck & Waltman, 2021, p. 5) that were identified from the key themes and keywords in the text data set. The map includes only the items and links between them, representing the connections or relations between two or more items. For example, co-occurrence links were used to represent the number of publications in which certain terms occur together, based on the keywords identified in each text selected as a data source.

The software's useful contribution to the policy problem structuring process is its ability to group each item or keyword into clusters, based on their characteristics such as weight

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[24] VOSviewer "can be used to construct networks of scientific publications, scientific journals, researchers, research organizations, countries, keywords, or terms. Items in these networks can be connected by co-authorship, co-occurrence, citation, bibliographic coupling, or co-citation links." (van Eck and Waltman, 2021, p. 3)

[25] A "network is a set of items together with the links between the items." (van Eck and Waltman, 2021, p. 5)

[26] Other types of items to create maps in VOSviewer could be for example publications, researchers, or terms (tags or key terms).

and score attributes[27]. In this case, the weight attributes are the links and total link strength between items based on their co-occurrence[28]. The software then labels the clusters using cluster numbers and different colors to represent their connections. Figure 11 shows the graphic created by VOSviewer, which visualizes the networks constructed based on the input data extracted from the text sources reviewed. This serves as a complementary tool to the categories reflected in the content analysis.

Relevant factors related to agricultural data governance were clearly revealed by visualizing and exploring the map created by VOSviewer. As a tool for addressing policy problems, VOSviewer effectively identified key themes and keywords related to agricultural data governance. Through the analysis of the literature sources examined, the software discovered a total of 35 co-occurring items or keywords.

[27] Both attributes are represented by numerical values. For example, "A weight of an item should in some way indicate the importance of the item. An item with a higher weight is regarded as more important than an item with a lower weight… A score attribute may indicate any numerical property of items." (van Eck and Waltman, 2021, p. 6)

[28] For any item this is "the number of links of an item with other items and the total strength of the links of an item with other items." (van Eck and Waltman, 2021, p. 6)

Figure 11 Keywords co-occurrence network-based map of agricultural data problem

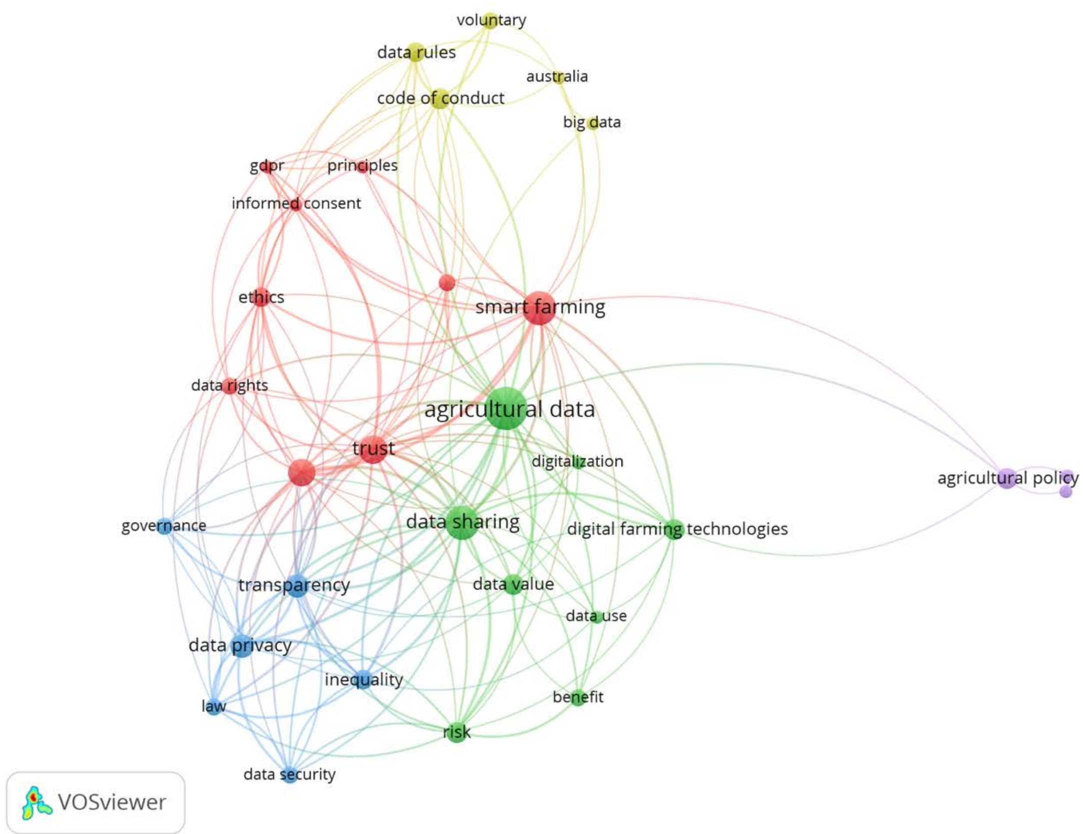


Figure 11 displays a co-occurrence network based on high-frequency agricultural data keywords found in the selected text data sources. VOSviewer's default colors were used to indicate the five clusters of agricultural keywords, with lines showing the distance between the keywords. The red color represents the smart farming cluster, with main connection lines to trust and data ownership. The blue lines connect the transparency cluster, yellow lines present the code of conduct cluster, green lines represent the data sharing cluster, and purple lines depict the agricultural policy cluster. The distance between the keywords on the network indicates the level of co-occurrence and their relationship. The closer the distance, the higher the co-occurrence and stronger the relationship between the keywords.

In addition to complementing the content analysis, this map provides further insight into the key policy problem factors related to agricultural data governance. By clustering related keywords according to their co-occurrence and highlighting their connections, the map illuminates the interrelationships between various themes and sheds light on their relevance to the overarching policy problem. Thus, the map enhances our understanding of the complex and multifaceted issues involved in governing agricultural data.

One limitation of using VOSviewer is that it relies solely on text data from reference manager files, which may not capture all relevant sources on a particular topic. To address this, future studies could consider using multiple sources of data, such as social media, government reports, or interviews with stakeholders, to provide a more comprehensive understanding of the policy problem.

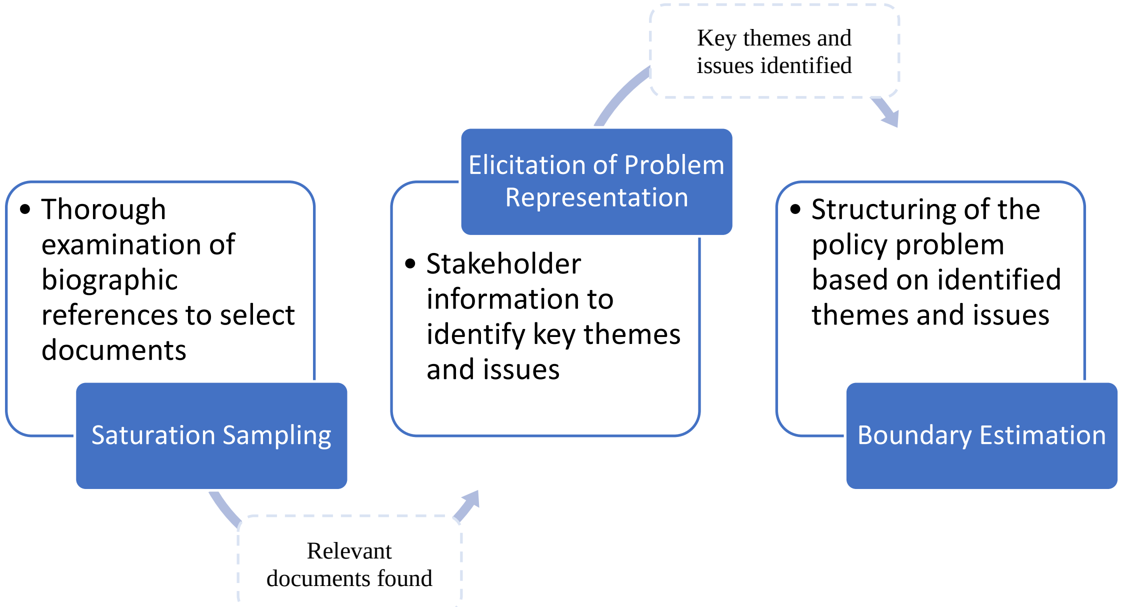
- **Boundary Analysis**

Boundary analysis is a method used to define the key elements of a policy problem by incorporating input from stakeholders who have explicit knowledge or experience with the topic (Dunn, 2018). The aim of the boundary analysis method in this study is to specify and conclude the structuring of the policy problem for governing agricultural data based on the key themes identified in the previous content analysis and software analysis. The purpose of this approach is to estimate "whether the system of individual problem formulations … is relatively complete" (Dunn, 2018, p. 89). In other words, the goal is to identify multiple problems that are defined in different ways by key stakeholders in the agriculture sector. Overall, this analysis seeks to establish the boundaries necessary to formulate the policy problem of governing agricultural data in a comprehensive manner.

Dunn's (2018) three-step process for boundary analysis includes saturation sampling, elicitation of problem representation, and boundary estimation. The first step, saturation sampling, involves an exhaustive review of biographic references in selected documents to identify additional actors or stakeholders who discuss agricultural data issues. This process continues until no new references are found, ensuring that a comprehensive list of stakeholders is identified. The next step, elicitation of problem representation, involves a systematic analysis of stakeholder descriptions of the problem. This analysis may include interviews, surveys, or other means of gathering information from stakeholders. The final step, boundary estimation, involves identifying the key elements or boundaries of the problem by analyzing the stakeholder descriptions and identifying areas of agreement or disagreement. By following this three-step process, boundary analysis can provide a comprehensive and structured approach to understanding the policy problem of governing agricultural data.

The content analysis method was used to obtain "problem representations from stakeholders" (Dunn, 2018, p. 91). Each text data set was revisited to select text units that explained how each actor or stakeholder described the issues of data governance for farm data. The context for the content under analysis was provided by scholars, farm associations, news sites in agriculture, and publications from international organizations. Finally, the boundary estimation process involved summing the cumulative frequency of key agricultural data problems from all text-data sources. A brief explanation of the three-step process is shown in Figure 12 and boundary estimations is displayed in a pareto chart in Figure 13.

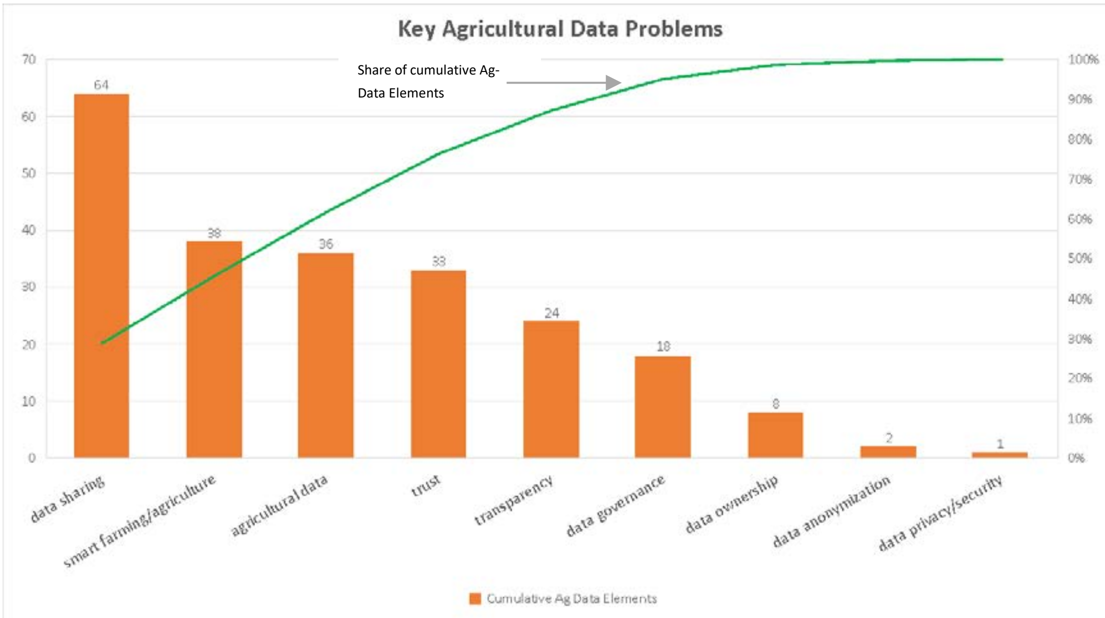
Figure 12 Explanation of the boundary analysis three-step process



Adapted from Dunn 2018

The first step involved accessing written descriptions of the problem by stakeholders in the agricultural sector using text data sets collection. From the available documents, the second step involved identifying problem representations within the bounded system of stakeholders. These are "ideas, basic paradigms, dominant metaphors, standard operating procedures, ... by which [stakeholders] attach meaning to events" (Dunn, 2018, p. 91). The third step, represented by the Pareto chart in Figure 12, shows the estimated boundary of the key agricultural data problems that were identified through content analysis. The Pareto chart primarily organizes the count of themes, subthemes, and keywords obtained from the content analysis. The revision of these themes was also compared with the keywords visualized in the VOSviewer map.

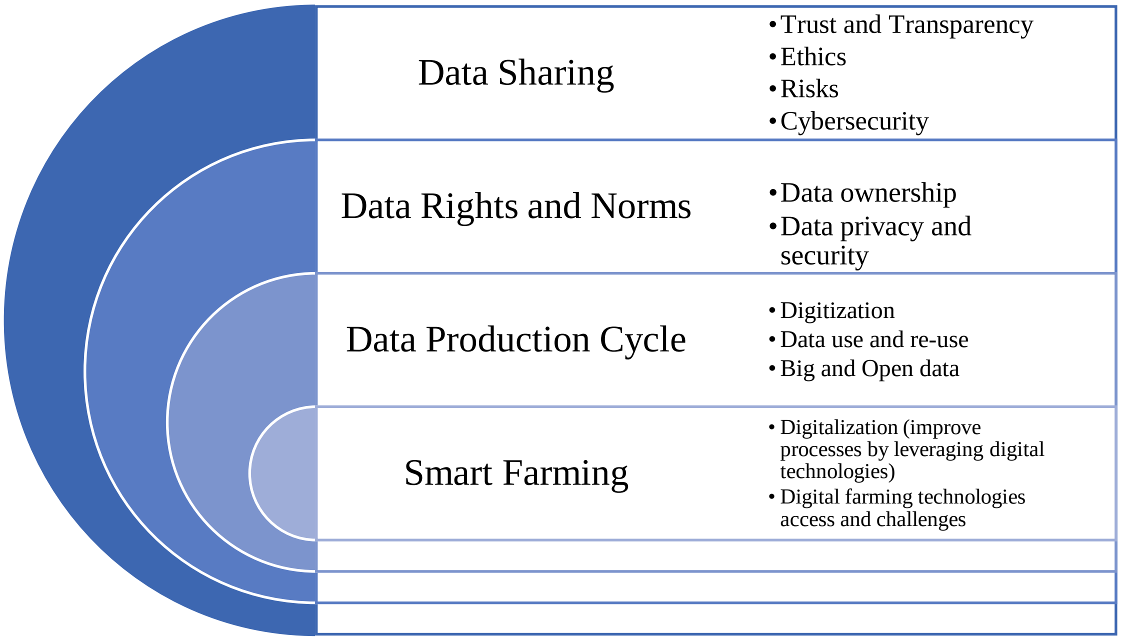
Figure 13 Boundary estimation of agricultural data key problem factors



Statement of Policy Problem

The three methods presented above provided the basis for defining a set of problem dimensions. The key agricultural data items were classified into four dimensions: data sharing, data production cycle, data rights and norms, and smart farming. Figure 14 provides an overview of the most important dimensions of the policy problem, based on the results of the content analysis, VOSviewer software, and boundary analysis.

Figure 14 Diagram of most relevant dimensions in the agricultural data governance policy problem



The identified dimensions of the agricultural data governance problem emphasize the importance of a data governance policy framework that establishes guidelines, standards, and roles to facilitate data sharing across the agriculture sectors in the United States. This framework should focus on developing trustworthy data-sharing systems and environments through mechanisms and measures that enable agricultural data access and use. To achieve this, the agricultural data governance framework should prioritize trust and transparency in data sharing, enhance mechanisms to increase data availability, and overcome technical barriers to data reuse within the sector. Such measures will enhance the value and benefits that the agriculture sector can derive from agricultural data, transforming it into a smart and digitally transformed industry.

The use of the three methods aimed to identify and map different perspectives on agricultural data governance, and structure it as a policy problem through a multi-stakeholder approach. However, it is important to note that these methods have a moderate level of replicability, as they rely on general guidelines and specific descriptions that may be subject to researcher subjectivity and research context.

The policy problem of agricultural data governance, as currently structured and assuming its proper structuring, appears to be a broad but relatively well-organized and moderately complex policy problem. To further evaluate the agricultural data policy problem, ten wicked problem characteristics developed by Rittel and Weber (1973) were used to demonstrate the moderately structured nature of this problem. These characteristics are presented in Table 11.

Table 11 Comparison of the criteria to classify structured policy problems

Characteristics	Agricultural Data Governance Problem
Decision-makers	USDA agencies, such as the National Agricultural Library (NAL), or the National Agricultural Statistics Service (NASS)
Stakeholders	Broad but relatively well-defined (farmers, agriculture tech providers, tech companies, agribusiness)
Value Consensus	Moderate/Bargaining
Preference Rankings	Relatively stable and transitive
Stop collection information rule	Relevant knowledge/information is large but limited
Ability to Forecast	Challenging/Uncertain
Policy Alternatives	Limited
Administrative and Political Obstacles	Some
Role of policy analysis in problem structuring	Some
Nature of policy problem	Secondary/Functional

Adapted from Rittel and Weber 1973

According to Mitroff (1974, p. 224 in Dunn, 2018), well-structured problems are those for which enough information is available to understand their sources and develop feasible policy solutions. While the agricultural data governance problem is complex, it is moderately well-defined, with evidence available to help settle differences between stakeholders. Unlike a value-based problem, this policy problem is not solely based on conflicting values or preferences, but rather on practical challenges related to data sharing and management. The policy solutions developed in the agriculture sector could be applied to other sectors facing similar challenges.

The policy problem of agricultural data governance is a complex and evolving issue, with multiple stakeholders involved in the governance of agricultural data, including farmers, agricultural technology providers, tech companies, and agribusiness. As data becomes increasingly central to agricultural production, there is a growing need to establish guidelines, standards, and roles to facilitate data sharing and use across the sector.

Additionally, as the volume of agricultural data continues to increase, there is a need for mechanisms to ensure data privacy and security, as well as to address cybersecurity risks. Furthermore, there is a need to overcome technical barriers to data reuse and establish trustworthy data-sharing environments to increase trust and transparency in the sector. Overall, a governance framework for agricultural data is essential to maximize the sector's benefits and value, transforming it into a smart and digitally transformed industry.

Chapter 3: Policy Options

This chapter employs a comparative case analysis approach to propose three distinct policy options for agricultural data governance, aimed at addressing the policy problem identified in Chapter 2. The methods used for the comparative case analysis include bench-marking and lesson-drawing.

The policy options, labeled as minimal, moderate, and maximal, are designed to offer distinctive solutions to the policy problem. To develop these options, this research maps the existing policy frameworks in other jurisdictions and explore the potential transferability of legal provisions to the agricultural data governance context in the U.S. This approach aims to fill the legal void that currently exists in the U.S. agriculture sector regarding the governance of agricultural data.

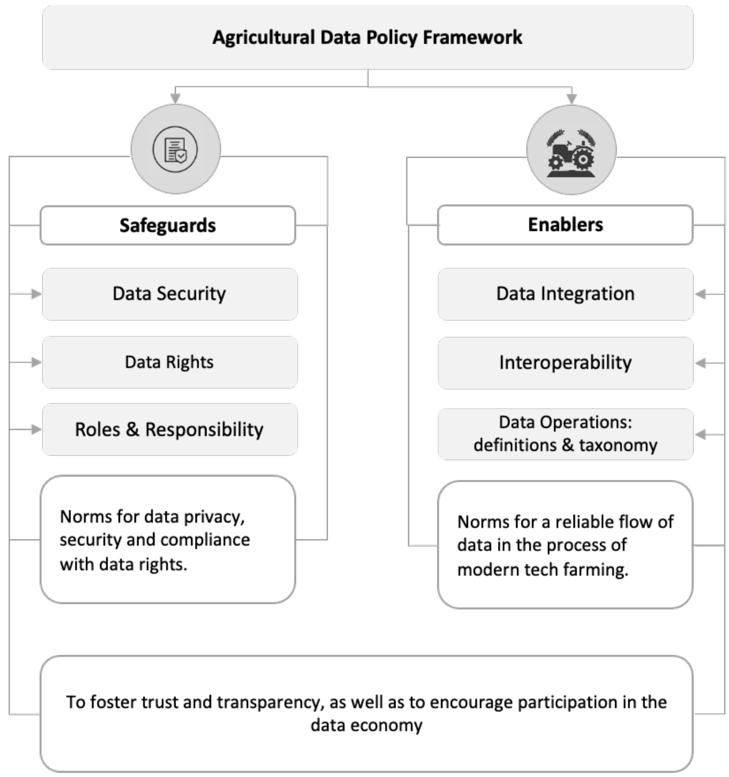
Generic Standards

Most legal regulations and policy provisions that govern data are structured around two main components: safeguards and enablers. These components include standards for protecting personal and non-personal data, as well as ensuring secure mechanisms and processes for the flow of private and public intent data sharing. Examples of these regulations and policies include the "Gramm-Leach Bliley" Act (GLBA) for the financial service industry, the Health Insurance and Portability and Accountability Act (HIPAA) for the healthcare industry, and the California Consumer Privacy Act (CCPA). However, in the United States, agricultural data is currently governed by contracts and licensing agreements controlled by private agricultural corporations. This practice creates an environment where farmers and primary producers have limited bargaining power and little incentive to share their data.

The Global Data Regulation Diagnostic publication from the World Bank (Chen, 2021) presents a detailed assessment of laws and regulations on data governance. Its content covers both safeguards and enablers for data governance across 80 countries ranging from low to high-income groups (Chen, 2021, p. 1). Figure 15 provides a useful overview of the different components of a data governance framework[29] that can be used to guide the analysis of policy options for agricultural data governance in the U.S.

[29] A framework understood as a structured and well-defined description of the data activities upon which a policy should be built. A policy framework in this research establishes a set of criteria for selecting features, elements, components, or mechanisms from each existing data governance regulation that could solve the agricultural data problem in the United States.

Figure 15 Data Governance Policy Framework Components considered for Agricultural Data



Adapted from Chen, 2021

Safeguards refer to norms or legal regulations that aim to protect the data-related rights of market players, while enablers are norms or laws that aim to facilitate the use and re-use of data (Chen, 2021). Both pillars, safeguards and enablers, contain components that foster trust and transparency among stakeholders in governing data.

By drawing on the best practices and lessons learned from other jurisdictions, this research aims to develop a set of policy options for agricultural data governance in the United States. These policy options will be based on a comparative case analysis of existing data governance frameworks[30], with a particular focus on the regulatory components of the Codes of Practice, the Gramm-Leach-Bliley Act (GLBA), the Health Insurance and Portability and Accountability Act (HIPAA), the California Consumer Privacy Act (CCPA), and the EU Data Governance Act. The selection of these laws and regulations was based on their relevance to the data governance dimensions, which include both safeguards and enablers, and their potential to address some of the challenges in the agricultural sector.

The Codes of Practice provide principles and guidelines to promote responsible data practices. The GLBA and HIPAA have frameworks for safeguarding personal data, which are important considerations in the agricultural sector where personal data such as financial information, bank loans and credit scores, and land ownership information may be collected from farmers. The CCPA has provisions for regulating the use of non-personal data, which are relevant for the agricultural sector where both types of data (personal and non-personal[31]) are generated and shared.

One of the key challenges in agricultural data governance is balancing the need for privacy and data protection with the benefits of data sharing and collaboration. On the one hand, farmers and other primary producers need to be able to trust that their data will be kept confidential and used only for agreed-upon purposes. On the other hand, data sharing can lead to important insights and innovations that can benefit the entire agricultural sector.

[30] These frameworks include a mix of safeguards and enablers, such as data protection regulations, data sharing agreements, and technical standards for data interoperability. However, there is no one-size-fits-all solution to data governance, and policymakers must carefully consider the unique context of their own jurisdiction when developing data governance policies.

[31] Non-personal data in the agriculture sector are agronomic data, such as soil type, crop type, planting density, fertilization, and pesticide usage.

Finding a good balance between these competing interests is a difficult but necessary task for this study.

Codes of Practice

This section analyzes four Codes of Practice (COPs), also known as Codes of Conduct. COPs are industry-led self-regulatory frameworks for agricultural data practices. These COPs aim to promote good agricultural data practices among farmers, producers, and agribusiness companies or ATPs. They comprise voluntary sets of rules based on principles (Sanderson et al., 2018) and are intended to shape the behavior of business or community organizations, and are enforced by the industry or sector itself (Sanderson, 2019, p.6). These codes address issues such as data ownership providing definitions and best practices for the management of agricultural data. While adherence to these COPs is voluntary, they offer a framework for stakeholders in the agriculture sector to work together and promote responsible, responsive, and transparent data contracting practices.

Currently, there are only four codes available: the U.S. Farm Bureau Privacy and Security Principles for Farm Data, the EU Code of Conduct on Agricultural Data Sharing by Contractual Agreement, the New Zealand Farm Data Code of Practice, and the Australian Farm Data Code. These codes are relatively new, with the U.S. and New Zealand pioneering the launch of their codes of agricultural data practices in 2014, supported by private agriculture industry associations and businesses, and in some cases, with governmental assistance.

While COPs represent an initial collaborative effort to promote awareness about the value of agricultural data among farmers, producers, and ATPs, they are relatively new[32], non-binding, and their impact, effects, and consequences in terms of effectively governing agricultural data between farmers and ATPs, as well as agribusiness companies, remain unknown. According to Sanderson et al. (2018, p. 15), given the voluntary nature of the four existing COPs, there are additional challenges at the macro structural-institutional level. These include the appropriation of an agile agricultural data normative framework[33], the extension and implementation of COPs, issues around trademark-based logos created from these codes, and the assessment of the effects or consequences of existing COPs.

The question of whether self-policing by farm associations and agribusiness groups is sufficient or whether additional oversight is necessary is complex. On the one hand, allowing industry stakeholders to regulate themselves can be more efficient and responsive to sector-specific issues, but on the other hand, it can also lead to conflicts of interest and a lack of accountability.

In this scenario, the COPs are not mandatory and lack legal enforceability, thus the parties engaged in data contracts have complete discretion over their adherence. Therefore, there is a possibility that certain parties may not adhere to the principles outlined in the codes, or that various stakeholders may interpret and implement them inconsistently.

These four COPs have three general goals. First, to raise awareness among farmers and producers about the importance of agricultural data. Second, to empower them to use data

[32] Most of them have been in force since 2014.

[33] Sanders et al (2018) understand as an agile ag-data normative framework as the set of rules, norms or principles regulating or norming the agricultural data practices.

to build a profitable future. And third, to encourage agribusiness companies and ATPs to adopt more responsible, responsive, and transparent data contracting practices. These codes serve as the foundation for resolving sector concerns related to agricultural data governance, including issues around data ownership.

These COPs propose a collective action approach to empower farmers and primary producers to pursue transparent transactions or practices of agricultural data through contractual agreements. They are based on definition of core principles and best practices for agricultural data, involving all stakeholders willing to comply, from farmers and producers to agribusiness and technology providers. According to Sanderson et al. (2018, p. 2), the purpose of agricultural codes of practice is "inextricably linked to consent, disclosure, transparency, and ultimately, the building of trust."

Other contributions from all of these COPs include the specification of terms and definitions. For example, the EU-COD defines what a data originator[34] is, what their rights are, and data pseudonymization[35]. In the case of the Australian Agricultural Data Rules, it covers the concepts of data governance, management, and implementation. It includes a capacity and capability-building component to educate farmers, as well as a risk, regulation, and compliance component to ensure cybersecurity.

All of the principles embodied in these codes for agricultural data practices are the result of collective action by stakeholders in the agriculture sector. Efforts to develop and publish

[34] Data originator is defined as the “person or entity that can claim the exclusive right to license access to the data and control its downstream to use or re-use” (EU-CoD, 2018)

[35] Data pseudonymization is the “procedure in which the most revealing fields within a data record are replaced by one or more artificial identifiers or pseudonyms.” (EU-CoD, 2018). Its main purpose is to “render the data record less identifiable and therefore lower the risks involved in its use”

codes of practice are based on consensus and agreements among interested farm associations, agribusiness companies, and other agricultural industry organizations. The role of the government in promoting credibility and legitimacy in the principles promoted by COPs, as well as monitoring compliance with them, is important. Governments can serve as a third-party enforcer of compliance with the principles and act as a mediator in cases of disputes.

- **New Zealand Farm Data Code of Practice**

The Farm Data Code of Practice Version 1.1 was launched in New Zealand in 2014[36] after extensive consultation and planning across the agriculture sector. This code provides guidelines for effective data sharing in the country's agriculture industry and is adhered to by organizations such as Dairy NZ, the Red Meat Profit Partnership, and the Ministry of Primary Industries to ensure that farmers' information is handled appropriately. The code offers recommended standards and requirements for collecting, storing, and sharing agricultural data and is owned and operated by Farm Data Accreditation Ltd (FDAL), an independent company whose shareholders include the industry representative organizations that created and mandated the code.

The Farm Data Code of Practice in New Zealand regulates organizations that collect, store, and share primary agriculture data, with a focus on implementing practices that provide primary producers[37] with confidence regarding their data security. Registered

[36] According to the New Zealand Code of Practice, in "April 2015, ownership of the Farm Data Code of Practice was transferred to an independent company, Farm Data Accreditation Limited." More information available at:

[37] "Primary producers" is the term used to refer to farmers in the New Zealand COP.

organizations have agreed to disclose their practices and policies related to data rights, processing, sharing, storage, and security (FDAL, 2016) to increase data sharing securely within the sector and promote innovation in services and products.

FDAL, an independent company, oversees the Code and provides administrative and operation services to agriculture companies with an annual license, certificate, and permission to use the trademark. FDAL also has an executive board that receives complaints about noncompliance with the principles, and determines whether agricultural companies' logos should be renewed on an annual basis, making it a safeguard for farmers and agribusiness. The distinctive roles and responsibilities of FDAL are what distinguish this code from the others, and will be considered for the purposes of this research.

- **European Union Code of Conduct on Agricultural Data Sharing by Contractual Agreement**

In the European Union[38], a coalition of European farm associations[39] from the EU agri-food chain launched the Code of Conduct on Agricultural Data Sharing by Contractual Agreement in 2018. Prior to these Code, agricultural data was collected, stored, and used

[38] See Kosior, K. 2019 "From Analogue to Digital Agriculture. Policy and Regulatory Framework for Agricultural Data Governance in the EU" ISEG Research Seminar „Governance, regulation and economic integration", Lisbon School of Economics and Management, University of Lisbon, 8 May 2019

[39] European farmers, and European agri-cooperatives (Copa and Cogeca), European Agricultural Machinery (CEMA), European Organisation of Agricultural, Rural and Forestry Contractors (CEETTAR), European Council of Young Farmers (CEJA), European Crop Protection Association (ECPA), European Forum of Farm Animal Breeders (EFFAB), European Compound Feed Manufactures' Federation (FEFAC), and European Seed Association (ESA).

by public institutions (Kosior, 2019b), but the rapid development and implementation of farming technologies that generate large amounts of data highlighted the need for the Code of Conduct.

This COP was developed with the input of various stakeholders from the agri-food value chain, including farmers, agri-businesses, and public institutions. This collaborative approach helped ensure that the guidelines are practical, effective, and widely accepted. Initially, nine agro-associations[40] developed the guidelines for processing and sharing agricultural data in the EU Code. The Code of Conduct was created to promote access to accurate agricultural data, which is a crucial step "to develop digital farming enabling farmers to produce more using fewer resources" (Koerhuis, 2018, p.1). It provides guidance on the use of agricultural data, particularly on the rights to access and use the data. It includes a checklist as well as key guidelines for operators to follow. Janzen (2018) and Koerhuis (2018) suggest that granting access to agricultural data will facilitate and accelerate data-driven business models in this sector.

This COP fosters a dialogue among all stakeholders in the agri-food value chain (Wiseman et al., 2019, p. 7) to encourage fair and transparent contractual agreement rules for data sharing. Unlike the codes in the United States and New Zealand, the European Union's Code of Conduct provides specific definitions to govern contracts between farmers and agri-business, preventing contractual agreements from being misinterpreted.

[40] Since 2018, the government has partnered with industry associations such as Copa-Cogeca[40], European Agricultural Machinery (CEMA), Fertilizers Europe, the European Confederation of Agricultural, Rural and Forestry Contractors (CEETTAR), European Council of Young Farmers (CEJA), European Crop Protection Association (ECPA), European Forum of Farm Animal Breeders (EFFAB), European Feed Manufacturers' Federation (FEFAC), and European Space Agency (ESA).

The Code of Conduct establishes guidelines focusing on the rights and obligations associated with the use and sharing of agricultural data. It uses a "compliance tool" (Wiseman et al. 2019, p.9) which is a contract checklist for agricultural data, to ensure a trustworthy environment to construct data-driven business models that benefit all stakeholders involved in using a product or service that collects or uses agricultural data. According to van der Burg et al. (2021, p. 6), the EU COP's key features are its five principles: data ownership, data access, control and portability, data protection and transparency, privacy and security, and intellectual property rights.

One additional point to consider regarding the EU Code of Conduct on Agricultural Data Sharing is the important role that data standardization plays in its implementation. Standardization is critical for ensuring data compatibility and interoperability between different stakeholders in the agricultural sector, as well as for improving the quality of the data itself. The EU Code of Conduct specifically encourages the use of existing standards for data exchange and storage, such as the ISO 11783[41] standard for agricultural technology and the AgGateway ADAPT framework[42]. This emphasis on standardization helps to

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[41] ISO 11783, also known as the Tractor Implement Management System (TIMS), is an international standard developed to enable interoperability between tractors and implements used in agriculture. It provides a communication protocol for electronic control units (ECUs) used in agricultural machinery, allowing them to exchange data and communicate with one another. The standard covers a wide range of functions, including the exchange of data between tractors and implements, the management of diagnostic and software updates, and the control of functions such as steering, transmission, and hydraulics. The use of ISO 11783 can improve the efficiency and productivity of agricultural operations by enabling different machinery components to work together seamlessly. Information available at: International Organization for Standardization (ISO). (2020). 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. https://www.iso.org/standard/57556.html

[42] The AGGateway ADAPT (Agricultural Data Application Programming Toolkit) framework is an open-source platform developed by the AGGateway organization to enable interoperability between different

overcome the challenge of data fragmentation and siloed information, allowing for more effective collaboration and data-driven decision-making across the agri-food value chain.

- **Australia Agricultural Data Rules: Enabling Best Practices**

The Agricultural Data Rules were developed in Australia and published in February 2020 with the support of the National Farmers' Federation and the Australian Government Department of Agriculture, Water and the Environment. This code was developed as part of the "Growing a digital future for Australian Agriculture" program, and originated from the 'Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia' (P2D) project which evaluated the desired state of digital agriculture in the country (Wiseman, 2019).

The National Farmers' Federation partnered with a range of stakeholders, including farmers, industry bodies, government agencies, and technology providers. These partnerships were critical in ensuring that the code was tailored to the needs of Australian farmers and industry participants, while also providing a framework for collaboration and innovation in the sector.

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software applications used in agriculture. The ADAPT framework provides a set of standard application programming interfaces (APIs) that can be used to integrate different agricultural software systems, such as farm management systems, precision agriculture tools, and machinery control systems. The framework is designed to be flexible and scalable, allowing it to adapt to different types of data and workflows used in agriculture. The ADAPT framework enables users to access data from different sources and use it to inform decision-making, improving the efficiency and profitability of agricultural operations. Information available at: AGGateway. (2021). AGGateway ADAPT. https://www.aggateway.org/GetConnected/ADAPT(inter-operability).aspx

The main objective of the Agricultural Data Rules is to not only develop a data rules framework, but also to include an action plan that will create an enabling environment for digital innovation in Australian agricultural industries (Wiseman & Sanderson, 2020, p. 3). This code incorporates definitions and principles from both the EU and New Zealand COPs, making it a more robust and comprehensive code for addressing the agricultural data problem in Australia.

To facilitate agricultural innovation through data-driven decision-making and a reliable flow of agricultural data, the Australian Agricultural Data Rules are structured around three key pillars: people, responsibilities, and structures. The roles of individuals handling agricultural data are essential to the success of the code, and the "capacity and capability" and "risk, regulation, and compliance" components address this issue. The former covers communication, education, and training, while the latter addresses risk assessment, cybersecurity, complaints, breach, and reporting (Wiseman & Sanderson, 2020, p. 6).

The code outlines six key principles for agricultural data management, including governance, transparency, privacy, security, accessibility, and usability. It provides guidelines for responsible data sharing, such as obtaining consent from data owners, ensuring data quality and accuracy, and protecting sensitive information. By including these principles and guidelines, the code provides a comprehensive framework for the management and sharing of agricultural data in Australia.

While the code provides a valuable framework for data governance and responsible data sharing, it may require significant resources and investment to implement effectively. Additionally, there may be challenges in ensuring compliance with the code's guidelines, particularly for small-scale farmers and other stakeholders who may have limited resources or technical capabilities.

- **The U.S. Privacy and Security Principles for Farm Data**

In 2014, the American Farm Bureau Federation (AFBF), commodity groups, farm organizations, and ATPs jointly formulated the "Privacy and Security Principles for Farm Data"[43], also known as the Core Principles, which is the most extensive code in the U.S. Two years later, in 2016, AFBF, along with other organizations and agribusiness companies, established the Ag-Data Transparency Evaluator Inc[44], a non-profit organization that developed the Ag-Data Transparent logo or seal of approval[45]. This logo recognizes compliance with the Core Principles for agricultural data. However, no scholarly literature or other documents are available that demonstrate or describe the verification processes for Core Principles compliance.

The goal of the U.S. Core Principles is to encourage as many agribusiness and agricultural tech companies[46] as possible to commit[47] to including them in their contracts and agreements with farmers. According to the information available on Ag-Data

[43] The Core Principles are available at: https://www.agdatatransparent.com/principles

[44] It is a non-profit organization providing the certification process based on the Core Principles at a cost depending on the size of the organization, whether it is a startup, standard or large. More information available at: https://www.agdatatransparent.com/about and at: https://www.agdatatransparent.com/principles.

[45] An official logo acting as a certificate of voluntary commitment to comply with the core principles of agricultural data practices.

[46] According to the AFBF web page information, over 37 organizations –agribusiness technology providers (ATP) contracting with farmers– have agreed to follow these Core Principles.

[47] Guarantee to incorporate the Core Principles into ag-data contracts mainly based on a sign of good faith, since the ag data principles are non-binding guidelines.

Transparent, over 37 organizations (*Certified Companies Ag Data Transparent*, 2022) in the United States have agreed to follow the Core Principles and have obtained the Ag Data Transparent certification as proof of compliance. This certification process is based on the 13 "core principles," (*Core Principles Ag Data Transparent*, 2022)[48] and companies or ATPs must answer 11 questions[49] about how they collect, use, share, and protect farmers' agricultural data. These answers are reviewed and approved by an independent third-party administrator (*Certified Companies Ag Data Transparent*, 2022), and when approved, ADT issues the certification seal.

The ADT seal or logo serves as an assurance to farmers that organizations can be trusted to handle their agricultural data in contracts. According to Todd Janzen, the ADT administrator, the seal "is helping provide transparency, simplicity, and trust for farmers and their tech providers." While the "core principles" for agricultural data are essential, the certification process demonstrates how they can be put into practice.

The Core Principles require agribusinesses to be open and transparent about their data collection and usage practices. Companies are expected to disclose the types of data they collect, how it is collected, and how it is used. They are also required to be transparent about the third parties with whom they share data and the purposes for which they share it.

In addition to transparency, the U.S. Core Principles emphasize the importance of security in agricultural data practices. The principles recognize that agricultural data is sensitive and valuable information that requires protection. The Core Principles require

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[48] Information available at : https://www.agdatatransparent.com/principles

[49] 11 Questions Ag Data Transparent, 2022. Information available at https://www.agdatatransparent.com/11-questions

agribusinesses to implement reasonable security measures to protect agricultural data from unauthorized access, use, or disclosure. The principles also require companies to provide farmers with information about their security practices, including how they secure data, what security measures they have in place, and how they respond to security incidents.

Overall, the U.S. Core Principles for Farm Data represent an important step towards establishing responsible data practices in the agriculture sector. By emphasizing the importance of data control, transparency, and security, the Core Principles provide a framework for agribusinesses and farmers to work together in a more responsible and trustworthy manner. The principles are not legally binding, but they provide a valuable set of guidelines that can help ensure that agricultural data is managed in a responsible and ethical manner.

In summary, the common objective of these codes is to create trusting environments and relationships for sharing and using agricultural data between farmers, producers, and service, machinery, and digital tech agribusiness providers based on contract agreements. Nonetheless, adherence to all agricultural data practices codes is entirely voluntary, as they are non-binding guidelines for parties who agree to work together based on data contracts. Figure 16 provides a visual comparison of these codes, illustrating the gradual contribution of each code to the agricultural data practices of the four countries.

Figure 16 Comparison of existing COPs

Adapted from GODAN[50] (2022)

Figure 16 shows an incremental comparison of the four COPs analyzed in this section. Each of these COPs includes comparable guidelines and principles to enhance agricultural data practices in their respective countries. The Australian COP, released in 2020, integrates numerous definitions and principles from the preceding codes, while also emphasizing the significance of enhancing capacity and capabilities within the agricultural sector to effectively collect, manage, and utilize agricultural data. This includes providing training and education to farmers and other stakeholders on data collection and analysis

[50] GODAN toolkit: "Code of Conduct Constructor" Available at: https://www.godan.info/codes/list/definitions

methods, as well as investing in the necessary infrastructure and technology to enable effective data sharing and collaboration.

COPs are voluntary and principle-based guidelines for the self-regulation of agricultural data practices. While they are not legally enforceable, they have the potential to drive significant industry-wide shifts in data practices. These COPs provide foundational components for governing agricultural data, engaging stakeholders, fostering trust and transparency, and creating innovative pathways to extract value from agricultural data. However, there is currently no conclusive evidence that these COPs are effective tools for supporting agricultural data practices in any of the countries where they are in force.

COPs can be a starting point for policy frameworks, as they encourage discussions and collaboration to find solutions that meet the needs and interests of all involved parties. The Global Open Data for Agriculture and Nutrition (GODAN), the Technical Centre for Agriculture and Rural Cooperation (CTA), and the Global Forum on Agricultural Research and Innovation (GFAR) have jointly launched a toolkit that enables stakeholders to develop and simulate their own agricultural codes of conduct.

The Agricultural Codes of Conduct Toolkit is the result of a consultative process involving the GODAN/CTA Sub-Group on Data Codes of Conduct, as part of a planned global collective action on Empowering Farmers through Equitable Data Sharing. The toolkit aims to enable stakeholders to better understand the needs and concerns of all actors involved in the agricultural data value chain, thus strengthening trust across the industry. It features 17 clauses that users can access and select from depending on their relevance. While these clauses are not exhaustive and do not replace a robust institutional framework, they can be useful in guiding decision-making and operationalizing ethical practices for the flow of agricultural data.

The online platform can play a critical role in creating a dialogue among stakeholders and finding solutions that address the needs and interests of all parties involved. In the words of Andre Laperriere, Executive Director of GODAN, "Codes of conduct help include smallholder farmers in decision making, policy design, and enhancement of privacy protection and trust, as well as providing considerable economic and health benefits."

U.S. Data Cooperatives

There are several companies in the U.S. that offer data services and solutions to the agriculture sector, including collaborative agribusiness models such as data cooperatives[51] and data pools. Six major organizations in the United States serve as intermediaries in agricultural data management. These organizations include the Ag Data Coalition (ADC), the Grower Information Services Cooperative (GiSC), the Farmers Business Network (FBN), and the most recent federally funded initiative of the United States Department of Agriculture, the National Agricultural Producers Data Cooperative (NAPDC). Other organizations such as the Open Ag Data Alliance (OADA), AgGateway, and others have

[51] Data cooperatives are "entities established to facilitate the collaborative pooling of data by individuals or organizations for their mutual economic, social, or cultural benefit. From an economic perspective, data cooperatives aim to rebalance the asymmetric relationship between data subjects and those who use data to develop services and products" (Baloup et al., 2021, p. 29)

also been discovered[52]. Table 12 summarizes information from the four major agricultural data companies.

These collaborative agribusiness models, play a key role in ensuring buy-in from all stakeholders, particularly farmers, in data-driven solutions, and highlighting the benefits that come with effective data governance. They provide oversight and transparency over the use of data entrusted to them, and ensure that data-driven strategies add value to the agri-food chain in the United States.

Table 12 Agricultural Data Cooperatives in the U.S

Organization	Description
ADC	It is a non-profit organization created in 2016. Its organizational purpose is to educate the agriculture sector about the value of ag-data – as an agriculture sector asset– and its potential for data sharing between farmers, universities, and other companies.
GiSC	It has been a farmer-owned national data cooperative since 2014. Its main objective is to provide farmers with a network of technology partners. Also, it is an independent platform that gives agriculture technology and data information and storage to improve farm decisions and promote the industrial agriculture revolution.
FBN	It is a business network of independent farmers that have shared agriculture data since 2014. It claims that its mission is "by democratizing information, providing unbiased analytics, and creating competition for farmers' business." (FBN, 2020) As a driven

[52] Others are: AgMatix company for linking field research type data; AgNIC (A collaboration among libraries and organizations that promotes access to authoritative agricultural information and data.); United States Agricultural Information Network (USAIN); the Agricultural Research Data Network (ARDN); and Data Commons.

Organization	Description
	information source, this network guarantees transparency and fairness as values when dealing with ag data.
NAPDC	It is defined as a project. The overall goal of this project is to develop a blueprint for a national data framework and cooperative where producers, universities, and not-for-profit entities can store and share data and develop powerful tools that enable producers to maximize their production and profitability. The NAPDC will develop a blueprint for a national agricultural producers’ data framework; engage and support diverse participation including all types of agricultural research institutions, producers, and representatives of a relevant data producer and end-user organizations; and communicate and disseminate findings of all activities through publications, peer-reviewed articles, and presentations to scientific and producer groups.

These companies function as independent data aggregation platforms that share agronomic precision data with a common goal of creating a secure system for processing agricultural data efficiently. They offer centralized locations for managing all agricultural data. For instance, GiSC offers the AgHub tool, which collects and securely stores all agricultural data from digital technologies such as tractors, sprayers, sensors, and drones.

These cooperatives emphasize a farmer-first approach and claim to be an "independent, unbiased, and objective farmer-driven information source," as stated on the FBN[53] website. Others, like Open Ag Data Alliance, create "a secure data ecosystem that enables data security, privacy, and interoperability for the entire agriculture industry"[54] through open software available to farmers. These six data cooperatives mentioned are only examples of

[53] More information available at: https://www.fbn.com/about
[54] Information available at: http://openag.io/principles/

potential opportunities to create new entities that address the ever-increasing volume of agricultural data challenges for farmers.

In conclusion, data cooperatives and other data intermediaries are emerging as key players in the agriculture sector. These organizations offer secure and centralized platforms to manage agricultural data, provide oversight and transparency over the use of data entrusted to them. Moving forward, the continued growth and success of these data cooperatives will depend on their ability to maintain trust among all stakeholders, particularly farmers, and to keep pace with the rapidly evolving technological landscape in the agriculture sector.

U.S. National and State-Level Laws and Regulations

The policy landscape and legal framework regulating agricultural data governance in the United States reveals challenges and uncertainties. Although there are regulatory bill initiatives, none of them aim to set industry-specific norms for data flow, sharing, privacy, and security. Modernization and innovation of agricultural data infrastructure at the public institutional level, such as the U.S. Department of Agriculture (USDA), is still pending.

The Agriculture Improvement Act (P.L. 115-334), also known as the “2018 Farm bill,” was signed into law in December 2018 and will remain in effect until 2023 (McMinimy et al., 2019). This Act was part of the U.S. Congress's periodic agricultural policy revisions that largely extended “agricultural commodity support programs along existing lines while modifying them in various ways” (McMinimy et al., 2019, p.1). The major changes focused on reallocating funding across agriculture and food programs.

The farm Bill 2018 responds to a periodic regulatory revision that addresses a wide range of agricultural and food-related issues; for instance, issues related to “agricultural conservation, credit, rural development, domestic nutrition assistance, trade and international food aid, organic agriculture, forestry…” (McMinimy et al.,2019, p. 1) among others. One of the new Farm Bill 2018 provisions is the extension of support for urban agricultural programs as well as the creation of new and specific authorities (Janzen, 2018). However, the modifications in the law did not address the issue of agricultural data governance, including standards, safeguards and enabler mechanisms, or processes to manage it in a way that farmers could easily access information they reported themselves via a single platform.

Despite these challenges, the USDA has made progress in recent years. For example, the 2014 Farm Bill mandated the Acreage Crop Reporting Streamlining Initiative (ACRSI), aimed at reducing the burden of data submission for farmers and preventing duplication of data received in various department programs (Ristino & Hart, 2022, p. 7). ACRSI has established a standardized framework for farmers to report acreage data to the USDA. The institutional role of USDA is to develop and publish reporting standards for the framework as part of the initiative.

According to Ristino & Hart (2022, p.7), ACRSI data is shared electronically and securely between farmers and relevant program areas. ACRSI demonstrates the benefits and value of creating data standards that facilitate more efficient, secure, and accurate data sharing across the USDA (Ristino & Hart, 2022, p. 7). However, the disconnect between USDA agencies promotes institutional silos, making the integration, sharing, and use of agricultural data even more difficult.

In 2018, the USDA established a Chief Data Officer (CDO) and assistant Data Officers in each mission to improve data governance practices within the agency. This institutional modification resulted in the creation of the Enterprise Data Analytics Platform and Toolset (EDAPT). EDAPT connects data from 150 sources, both internal and external, to provide a comprehensive collection of administrative data and a standardized set of centrally available data analytics tools. The department-wide dashboard created a more data-focused culture, building technical and leadership capacity and inspiring other CDOs to develop similar platforms within their agencies (Ristino & Hart, 2022, p. 7).

The USDA's development of the Data Strategy for 2021-2023 represents a recent effort to tackle the challenges of governing agricultural data within the agency. The Strategy's first goal is focused on Data Governance and Leadership. In line with this, the USDA released the USDA Data Act Governance and POC Charter in 2019. The Act seeks to enhance data quality within the agency by establishing governance processes, protocols, roles and responsibilities, and rules for accessing, controlling, and sharing data within the agency's structural organization. The USDA's growing awareness of data issues and its critical institutional role in promoting the benefits of effective use of agricultural data highlights the importance of continuing efforts to modernize and enhance data governance in the agriculture sector.

In 2018, Senators Amy Klobuchar and John Thune introduced the Agricultural Data Act (Ag-Data Act, 115th Congress, 2017-2018), a bipartisan bill aimed at streamlining the collection and sharing of agricultural data for the benefit of U.S. agriculture producers. The primary goal of the bill was to increase knowledge about how conservation practices impact farm and ranch profitability and soil health by collecting, reviewing, and analyzing data. The bill intended to make USDA data available to researchers and land grant universities to encourage the study of conservation practices and their effects on farm profitability and soil health (Janzen, 2018a).

According to Janzen (2018a), the purpose of this bill is to streamline agricultural data collection within the USDA and make it available for research purposes to land grant universities and other organizations.

At the state level, Minnesota's legal regulations identify the various types of agricultural data in the public sector. However, they do not provide a description of the rules, norms, or processes to access, share, and use such public data. In 2020, Chapter 13 outlined the Government Data practices, and Section 13.643 and 13.6435 specifically deal with Agricultural Data types. Table 13 below provides a detailed description of the content of both sections of the Minnesota legislation.

Table 13 Minnesota Agricultural Data Types Regulation

Section	**Title**	**Subdivisions**	
13.643	Agricultural Data	1. Department of Agriculture Data	(a) Loan and grant applicant data (b) Farm advocate data
		2. Farm assistance data	
		3. Aquaculture permit data	
		4. [Repealed, 2001, c202s21]	
		5.Data received from federal government	
		6. Animal premises data	
		7.Research, monitoring, or assessment data	
13.6435	Agricultural data coded elsewhere	1. Scope	
		2. Department of Agriculture	(a) Agriculture best practices loan program

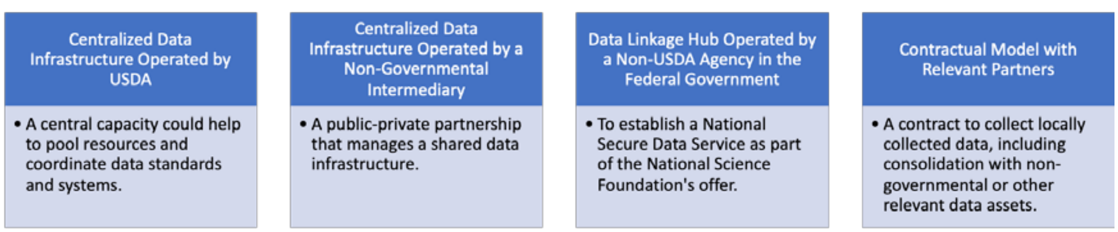
		(b) Aquaculture data (c) Aquatic farm license (d) Agricultural Commodities Promotion Council. (e) Agricultural producer association and commodity handlers
	3. Pesticide control	(a) Registration. (b) Dealer and applicator records
	4. Agricultural applications; protection of trade secrets.	(a) Industrial hemp licensing data.
	5. MS 2018 [Repealed, 2020 c 89 art 1 s 21]	
	6. Meat inspection data	
	7. [Repealed, 1Sp2001 c 2 s 162]	
	8. Dairy products	
	9. [Repealed, 2010 c 382 s 87]	
	10. Rural Finance Authority	
	11. Farm products; grain buyer licensee data.	
	12. Farmer-lender mediation.	
	13. Ethanol producer payments.	
	14. Agricultural water quality certification program	

Adapted from Minnesota, Status 2020. CHAPTER 13 GOVERNMENT DATA PRACTICES

The subdivision 4 of Section 13.6435, "agricultural applications; protection of trade secrets," is a significant step towards addressing legal issues and disputes related to ag data. However, Ellixson & Griffin (2016, p.2) point out that as of 2016, there were no laws covering the ownership of agricultural data or the consequences of misusing that data.

The agricultural sector's national and public data infrastructure is essential for providing critical agricultural insights, improving the effectiveness of farm bill programs, and offering better value to farmers and taxpayers (Ristino & Hart, 2022). To address these issues, the AGree Initiative, Three Canyon Farms, Data Foundation, University of Missouri Center for Regenerative Agriculture, and the Meridian Institute collaborated on the webinar, "Models for Modernizing Agriculture Data Infrastructure: Lessons Learned from Data Innovation in Other Sectors" on June 9, 2022. They discussed the recently published report, "Modernizing Agriculture Data Infrastructure to Improve Economic and Ecological Outcomes," which outlines four practical options for modernizing the USDA's data infrastructure to adapt, innovate, and ensure food security in the future (Ristino & Hart, 2022). Figure 17 illustrates these four models.

Figure 17 Four Models to Modernize the USDA Agricultural Data Infrastructure



Adapted from (Ristino & Hart, 2022, p. 3)

The current USDA data infrastructure is struggling to assist farmers in addressing challenges, such as the extreme weather events that caused the Midwest floods in 2019, disruptions in global supply chains like those experienced in 2021, and the rising prices of fertilizers (Ristino & Hart, 2022). Adopting one of the four proposed models could help improve the low institutional performance of the USDA in assisting agriculture digital transformation.

A centralized model for data infrastructure, operated within the USDA, could provide reliable data standards and build trustworthy systems for farmers and other stakeholders. However, Ristino and Hart (2022, p. 3) argue that due to the USDA's limited infrastructure capacity and heavy inter-institutional regulations, this model may be impractical.

The second model proposes centralizing the data infrastructure under a public-private partnership. This model combines the appeal of enabling government authorities for data protection and resources with the flexibility of the private sector, including its ability to protect proprietary information.

A third model involves designing a data linkage hub. Ristino & Hart (2022) state that ongoing discussions are underway to determine the benefits of this model. It would provide a highly secure environment for integrating data with some usage restrictions.

The final model proposes a contractual approach, which is sensitive and requires coordination and negotiations with farmers regarding the economic contractual rates (Ristino & Hart, 2022, p. 14). This approach requires clear incentives to compensate partners or data providers for data exchange and transactions.

While not prescriptive, these four models offer potential solutions to the challenges facing the USDA agency's data practices. In a webinar featuring speakers such as Robert Blair, president of Three Canyon Farms, it was noted that farmers have a distrust of data reporting and that the USDA is falling behind in terms of data practices in the information age (Atwood et al., 2022). Blair emphasized the need for the USDA to modernize its infrastructure to collect and promote data flow among farmers and other USDA agencies. Agriculture stakeholders recognize the importance of using data to improve food safety and security at a macro level.

The four proposed models for modernizing the USDA's data infrastructure system offer an opportunity to build trust and collaboration between farmers and other stakeholders in the agriculture sector, as well as unlock economic opportunities by leveraging data value. For example, better information about farms' productivity and risk can help address dynamic weather and economic challenges (Ristino & Hart, 2022, p. 4) and researchers could use data to understand how different farming practices affect productivity and environmental outcomes, which can enable ecosystem markets.

However, while these models address the issue at the meso-institutional level, governing agricultural data at the macro sector level remains a challenge. Private agribusiness firms are already using data to make production decisions and promote carbon markets, and agricultural machinery manufacturers are connecting equipment to the cloud for real-time data collection. Meanwhile, the USDA's data infrastructure has stalled, hindering its ability to support farmers and enhance program performance.

Lesson Drawing and Benchmarking

This section summarizes the main lessons, best practices, and benchmarks drawn from the examination of existing regulatory frameworks for data governance in the U.S., other countries, other sectors, and Europe. Lesson-drawing is a process that requires more than just highlighting successful examples of current programs or processes addressing similar problems elsewhere. As Rose (1991, p. 19) notes, it also requires examination of under what conditions and to what extent a current program or process would work elsewhere.

One lesson to draw from the codes of practice is the importance of agricultural data definitions. While the U.S. code of practice does not explicitly describe the types of data covered by the set of principles, the codes from New Zealand and the European Union do so to varying degrees. The EU COP provides a comprehensive list of definitions that accurately describe the scope of all three codes[55] (van der Burg et al., 2021), including the importance of data originators[56] having control over their data.

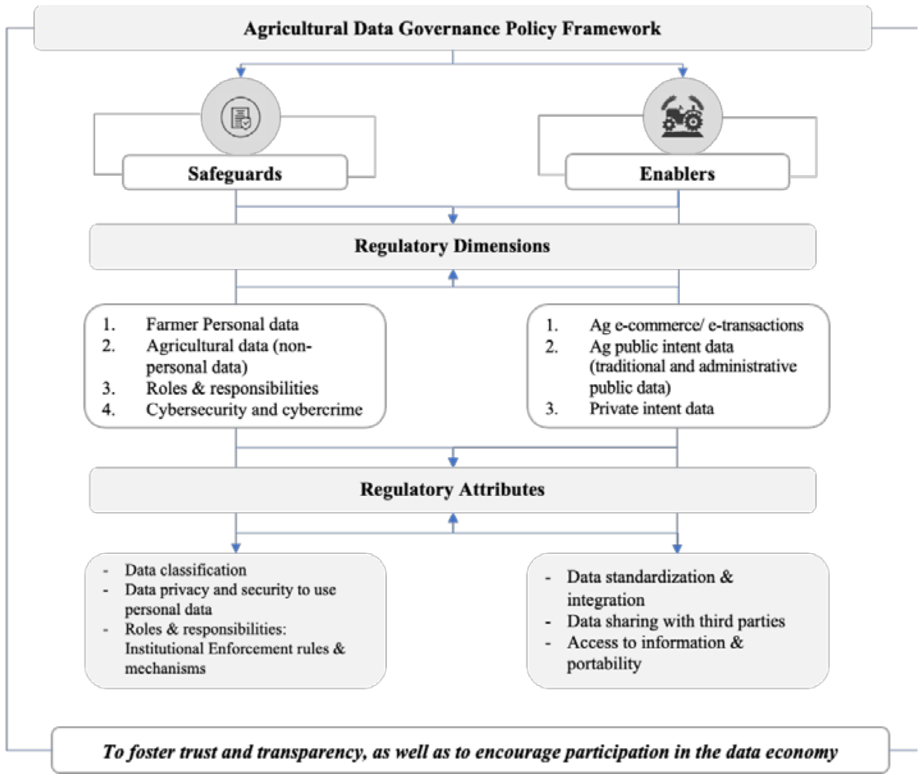
One of the strengths of codes of practice (COPs) is that they are principle-based and reflect what the industry considers good practice in agricultural data management (Wiseman et al., 2019, p. 11). Instead of prescribing specific processes or actions, COPs focus on the desired outcomes of data practices. This approach emphasizes consent, disclosure, and transparency in data practices through contractual agreements rather than dictating how agribusinesses should manage their data.

Another lesson learned from examining the COPs, is the importance of the Australian Data Rules, which provide an action-oriented program for capacity building, training, and risk management. Figure 18 summarizes these regulatory lessons drawn from the COPs, which are concise and relevant to the proposed data governance framework.

[55] EU code definition of agricultural data: “data related to agricultural production, including farm data and all types of data generated within the farming processes”

[56] Data originator: “the person or entity with the exclusive right to license data access and control its downstream use and re-use.” Definition from the EU Code of Conduct (p.6).

Figure 18 Agricultural Data Governance Policy Framework: regulatory dimensions and attributes to design the policy options



Adapted from Chen, 2021

Furthermore, benchmarking allows for the comparison and measurement of standards and strategies that can foster trust and transparency. The Gramm-Leach-Bliley Act (GLBA)[57] is a significant example not only because it established data handling standards, but also because it expanded consumer rights. Customers now have the right to access their "nonpublic personal information (NPI)[58]" at any time, increasing transparency between consumers and financial institutions. This increase in transparency has given consumers

[57] Gramm-Leach-Bliley Act, Pub. L. No. 106-102, 113 Stat. 1338 (1999).

[58] Nonpublic personal information refers to any information that can be used to identify an individual and is not available to the public. Examples of NPI include a person's name, address, social security number, credit card number, and financial account information. GLBA requires financial institutions to disclose their policies for collecting, sharing, and protecting NPI, and to give customers the right to opt out of having their NPI shared with third parties.

the ability to control how their data is handled and to opt out of sharing information with third parties.

Similarly, the U.S. HIPAA[59] regulation sets rules and standards governing the privacy and security of personal health data in the country. By establishing compliance and security rules, HIPAA ensures a reliable flow of health and personal data. For instance, it defines the roles and responsibilities of institutions providing healthcare and health insurance companies to protect patients' personal information.

To encourage innovation, best practices for agricultural data management should prioritize implementing data governance strategies such as defining roles and responsibilities for decisions involving agricultural data, promoting data sharing, building trust in data collection, use, and sharing, and ensuring adequate safeguards against the risks associated with data misuse.

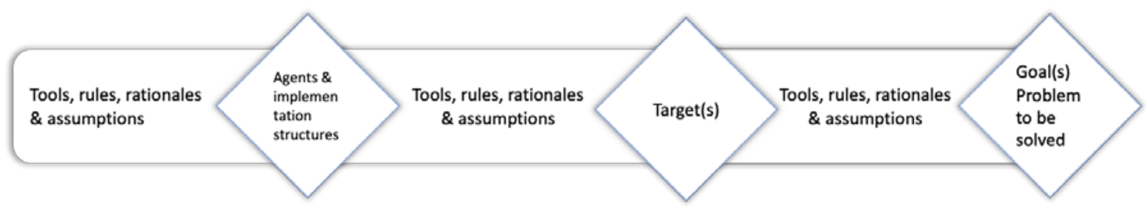
In the US, data cooperatives have emerged to address the lack of proper management and utilization of the data collected, as well as the absence of a standardized comprehensive security system for the flow of agricultural data. While these cooperatives offer a variety of digital solutions, an agricultural data governance framework should aim to simplify data exchange between companies, farmers, and the public sector. It should provide a comprehensive solution to the vulnerability of agricultural data to breaches and cyber-attacks.

[59] Health Insurance Portability and Accountability Act of 1996, Pub. L. No. 104-191, 110 Stat. 1936 (1996).

Policy Options Design

This research proposes three policy alternatives or options[60] as potential solutions to address the policy problem of agricultural data governance in the U.S. A well-designed policy should have clear, specific, and consistent goals, with links to the targeted behavior of the population, and ultimately the desired outcomes (Schneider, 1997, p. 35). The policy alternatives proposed in this research are tailored to the data governance pillars, which include safeguards and enablers, as per the legal data governance framework presented by WDR21 (World Bank, 2021), that encompass various types of data and stakeholders. Figure 19 illustrates the policy design components considered in the formulation of the policy alternatives.

Figure 19 Components of Policy Design



Adapted from (Schneider, 1997)

Tools and rules are procedural aspects of policy design that specify who is responsible for what, where, and when (Schneider, 1997, p. 97) in order to achieve certain benefits, such as capacity-building or providing incentives for action. Rationales and assumptions are explanations or reasons for the design decisions made, such as the choice of target population, tools, rules, and goals (Schneider, 1997, p. 99). The rationale connects the

[60] In policy-making, a policy alternative or option refers to an action that produces specific consequences or effects (Stone, 2012, p. 225). The policy alternatives were developed based on a comparative analysis of existing data governance frameworks described in this chapter.

policy elements to the context, making explicit claims that the design is responsive to the problem and will have a positive impact. Assumptions are the underlying logic that connects the selected elements together. Policy goals and problems to be solved are intentional aspects of policy design. These are expressed in objective and technical terms, but they represent desired outcomes. They can be broadly defined and framed in terms of public interest or narrowly defined and framed to affect only specific groups (Schneider, 1997).

Designing a data governance policy framework involves establishing guidance norms and rules, data quality standards, defining roles and responsibilities for compliance and security, and promoting capacity building, particularly among farmers. The overall objective is to develop a policy that governs the flow of agricultural data while promoting trust and transparency among all stakeholders.

An agricultural data policy should be drafted as "principle-based and technologically neutral laws and regulations... [to] help them remain relevant as technologies evolve and reduce compliance burdens” (World Bank, 2021, p. 191), which means creating an adaptable policy. A data governance policy framework requires government agencies in the agriculture sector to act not only as regulators but also as investors in good data practices that can generate value from agricultural data.

An expert judgement from the international institution, OECD, and its report "Digital Opportunities for Better Agricultural Policies" (OECD, 2019), states that governments should take the lead in improving access to agricultural data. One key role of the government in micro/farm level agricultural data is to enable the ability to link datasets while preserving confidentiality as necessary (Sanderson et al., 2018). The recommendations of OECD (2019) have been synthesized in Table 14.

Table 14 Government role and what they should do

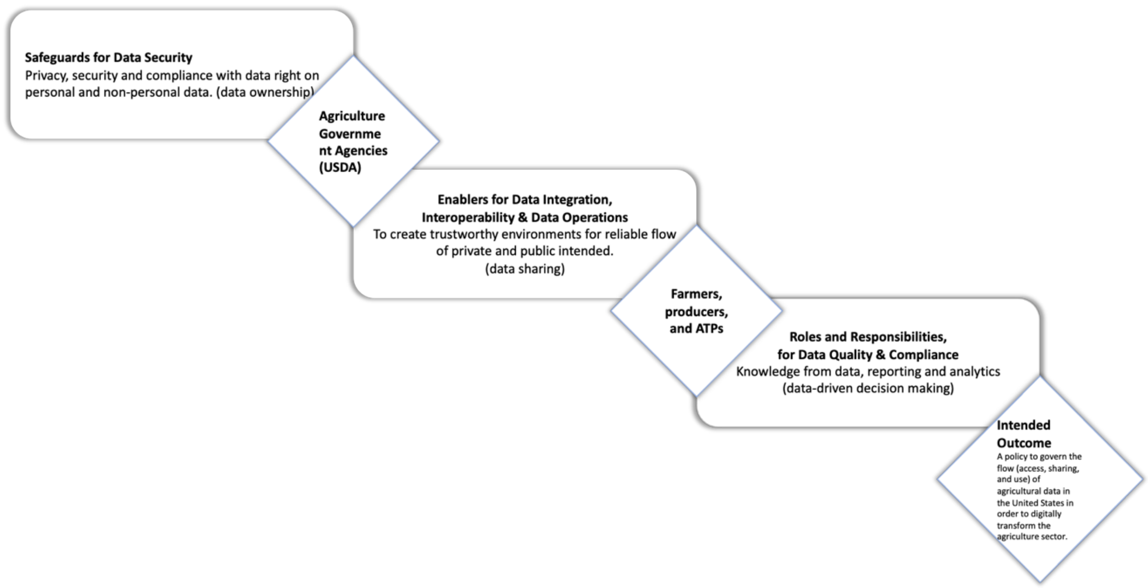
Public organizations/institutions	**Functions/roles (what needs to be done…)**
Government agencies: statistical agencies, administrative agencies (e.g., paying agencies for voluntary programs) and regulatory agencies (e.g., environmental regulators)	To increase their interaction and explore ways to pool data. They should also work together with data providers and data users to establish a clear framework governing data access.
Governments	To formulate clear policies for access and use of administrative data which consider both the benefits and risks.
	To investigate how administrative data can be re-used to support: 1) agricultural and agri-environmental policy implementation; 2) policy-relevant research; and 3) services to farmers.
	To create a coherent, tiered data dissemination strategy to improve access to agricultural micro data.
	To explore ways to incentivize provision of private sector data for public use and for agricultural research; options include monetary incentives (i.e., payments for data provision) and non-monetary incentives such as provision of regulatory safe harbors for data providers.

Data-collection agencies	To explore how the burden of existing data collection by government organizations can be lessened while maintaining or strengthening data collection using digital technologies.
	To put in place data management frameworks which include methodologies for the evaluation of data quality for data from alternative sources and planning.

Adapted from OECD (2019) “Digital Opportunities for Better Agricultural Policies”

The data governance framework includes safeguards to protect personal data and balance the interests of data reuse and non-personal data. Enablers promote mechanisms for data sharing and incentivize both the public and private sector to use and reuse data. The framework also defines roles and responsibilities for creating an environment that fosters education on digital technologies and their implementation. The intended outcome is to create robust and adaptable data governance regulations that include safeguards to prevent the misuse of data, as well as enablers that facilitate access to and use of data. Figure 20 captures the components of the data governance framework for each policy option in this research. In order to integrate the role of institutions, the "roles and responsibilities" pillar is an additional component of each policy option data governance framework. Outcomes are added to the policy options design to serve as an analysis criterion for each of them.

Figure 20 Components of policy design for agricultural data governance policy options



Safeguards are an essential component of a data governance policy framework, as they provide mechanisms and processes to create a secure environment for accessing and using personal and non-personal data. They support individuals' agency to control their data, ensuring their data rights to give consent to the use of personal data (World Bank, 2021, p. 191), such as farmers' addresses and identification numbers, or third-party access to non-personal data, such as crop production. The goal of these norms is to ensure data security and promote trustworthiness.

The inclusion of safeguards in the policy options design is crucial due to the concern of power asymmetries arising from a data control approach, rather than a data ownership perspective. Therefore, safeguards are established in the form of substantive rights, such as preventing unauthorized disclosure or unfair use of personal and non-personal data, and procedural rights that promote transparency and accountability, such as the right to receive notice, object to data usage, and access, correct, or erase data (World Bank, 2021, p. 194).

Enabling norms and rules for the good practice of data use and reuse are a fundamental pillar of a data governance framework. Enablers are primarily analyzed based on the domain of the data, i.e., whether the data are generated or controlled by the public or private sector, or both (World Bank, 2021, p. 199).

Institutions play a critical role in implementing regulations. They have distinct values, norms, and operating procedures that define their culture (Schneider, 1997, p. 76). The USDA is the federal agency responsible for the agriculture sector, and it has the potential to modernize its structure to support sector data governance and promote a data-driven culture within the sector.

Incorporating justice as a central standard in policy design can create an institutional data-driven and digital technology culture that serves the interests and principles of distributive justice (Schneider, 1997, p. 64). To achieve desired outcomes, policy design should target specific populations (Schneider, 1997, p. 35). The goal of an agricultural data governance policy framework is to create strong and resilient policy options that can adapt to the rapid and ongoing evolution of IR 4.0 technologies such as AI, IoT, and ICTs. Such a framework should also be able to deal with multi-stakeholder conflicts over the medium-to-long term (Howlett, 2019, p. 28).

To achieve both robustness and resilience in policy design, Howlett (2019, p. 30) suggests the need to design and adopt policies that feature agility and flexibility in their components and processes. Therefore, institutions' role in policy design is to determine the necessary robustness and resilience to respond to the need for a mutually influencing co-evolution of technology and regulatory frameworks.

After considering all these factors in proposing an agricultural data governance framework, this research presents three policy options: minimalist, moderate, and maximalist. Table 15 summarizes these three policy alternatives, including the rules, norms, degree of intervention by institutions, goals, the expected problems to be solved, and desired outcomes.

Table 15 Three Policy Options for an Agricultural Data Governance

		Minimal	**Moderate**	**Maximal**
From the least to the most visible/tangible role of government	Government level	Formal record of standard operating procedures	Regulatory–Federal level	Statutory–State level
	Regulation visibility	Low visibility internally published (agencies internal rules)	Moderately visible through federal states regulations (regulatory agencies)	Highly visible through codification in statute law publication (Congress public legislation)
Policy Goals		Equity–equal opportunities for all stakeholders to benefit from the value of data	Equality–efficiency trade-offs	Equality–efficiency, and security

	Minimal	Moderate	Maximal
Policy Outcomes	State and local agencies internal values that have implications for policy outputs, benefits. (Everyone gains)	Protective regulatory (bargaining, compromise)	Redistributive (ideological and class conflict)

Adapted from Stone (2012) and Birkland (2011)

These three policy options represent three policy levels. The first level, the minimalist policy option, it is a data governance solution that emerge from the COPs created by the agriculture sector farm-led associations. A second level, the moderate policy option, it is a data governance solution that sets out rules for all private and public parties to follow regarding data use. And finally, a third level, a maximalist policy option, it is a data governance solution integrating data governance level 1 and 2 and considering the rights on and of data at the national level, i.e., a data governance act for agricultural data.

- **Option 1: Minimalist**

The purpose of the minimalist policy approach is to address the issue of mistrust in current agricultural data practices through contractual agreements between farmers and providers. This option is minimal in its scope as it aims to transform the voluntary nature of the U.S. Code of Practice (COP) and involve agriculture institutions and agencies in implementing processes and mechanisms to oversee and evaluate Agriculture Tech Providers (ATPs) and other agribusinesses that carry a data transparent logo. The goal is to ensure that ATPs adhere to ethical data practices and provide transparency in their data sharing agreements with farmers.

Intended goal: to shift the agricultural sector's mindset towards agricultural data governance, grounded in the U.S. core principles for data practices.

The goal of the minimalist policy approach is to shift the agricultural sector's mindset towards agricultural data governance by transforming the voluntary self-regulated set of guidelines and principles in the U.S. COP into a legal normative data framework that governs decision-making on agricultural data sharing. Government agriculture agencies would play an intervening role in supervising the process for obtaining a data transparent logo, seal, or trademark and establishing a standardized agreement model specific to the agricultural sector in the U.S. In essence, the goal is to achieve a more meaningful model of consent for using and reusing agricultural data between the private and public sectors and farmers in the modern digital age.

Enabling trustworthy data operations is crucial for promoting transparent agricultural data practices based on the U.S. Code of Practice and the Core Principles.

This requires implementing technical and organizational measures to ensure data integrity, security, and privacy, such as data encryption, access controls, and audit trails. Moreover, it involves fostering a culture of transparency and accountability in data operations, which includes informing data subjects about data collection and processing activities, obtaining their consent when necessary, and providing them with access to their data and the means to correct or delete it. By enabling such data operations, the agricultural sector can enhance trust among stakeholders and promote the responsible use and reuse of agricultural data.

A good starting point is to make the U.S. COP's "core principles" legally binding, as they have been defined and agreed upon by farmers[61] to improve agricultural data governance practices. These core principles set rules and standards for data sharing, use, and reuse, and can help determine the roles and responsibilities of the USDA and its subagencies, as well as establish a standardized classification of agricultural data types for use in contractual agreements. To encourage compliance, the USDA can supervise the process of obtaining a trademark or logo from ATPs and agri-businesses committed to promoting transparent data practices. Regulations and institutional interventions can also help foster trust and encourage compliance behaviors, as unified data classification is a key enabler of data reuse (World Bank, 2021, p. 202).

Enablers to data interoperability & integration for making attractive incentives for public and private intent data sharing

Data interoperability and integration can enable the seamless exchange of data between different systems, applications, and stakeholders in the agricultural sector. This can be achieved by adopting standard data formats, APIs, and protocols for data sharing, use, and reuse. Several enablers can promote data interoperability and integration:

- Open data standards: Open data standards can enable data to be shared and integrated across different platforms, applications, and stakeholders. Standards

[61] Farmers who are part of or participate through the American Farm Bureau Federation (AFBF)

such as the AgGateway ADAPT framework can facilitate interoperability among precision agriculture devices and software systems.

- Incentives for data sharing: Public and private sector actors can be incentivized to share and integrate data through financial, social, and technical means. For instance, government subsidies, tax credits, or grants can encourage data sharing among farmers, while social recognition, reputation, or peer pressure can motivate private sector actors to share data.
- Data intermediaries: Data intermediaries can act as trusted third parties to facilitate data sharing and integration among different stakeholders. Intermediaries such as farm management software providers or agricultural cooperatives can aggregate and harmonize data from different sources, ensuring data quality, security, and privacy.
- Data analytics: Advanced analytics tools such as AI, machine learning, and predictive modeling can help integrate and derive insights from disparate data sources, enabling better decision-making and value creation for all stakeholders involved.

The overall goal of a data governance framework in the agriculture sector is to incentivize trustworthy mechanisms for data sharing, both public and private. In addition to legally recognizing core principles, agriculture agencies need to modernize and create government data exchange platforms to ensure data interoperability. This will create opportunities to open certain types of public intent data for exchange and create incentives while removing barriers to voluntary data sharing involving private sector actors such as ATPs and data cooperatives. The value of agricultural data can benefit multiple stakeholders, and guidelines or standard contractual provisions should be formulated to govern the fairness of terms of use.

Roles and responsibilities for data quality and compliance for shaping the agriculture data economy to continue in the path of the digital transformation

To ensure the development of a thriving agricultural data economy, roles and responsibilities for data quality and compliance must be clearly defined and implemented. This requires a concerted effort from both the public and private sectors. Government agencies, such as the USDA, can play a key role in developing and enforcing data standards. This includes establishing mechanisms to monitor and ensure compliance with the current U.S. COP[62] principles and guidelines.

Private sector entities, such as ATPs and data cooperatives, have a responsibility to uphold these standards and ensure that the data they collect and share is of high quality and meets established guidelines. This includes implementing data quality control measures, such as data validation and verification processes, to ensure that the data is accurate and reliable.

To increase transparency and trust between farmers, ATPs, and other third parties, a model of adaptable contractual agreements overseen by agriculture agencies should be developed. Rules are necessary to enforce compliance with contractual agreements, and public agencies can assist in policing and enforcing them effectively. One of the specific roles of these institutions could be to monitor and evaluate trademark usage and provide

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[62] The goal of legally and bindingly regulating the current U.S. COP is to reduce the "digital divide" between those who have knowledge (i.e., ag. tech service providers) and those who do not, through the implementation of transparent and fair data sharing practices.

continuous feedback loops to promote sector engagement, learning, and improvement. It is essential to set roles and responsibilities within agriculture agencies at the federal and state levels to govern data governance in the U.S. effectively. Overall, clear roles and responsibilities are essential for shaping the agriculture data economy in a way that fosters innovation, growth, and sustainability.

- **Option 2: Moderate**

A moderate policy option aims to address the agricultural data governance problem in the U.S. by proposing the development of trustworthy systems. This involves not only overseeing the COP and evaluating ATPs and agri-businesses carrying a data transparent logo but also creating public institutional capacity to introduce safeguards and enablers that ensure data rights and facilitate cross-border sector data sharing, while also ensuring compliance with regulatory requirements.

Intended goal: ***To create a data governance trustworthy and transparent environment by regulating agricultural data rights and obligations of parties involved in data practices and transactions***

The intended goal of a moderate policy option is to establish a transparent and trustworthy data governance system for the agricultural sector by defining the data security responsibilities of parties involved in transactions through contractual agreements. The USDA should have an effective and independent role in ensuring data security, including registering data intermediary companies. Data intermediaries can facilitate safe data sharing and use, promoting equitable access to data and its value (World Bank, 2021, p. 265). The agency can monitor the implementation of data rights, including privacy and security, and handle complaints about legal violations. This role could increase trust in data practices among agricultural stakeholders.

Safeguards for appropriated data security conditions for cross-sector border exchange of agricultural data

Appropriate data security conditions are essential for promoting cross-border exchange of agricultural data. One of the safeguards that can be established are agricultural-specific data privacy and security rules and regulations. The USDA could work with stakeholders to develop such rules and regulations that take into account the unique aspects of agricultural data, such as farm location and practices, and ensure that data is handled appropriately.

Furthermore, the USDA could require data intermediaries and ATPs to undergo regular security audits and assessments to ensure that they are complying with data security regulations and standards. The agency could also establish penalties for non-compliance to deter ATPs and intermediaries from engaging in risky data practices.

In addition, the USDA could promote the use of data encryption and other security measures to protect data during transmission and storage. This could be accomplished through the creation of guidelines and recommendations for farmers and other stakeholders on how to securely transmit and store agricultural data.

To promote cross-border data exchange, it is important to consider the impact on the country's competitiveness and international trade opportunities. In order to ensure appropriate data security conditions for cross-sector data flows, it may be necessary to adopt provisions criminalizing unauthorized or illegal access to infrastructure, systems, and data. Government agencies in the agriculture sector should also consider implementing regulatory approaches that ensure adequacy and accountability, including specific conditions that permit data transfer, mutual agreements, and schemes to require, permit, or limit cross-border data transfers.

ATPs and other third parties providing services cannot engage in data exchange without a trustworthy system or environment. Trust in the data sharing system depends on people's confidence that others will follow the rules and agreements, and that there is an authority enforcing those rules and agreements. In the agriculture sector, in order to build trust in the data sharing system, privacy and security should be guaranteed, as well as benefits for all parties involved.

Enabling data operations for data cooperatives and data integration for an Agricultural Data Governance and Accreditation Board (a data governance body)

To enable data operations for data cooperatives, it is necessary to establish data governance and accreditation boards that can provide guidance on data management practices, promote interoperability, and foster data sharing within the agricultural sector. Such boards can also provide technical and policy support to data cooperatives, helping them to develop and maintain data management systems that are consistent with industry standards and best practices.

The integration of data from various sources is essential for achieving the full potential of data cooperatives. Data integration involves the process of combining data from different sources to create a unified view of the data. This can be done using a variety of tools and techniques, including data warehousing, data mining, and data modeling.

An Agricultural Data Governance and Accreditation Board can help facilitate data integration by establishing data standards, providing guidance on data quality, and promoting best practices for data management. The board can also serve as a central point of contact for data sharing and collaboration among stakeholders in the agricultural sector.

A data governance board could be created or organized within the USDA federal agency. This board would function as a steering committee, responsible for overseeing the collection, transfer, storage, and analysis of agricultural data. ATPs, data intermediary companies, and data cooperatives would be required to register with the board and contribute to generating knowledge and advice, as well as providing a feedback loop to farmers and policymakers. This would ensure that the board has a broad perspective on the industry and can make informed decisions about data governance. Additionally, the board would be responsible for establishing and enforcing standards for data quality, security, and privacy. It would also be tasked with developing guidelines for data sharing agreements and monitoring compliance with those agreements. This would create a more cohesive and trustworthy data ecosystem for the agriculture sector, increasing transparency and promoting collaboration between stakeholders.

To ensure that private sector stakeholders act in the best interests of data originators such as farmers and producers, the USDA Data Governance and Accreditation Board could provide guidance and oversight. These stakeholders could advise data originators on the possible uses of their data and the terms and conditions for such uses. Additionally, USDA agencies and data intermediary organizations could collaborate to build capacity on data governance issues and provide training on the importance of agricultural data and its potential economic impact. An open-share data platform could also be developed to facilitate data sharing and collaboration between stakeholders in the agriculture sector.

Overall, the establishment of data governance and accreditation boards can help ensure that data cooperatives operate in a trustworthy and transparent environment, with clear rules and responsibilities for data management and sharing. This, in turn, can promote innovation, facilitate data-driven decision-making, and drive growth in the agricultural sector.

Roles and responsibilities of government agencies in strengthening technical data capacity, communications, and compliance as well as data literacy, to enable e-communication and e-transactions

The government agencies have a critical role in strengthening technical data capacity and data literacy to facilitate e-communication and e-transactions in the agriculture sector. This includes providing technical assistance to farmers, ATPs, and other stakeholders in implementing data governance best practices, such as secure data sharing and compliance with data privacy regulations.

The government agencies also need to strengthen their own technical capacity to oversee and enforce data governance policies and regulations. This can involve the development of new technologies or systems for monitoring and auditing data practices, as well as the recruitment of skilled personnel to oversee data governance operations.

In addition, the government agencies should play a role in promoting communication and collaboration among stakeholders in the agriculture sector. This includes facilitating the exchange of best practices and promoting the adoption of data governance standards across different sectors and regions.

The role of an agricultural data governance and accreditation board is to evaluate and accredit ATPs and companies based on their compliance with the core principles of the U.S. COP. In addition, the board will establish a fee schedule for accreditations and renewals and will receive a complete checklist from organizations seeking accreditation. Furthermore, the board will receive and address complaints from farmers and primary producers, as well as complying organizations, and will review all cases of noncompliance and recommend corrective action. To sum up, the roles and responsibilities of government agencies in improving technical data capacity, communications, and compliance are critical for ensuring the safe, secure, and responsible use of agricultural data.

This moderate policy option aims to promote a multi-stakeholder, purpose-driven approach to data management and governance. The goal is to enable institutions to adapt to the rapidly evolving digital data ecosystem while enhancing their legitimacy, transparency, and accountability.

- **Option 3: Maximalist**

The maximalist policy option seeks to fully embrace digitization in agriculture by establishing a comprehensive regulatory framework for data security, integration, and interoperability. This would involve developing national data governance standards, establishing clear rules and guidelines for data sharing, and incentivizing compliance with these rules through various means, such as tax breaks and subsidies. The goal of this policy option is to create a secure and dynamic digital economy that facilitates agricultural data access, sharing, use, and re-use while protecting data privacy and security.

Intended goal*: *Integrate agricultural data rights governing sharing and ownership, as well as privacy and security rights, while regulating data intermediaries and creating incentives for reusing public administrative agricultural data.

A comprehensive data governance framework must be established to integrate agricultural data rights governing sharing and ownership, as well as privacy and security rights, while regulating data intermediaries and creating incentives for reusing public administrative agricultural data. This framework should include the following components:

- Clear definitions of data rights, including ownership, control, and sharing rights, as well as privacy and security rights.
- Regulations for data intermediaries, including data cooperatives and ATPs, that ensure compliance with data privacy and security regulations and that protect farmers' and producers' data rights.
- Incentives for reusing public administrative agricultural data to increase the efficiency and effectiveness of agricultural practices.
- A mechanism for resolving disputes related to data ownership and access, including the creation of a data governance body that oversees the implementation of data governance policies and ensures compliance.

Creating an institutional environment as a foundation for an ecosystem hub[63] for agricultural data sharing involves bringing together all relevant stakeholders and establishing clear rules and regulations governing agricultural data practices. This may include creating incentives for data sharing, establishing data privacy and security protocols, and setting up a governance framework for data intermediaries. The ecosystem hub can serve as a central point for sharing data and knowledge, facilitating collaboration, and fostering innovation in the agricultural sector. By promoting greater transparency and accountability, the ecosystem hub can help build trust among stakeholders and encourage greater participation in data sharing efforts.

Agricultural data governance framework based on data rights could indeed provide a legal framework that protects data originators' rights and promotes trust in data sharing. This can increase the amount of data made available for re-use and encourage data altruism across the agriculture sector in the U.S. A robust data governance framework can also foster institutional intermediation services, promoting sustainable data-based economic transactions benefiting the agriculture sector.

In general, the goal of this approach is to ensure that all stakeholders in the agricultural sector are protected by a robust data governance framework that promotes transparency, accountability, and trust in the data sharing process.

Safeguards for data security for agricultural data as non-personal data and data originators' data rights protection

[63] Ecosystem Hub is defined as a network of institutions or organizations providing services, and more importantly, maintaining overall connectivity as hubs to improve elder care services.

To ensure data security and protect data originators' data rights in the agriculture sector, the following safeguards can be put in place:

- Data anonymization and aggregation: non-personal data in agriculture can be made anonymous by aggregating data into statistical models. This ensures that data is not associated with any individual, and thus, privacy is protected.
- Data access controls: Access to sensitive data should be restricted to only authorized individuals, organizations, and data intermediaries. This can be done through password protection, data encryption, or other access control mechanisms.
- Regular security audits: Regular security audits can be conducted to ensure that data is secure and that data originators' data rights are being protected. This can help identify any potential vulnerabilities or breaches in the data system and allow for prompt action to be taken to address them.

The regulatory environment should strike a balance between protecting data originators' rights and incentivizing innovation and data sharing in the agriculture sector. By providing necessary protections for data security and privacy, and establishing backup and recovery systems, farmers and primary producers can feel more confident in participating in data sharing and economic activities without fear of exploitation.

Enablers to increase data integration, interoperability, and operations to access information and to create incentives by removing barriers to voluntary data sharing and facilitate a smart digital agriculture in the U.S.

Enabling data integration, interoperability, and operations, and creating incentives requires the removal of barriers to voluntary data sharing and the facilitation of a smart digital agriculture ecosystem in the U.S. This can be achieved by investing in modern infrastructure, promoting the adoption of common data standards and protocols, fostering the development of data intermediaries and data cooperatives, and promoting transparency and trust in data sharing among stakeholders. In addition, creating incentives, such as providing tax credits or funding opportunities, can encourage voluntary data sharing and the adoption of digital technologies, which can lead to more efficient and sustainable agriculture practices.

Rights to/on Data as a force for public good

Data is a non-rivalrous good, meaning its use by one party does not diminish its use by another. To ensure fair use of agricultural data, organizations holding the ADT logo accreditation and following the U.S. COP "core principles" should inform farmers and primary producers about the rights they assert in relation to the data, as well as the rights the producers have regarding the data. It is also essential to disclose the terms under which agricultural data is made available to authorized third parties or those acting on behalf of the primary producers.

The concept of data rights as a force for public good refers to the idea that data, especially agricultural data, should be viewed as a valuable resource that can benefit society as a whole. This means that data originators (i.e., farmers and primary producers) should have the right to control how their data is collected, used, and shared, and that the public should have access to certain categories of data that can be used to improve agricultural practices, support research, and inform public policy. By recognizing data as a public good, institutions and agencies in the agriculture sector can create a regulatory environment that encourages data sharing and innovation while also protecting data privacy and security. Ultimately, this approach can help to promote sustainable agriculture and economic growth while ensuring that data is used for the greater good of society.

Creating a data governance framework entail putting regulations, procedures, and norms in place at the macro institutional level. According to Séronie, encouraging adherence to established rules, processes, and standards for data usage can result in increased efficiency, better technical performance, lower costs, and lower environmental impact at the macro level (2020, p.4). Furthermore, it can pave the way for a cultural shift toward understanding how to manage and govern data. Table 16 compares the three policy options proposed for addressing the agricultural data policy challenge in the United States.

Table 16 Comparison of the three policy options

Regulatory Data Governance Attributes	**Option 1: Minimalist.**	**Option 2: Moderate.**	**Option 3: Maximalist.**
Safeguards	No specific safeguards for data protection and sharing.	Establishing appropriate safety conditions for cross-border exchange of agricultural data in the agriculture sector.	Safeguards for agricultural data as non-personal data and protection of data originators' data rights.

Regulatory Data Governance Attributes	Option 1: Minimalist.	Option 2: Moderate.	Option 3: Maximalist.
Enablers	Enabling a trustworthy system to foster transparent agricultural data practices through the U.S. Code of Practice and the Core Principles	Incentivizing public and private intent data sharing by removing barriers and increasing access to information for smart digital agriculture in the U.S.	Strengthening technical data capacity and communications, as well as data literacy, to enable e-transactions.
Institutional Roles and Responsibilities	Roles and responsibilities for shaping trust in agricultural data and the agriculture data economy to continue in the path of digital transformation.	Establishing Data Cooperatives and an Agricultural Data Governance and Accreditation Board (a data governance body)	Rights to/on Data as a force for public good. Regulating agricultural data rights and obligations of parties involved in data practices and transactions.
Intended outcomes	Changing the agricultural sector's mindset toward agricultural data governance based on the U.S. core principles for data practices.	Creating a trustworthy and transparent data governance environment for regulating agricultural data rights and obligations of parties involved in data practices and transactions.	Integrating agricultural data rights governing sharing and ownership, as well as privacy and security rights, while regulating data intermediaries and creating incentives for reusing public administrative agricultural data.

In the agricultural sector, it is important to establish rules for access as well as to facilitate and ensure data use and reuse. Therefore, in light of the agricultural data governance policy problem, it is necessary to control data access and sharing by defining the roles and responsibilities of agencies and institutions. These are additional components included in this research's data governance framework. Additionally, institutions in the agriculture sector should specify and define the types of data, such as public and private intent agricultural data, that can be shared, used, and reused.

Chapter 4: Policy Proposal

The objective of this chapter is to use methods of policy forecasting to generate a policy proposal from the three options presented in Chapter 3. These methods will be used to determine which of the three policy models, either individually or in combination, is most likely to advance the goals of agricultural data governance, and whether any of them should be rejected based on their predicted effects. The results will be used in the Conclusion to suggest next steps and further research needs.

Forecasting in policy analysis refers to a "set of procedures for creating information about future states of society based on present or prior information" (Dunn, 2018, p. 119) related to a particular policy issue or problem. The goal is to generate information about future societal states regarding a specific policy issue based on present information. Table 17 presents a description of the forecasting methods that will be used to forecast the policy framework for governing data in agriculture in this research.

Table 17 Forecasting Methods

Forecasting Form	What it is?	How to apply?
Projection	It involves identifying the relevant actors, assessing their goals and strategies, and analyzing the potential impact of policy options on these factors. It helps policymakers to anticipate and evaluate the potential consequences of different	It involves analyzing historical data to identify patterns and trends that can be used to predict future outcomes.

	policy options before making decisions.	
Prediction	It is based on theoretical explanations of why some trends should be implemented in the future.	Prediction based mapping data governance legal frameworks across sectors to analyze the alternatives available that can be adaptable to design data regulations in the agriculture sector.
Expert judgment	It is based on the professional experience and authority of persons (scholars) who are presumed to have special capabilities to foresee future states of society.	Expert judgments will come from webinar presentations, or the work of other scholars. (Experienced based, conjecture)

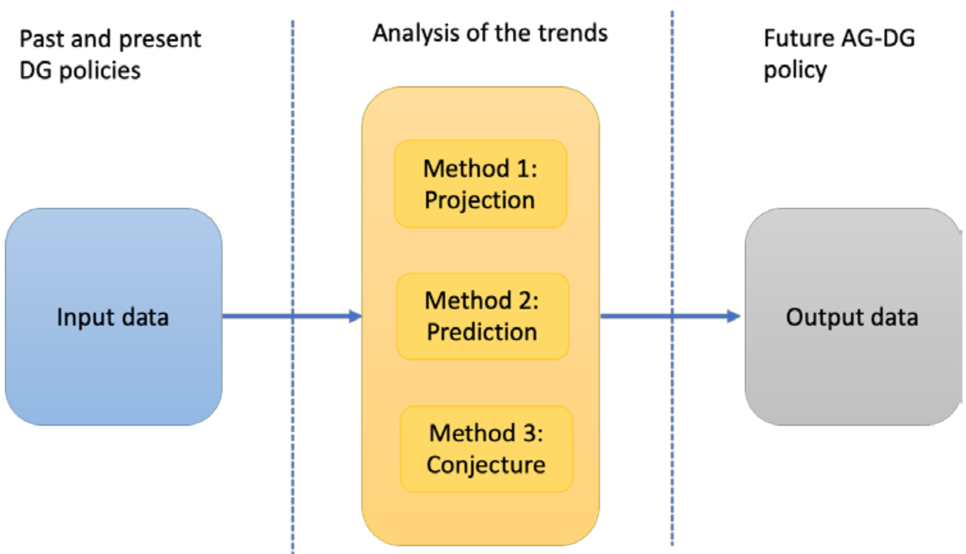
Adapted from Dunn, 2018

This research uses projection, prediction, and expert judgment (or conjecture) as forecasting methods to estimate the potential outcomes of the three policy options for agricultural data governance. These methods aim to provide insight into the expected or estimated policy outcomes of a framework for agricultural data governance.

As stated in the beginning of this project, the policy output of agricultural data governance is the production and sharing of high-quality data, and the resulting outcome is a cost-effective digitization of the agricultural sector. The ultimate objective is to establish a socially, economically, and environmentally sustainable agricultural sector. As this research assumes a direct connection from outputs to outcome to impact, the policy forecasting here is limited to outputs.

In the case of the agricultural data problem in the U.S., forecasting policy options can lead to the development of an agricultural data governance framework that meets the expectations of all stakeholders while improving efficiency and sustainability in agriculture. By forecasting the contents of the three new policy options, this research aims to determine the most plausible option for the future of the agriculture sector in the U.S. Figure 21 illustrates the structure of the forecasting process.

Figure 21 Forecasting process structure



Projection

Due to the lack of a comprehensive national inventory of data governance regulatory practices in the U.S., early projections of the three policy options proposed in this study are challenging. However, the current and rapid development of what scholars refer to as the "data economy" (Chen, 2021, p. 29) justifies the need for flexible policies that can facilitate the growth of various data-driven products, services, and business models.

COPs represent an initial sector-specific effort to address emerging concerns surrounding agricultural data practices. In the U.S., the COPs, also known as "core principles," have been adopted by large farmer-led organizations and associations such as the American Farm Bureau Federation (AFBF). However, only 37 agriculture tech providers[64] have undergone the certification process of the Ag Data Transparent Evaluator (ADT) and agreed to incorporate the "core principles" into their contracts and agreements with farmers (Janzen, 2021[65]).

This COP or "core principles" in the U.S. represent a mid-stream, non-binding form of agricultural data regulation due to the voluntary commitment of agriculture tech providers to data transparency with farmers and the lack of an assessment or evaluation process for their compliance.

A minimal policy option for agricultural data governance provides the minimal enablers for data sharing, compelling agriculture tech providers to adhere to the "core principles" when collecting, storing, and transferring farmers' agricultural data. In this minimalist policy option, state agriculture public entities such as the U.S. Department of Agriculture have a minimal role contribution. This agency serves as an enabler in verifying compliance with the "core principles" and auditing companies with the ADT seal and their agricultural data contracts and agreements.

[64] Figure 6 depicts more than 100 technology firms that are digitally transforming farming practices.
[65] Information available at: https://www.agdatatransparent.com/about

Many U.S. companies that collect agricultural data have yet to commit to the agricultural data "core principles" (Janzen, 2021[66]). However, adopting a minimal policy option based on the existing COP could be rapidly embraced and effectively implemented, given the established principles and certification process recognized by large farmer-led associations. With clear role definitions and public institution support, the number of companies participating and signing on to the "core principles" and achieving Ag Data Transparent certification could significantly increase in the short term.

Moving forward, a moderate data governance policy option could include not only introducing safeguards for agricultural data sharing but also enabling the flow and reuse of non-personal public administrative agricultural data. While this represents a new policy context and content, forecasting its success is difficult.

A maximalist data governance policy would include both safeguards and enablers, protecting data rights and facilitating the use and re-use of public administrative agricultural data while ensuring its safe flow among stakeholders. This policy would promote a trustworthy agricultural data system by increasing awareness of the value of agricultural data and encouraging participation in the ag sector data economy. However, like the moderate policy alternative, projecting the effectiveness of this policy prediction is challenging.

These three policy options are currently conceptual and projecting their effectiveness is difficult and insufficient. However, based on a comparative macro analysis of the literature and the Global Data Regulation diagnostic, which assesses data governance laws and

[66] Information available at: https://www.agdatatransparent.com/about

regulations across 80 countries, it is accurate to project that a normative legal framework for agricultural data governance would be an important addition to the future of the agricultural data economy in the U.S.

Prediction

Foreseeing the future impact of a data governance policy framework for the agriculture sector in the United States involves considering the potential positive and negative feedback loops. These will be evaluated by institutions and stakeholders who are subject to the enforcement of these regulations and norms. The predictive approach relies on a set of causal assumptions about how a particular policy may be implemented and what its outcomes will be. As a result, forecasting the three policy options involves predicting not only their feasibility but also their impact on the agriculture sector.

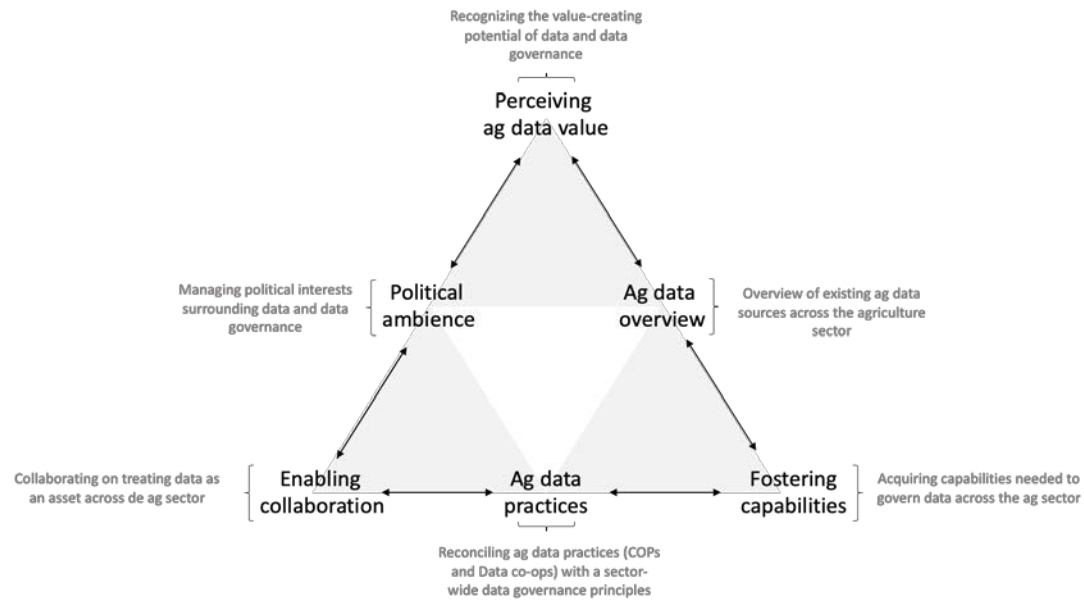
To theorize and predict the feasibility of the three agricultural data governance policy options, this research section draws on the notion of a collective action problem. This approach presents a theoretical perspective that compares existing literature on collective action to explain data governance as a current issue within the data economy. The aim is to attempt a prediction that explains the reasons for adopting a minimalist, moderate, or maximalist policy alternative.

The Coleman Boat model provides a predictive framework that outlines how certain factors can lead to specific outcomes through various mechanisms. In the context of agricultural data governance, the Coleman Boat model represents the relationship between the macro and micro aspects of the social system. At the macro level, agricultural data governance is institutionalized as a policy framework that sets the norms for sector participation. The meso level is crucial in determining whether individuals participate in and share data within the framework, as their decisions are influenced by factors such as trust, transparency, and legitimacy.

Integrating Benfeldt et al.'s (2020) collective action theory approach to data governance into the model can offer a more comprehensive insight into the meso and micro processes that influence participation in Ag-DG. This perspective highlights the challenges of mobilizing an organization to adopt a data governance framework. It emphasizes the importance of understanding the internal dynamics of the system or organization, which includes comprehending the motivations and behaviors of individual actors.

Benfeldt et al.'s (2020) approach identifies six constituent challenges that must be addressed to successfully adopt data governance within public organizations, including perceiving value, enabling collaboration, fostering capabilities, data overview, local practices, and political ambience (Benfeldt et al., 2020, 308). These challenges are interrelated and form a "problem triangle," as illustrated in Figure 22, which is adapted to the agricultural data governance policy problem.

Figure 22 Data Governance Collective Action Problem in Public Organizations



The problem triangle describes the difficulties faced by actors with diverse and possibly conflicting interests, who struggle to find common ground and collaborate towards a shared objective. By integrating Benfeldt's ideas into the Coleman Boat model, we can gain a better understanding of how these challenges affect individual and organizational participation in agricultural data governance.

At the micro level, the challenge of recognizing the value of sharing data may influence the decisions of individual stakeholders to participate in Ag-DG. Additionally, the challenge of enabling collaboration may impact the effectiveness of the framework as a whole, as it influences how well stakeholders work together.

To overcome these challenges, it is necessary to foster capabilities, provide an overview of the available data, align local practices, and create a conducive political environment. This integrated framework provides a more comprehensive explanation of the mechanisms that lead to successful agricultural data governance.

Benfeldt et al. (2020, p.309) explain:

> Perceiving value of data governance is challenging because actors in a collective tend to ascribe different meanings to the purpose or outcome of the collective action. Enabling collaboration between functions on data governance is complicated because actors tend to take actions that protect their individual interests at the expense of achieving a greater joint outcome. Fostering capabilities for governing data is difficult because doing so requires effectively managing heterogeneous resources contributed by different actors to the common "good" produced in a collective. (Benfeldt et al., 2020, p. 309)

Adopting a data governance framework is assumed to be beneficial because it involves implementing processes and principles that are supposed to be enterprise-wide.” (Benfeldt et al., 2020, p. 306). Therefore, from a collective action theoretical perspective, agricultural data has the potential to become a collective good based on the willingness and capabilities of users to take advantage of it.

In addition, within the context of the digital data economy, Kerber & Frank (2017) propose a framework that identifies the main causes of potential market failure problems in data trading within the Internet of Things (IoT) applications. These market failure problems include information asymmetries about data quality and source, a lack of demand for data due to a lack of awareness of its value, a lack of interoperability and standardization, pricing problems, and strategic reasons for data holders not to share, trade, or give access to data.

In the current agricultural data landscape, private companies have demonstrated the value of collecting and utilizing agricultural data. However, the U.S. Department of

Agriculture (USDA) has lagged behind in terms of data collection, integration, and utilization. For instance, the USDA collects vast amounts of data to support a diverse range of agricultural programs. Nevertheless, the lack of clear collaboration across agencies has hindered data utilization. As a result, there are numerous disconnected data silos within the USDA that, at times, require employees to make manual data calls to gather essential information for analysis (Ristino & Hart, 2022, p. 5). Consequently, data-driven decision-making practices are challenging to implement.

Expert judgment or Conjecture

The conjecture approach relies on expert judgments, which are valuable because they concentrate on predictions of future trends and implicit knowledge of the probable triumphs or failures of various policy options, instead of past data or formal models. One critical aspect of this approach is making conjectures about the future state of technology and data. Moreover, it is important to note that expert judgment or conjecture can be a valuable tool in policy analysis and the development of agricultural data governance policies. While past data and formal models are useful, expert judgment can provide insights into future trends and the potential success or failure of policy options. However, it is essential to ensure that expert judgments are based on sound reasoning and evidence, rather than personal bias or unsupported assumptions.

For instance, the "Data for Better Lives" World Bank report argues that to use data for development purposes, a legal framework for data governance is necessary, which should include both safeguards and enablers (World Bank, 2021, p. 190). Safeguards are legal frameworks and norms that ensure trust in data governance and management by limiting harm from data misuse and breaches affecting data security and integrity. Enablers refer to policies, laws, regulations, and standards that enable the use, reuse, and sharing of data within and between stakeholder groups by promoting openness, interoperability, and portability.

In Industry Revolution 4.0, a data governance framework approach is necessary to transform data into a strategic asset for organizations and sectors. In the agriculture sector, scholars such as Jouanjean et al. (2020) and Wiseman et al. (2019) agree that starting with sector-specific solutions is key to solving data governance problems.

For example, Wiseman et al. (2019) examined three of the four existing codes of conduct (COPs) on agricultural data, except for the most recent one from Australia, and made recommendations. The authors suggested a farmer-centered COP on agricultural data as it would facilitate broad adoption and have a greater impact. However, it is crucial to ensure the legitimacy of the code and those who administer and accredit compliance. Adopting minimal normative regulation where farmers' associations and agriculture public organizations play a role could ensure proper implementation and enforcement of an agricultural data governance policy.

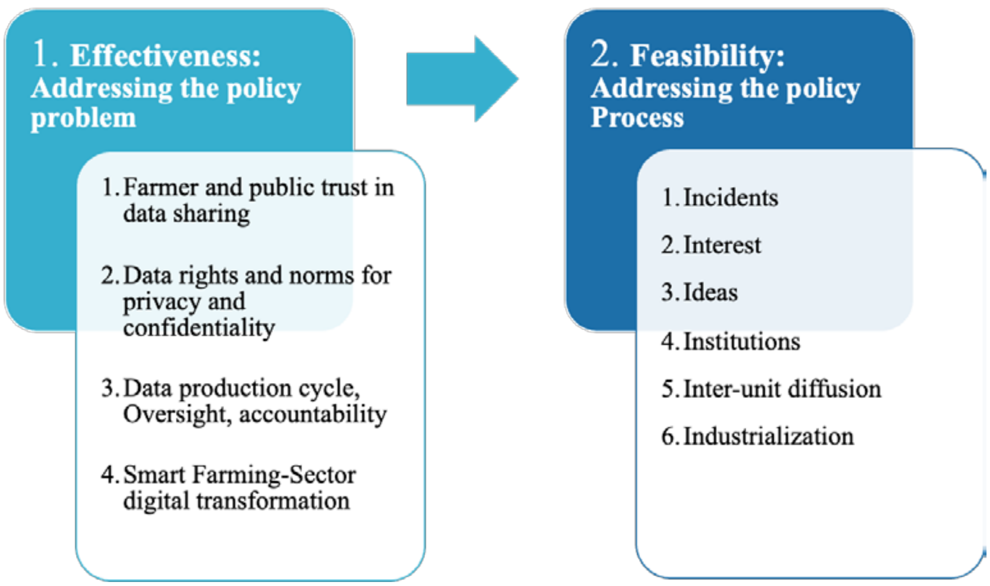
Sanderson and Wiseman (2018) stress the importance of developing a tailored data governance framework specific to the agriculture sector, due to the distinct categories of agricultural data. The use of voluntary-private membership contractual models, such as COPs, is recommended by Wiseman et al. (2019) to ensure data sharing and gain farmers' trust. However, since COPs are governed through private data contractual agreements, they may be more suitable for agribusinesses and companies working with farmers and using their data, rather than farmers-led organizations/associations. Nevertheless, to ensure proper implementation and enforcement of COPs and the credibility of farmers in their self-regulation, scholars argue that governments must also play a role in agricultural data management and practice (Wiseman et al. 2019, p.13). This highlights the need for normative regulation for agricultural data governance that represents smallholder farmers, not just through associations but also directly.

The rapidly evolving IoT technology requires regulatory efforts to be open to new innovations in order to solve data governance problems. Therefore, a legal framework for data governance, whether minimalist, moderate, or maximalist, should limit private parties' freedom to produce, create, and use data in new ways only as necessary to address market failure problems, such as lack of rights on data, competition problems, information problems, and transaction cost problems (Kerber & Frank, 2017, p. 17) and achieve other normative societal objectives.

A Two-Stage Model for Agricultural Data Governance Policy Framework

This section also includes a two-step feasibility analysis. In the first step, each policy option is analyzed based on the identified policy problem components to determine the factors that could define the effects or consequences of the chosen policy's success or failure. The second step attempts to predict which policy option would be feasible from a policy process selection perspective. This step addresses major issues influencing the policy process, including incidents, ideas, interests, institutions, inter-unit diffusion, and industrialization. These elements are crucial in the policy history process and require answering a set of minimum questions as part of the feasibility analysis to identify any outstanding issues or concerns with each policy alternative. Figure 23 illustrates the two-step process used to analyze each policy option and predict which one could be feasibly advocated for not only in terms of solving the agricultural data governance policy problem but also in terms of feasibility for adoption.

Figure 23 Two-step Step Forecasting Prediction Process



The three proposed options will be analyzed considering this theoretical-explanatory scenario and the dimensions of the policy problem to which an alternative public policy must respond. Table 18 describes the questions to be answered when analyzing each policy option.

Table 18 Questions to be answered by the agricultural data governance policy options for a policy problem feasibility analysis

Dimensions of the agricultural data governance policy problem	Questions to find the policy option with best outcomes
Trust between farmers and agricultural technology providers in data sharing	Does the policy option address the development of trust between farmers and technology providers through contractual agreements to govern agricultural data sharing?
Data privacy and confidentiality norms and rights	Does the policy option provide mechanisms for ensuring data privacy, security, and sharing rights for agricultural data use and reuse?
Oversight, accountability, and transparency in data production cycle	Does the policy option effectively encourage oversight, accountability, and transparency from government agencies, private companies, and other data intermediaries?
Digital transformation in the smart farming sector	Does the policy option enable the agriculture sector to advance in digital transformation by utilizing agricultural data and deriving benefits from its value?

Each policy option will be analyzed using this set of questions to determine if their data governance components address each dimension of the agricultural data governance problem. The analysis will generate results presented in Table 19 and Figure 24, assuming dichotomous values for all cases of predictive analysis of the policy options created specifically for this research.

Table 19 Prediction of a Policy Option for Agricultural Data Governance

	Addressing the policy problem dimensions						
Policy options	**Data sharing**	**Data rights privacy**	**Data production**	**Smart Farming**	**Policy adoption time**	**Policy adoption budget**	**% problem response**
Option 1	High	Medium	Medium	Under served	High	High	72%
Option 2	High	High	High	High	Low	Medium	83%
Option 3	High	High	High	High	Under served	Under served	67%

Figure 24 Rate of each policy option addressing the agricultural data governance policy problem dimensions

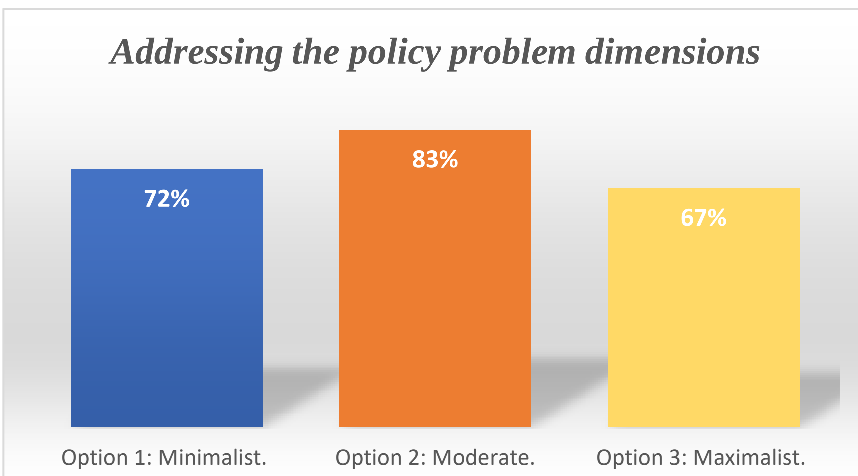


Table 19 presents the results of assigning dichotomous values to each data governance component in each policy option. The values of 1 or 0 are assigned based on the answers to the questions presented earlier. If a policy option addresses all dimensions of the problem through its data governance components, a value of 1 is assigned. On the other hand, if a policy option does not fully address the dimensions of the problem, a value of 0 is assigned. Each dimension of each data governance component for each problem dimension equals three. In this study, a score of 3 for each dimension of a problem dimension for each policy option is defined as "high," a score of 2 is defined as "medium," a score of 1 is defined as "low," and a score of 0 is defined as "underserved."

The last columns of Table 19 assign dichotomous values to the time and budget criteria required for implementing each policy option. The analysis concludes by adding up the values assigned to the data governance components for each dimension of the problem. If the total value is greater than 6, it indicates that all the values have been met. Based on these findings, the percentage of each policy option's response to the corresponding dimensions of the problem was calculated, as shown in Figure 24.

To explore the potential outcomes of the three-policy options proposed in this research and determine an optimal policy for governing agricultural data, Table 20 outlines six dimensions that must be considered during the policy analysis process. Each of the dimensions is associated with specific issues that should be addressed by each policy option. By examining how well each policy option addresses these dimensions and issues, we can determine which option is most feasible to advocate for within the policy process.

Table 20 Six dimensions for policy prescription analysis for agricultural data governance

Policy Dimension	**Issues to be addressed**
Interests and Ideas	- Collective action problems

	- Advocates of change or stasis - Powerful ideas to mobilize, frame, and determine policy change
Incidents	- Incidents that create windows for new ideas - Incidents of non-technical communication (e.g., in the agriculture food insecurity; food supply chain issues such as farming labor issues and shortages)
Institutions	- Institutions that allow policy responses to occur - Institutional strategies to optimize the use of institutions for policy response
Inter-unit	- Political economy/fiscal incentives - Globalization (“global supply chains effect”)
Industrialization	- Digital transformation in the agriculture sector: integration of new digital technologies (e.g., IoT, Cloud, Mobile, AI) changing the delivery of services.

A prediction model that combines the 6 ‘I's from policy advocacy to policy outcomes is effective when it follows a pathway that leads to positive outcomes. This involves carefully examining the factors involved in the policy process. The first step is to ask questions to determine if each policy option adequately addresses the dimensions of the agricultural data governance problem. The second step is to ask questions to determine which options are more feasible for adoption as a public policy.

Table 21 Questions to be answered by the agricultural data governance policy options for a policy process feasibility analysis

Policy Dimensions	Questions to Determine Optimal Policy Option
Incidents	What social, cultural, or economic incidents may influence or affect the policy process of the policy option?
Interests and Ideas	- Will the policy option shape and raise the perceived value of data governance through collective action by key stakeholders? - Will the policy option facilitate collaboration of data governance ideas and development of capabilities for governing agricultural data?
Institutions	Are implementing agencies capable of carrying out the policy alternative? Can necessary agreements be reached among government, private sector, and other partners, including those that are legally binding?
Inter-Unit diffusion	Can this policy option transfer specific parts of policy from other sectors' data governance policies? Or can this policy use or selectively copy policy mechanisms from other sectors (e.g., HIPAA or CCPA)?
Industrialization	Is this policy option the most beneficial for the sector's advancement in the digital transformation era?

Based on the evidence previously gathered in this research, and considering the existing legal regulations on data governance, this study proposes to select among three high-potential policy options for addressing the problem of agricultural data governance in the United States. Similar to the previous analysis of the three policy options, this analysis assumes dichotomous values for all cases of predictive analysis of the policy options created specifically for this research. The results are shown in Table 22 and Figure 25. The detailed values assigned to each dimension can be found in the annexes.

Table 22 Prediction of a policy option for agricultural data governance in the policy process adoption

Policy options for Ag Data governance	**Policy Process Feasibility Dimension**					
	Incidents	Interests and Ideas	Institutions	Inter-Unit diffusion	Industrialization	% Policy Feasibility
Option 1: minimalist	High	Medium	High	Medium	Under served	70%
Option 2: Moderate	High	Low	High	High	High	80%
Option 3: Maximalist	Medium	High	Under served	Medium	High	50%

Figure 25 Rate of Policy Process Feasibility For each Policy Option

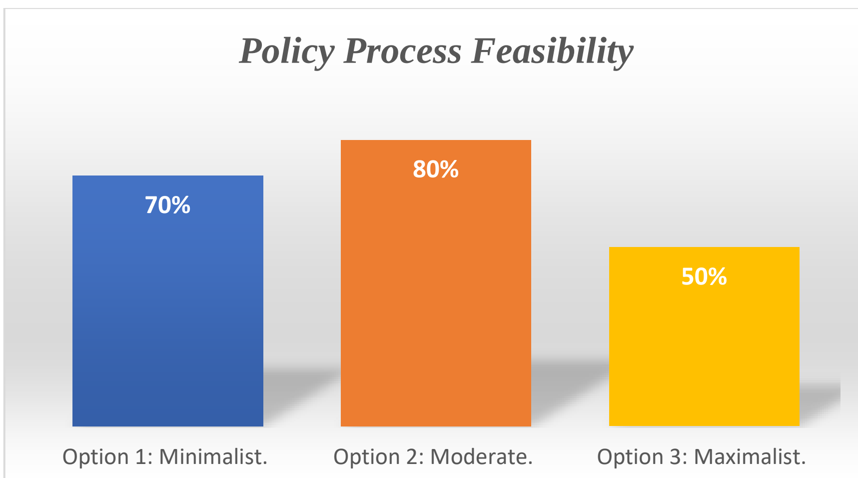


Table 22 provided the criteria for analyzing each of the policy options based on the public policy adoption process. A value of either 1 or 0 was assigned to each policy option for each dimension. These values were classified as "high," "medium," "low," or "underserved." The "high" rating was calculated by summing the values assigned to each dimension for each policy option. The specific values assigned to each factor in each dimension for each policy option are detailed in the annexes. Using the total sum of each policy option for each dimension in the public policy process, we calculated the percentage of feasibility for implementing each policy option. The total sum was a value of 10, representing the sum of each dimension's possible value.

Tables 19 and 22 show that the Minimalist policy option receives high ratings in the incidents and institutions dimensions but low ratings in the interests and ideas, inter-unit diffusion, and industrialization dimensions. The Minimalist policy option appears to prioritize addressing the dimension of trust between farmers and agricultural technology providers in data sharing, with a high level of feasibility in terms of incidents, institutions, and policy adoption time and budget. However, it shows low feasibility in addressing the dimension of data privacy and confidentiality norms and rights, and only moderate feasibility in the dimension of oversight, accountability, and transparency in data production cycle. Concerning policy process feasibility, the Minimalist option has a moderate percentage of policy feasibility, indicating that it may encounter some challenges in terms of interest and ideas and inter-unit diffusion.

Based on the information provided in the two tables, it is important to note that policy options for agricultural data governance should be carefully considered in terms of their feasibility and ability to address the dimensions of the problem. The Minimalist policy option may be effective in addressing the issue of trust between farmers and agricultural technology providers in data sharing, but may face challenges in terms of data privacy and confidentiality norms and rights, as well as oversight, accountability, and transparency in the data production cycle. It is also important to consider the level of policy process feasibility, which includes incidents, interests and ideas, institutions, inter-unit diffusion, and industrialization. By carefully examining and selecting the appropriate policy option, policymakers can ensure that the agricultural sector benefits from the use of data while also protecting the rights and interests of farmers and other stakeholders involved in the process.

The Moderate policy option outperformed both the Minimalist and Maximalist options in both dimensions. It achieved an 80% feasibility rate in the Policy Process Feasibility Dimension and an 83% problem response rate in the agricultural data governance problem dimensions, making it the most viable option for addressing the issue.

The Moderate option excelled in all four dimensions of the agricultural data governance problem, including trust between farmers and agricultural technology providers in data sharing, data privacy and confidentiality norms and rights, oversight, accountability, and transparency in the data production cycle, and digital transformation in the smart farming sector. It also received a high score in the industrialization dimension of the Policy Process Feasibility table, indicating that it is the most advantageous option for the sector's advancement in the digital transformation era.

The Moderate policy option is expected to have a significant impact on the agricultural data governance problem while remaining feasible for implementation. Therefore, it is the most practical policy option for addressing the agricultural data governance problem.

Despite scoring high in all four dimensions of the agricultural data governance problem, the Moderate option may face obstacles in terms of adoption time and budget, as rated as medium in the Policy Options table. Furthermore, traditional farmers may resist or pose barriers to the option's implementation, despite its high score in the industrialization dimension. It is therefore essential to discuss these potential challenges to gain a more comprehensive understanding of the feasibility and potential impact of the Moderate policy option.

Based on the analysis so far, we can rule out the Maximalist option because it received the lowest score in all dimensions of the public policy adoption process. The Maximalist option scored poorly in the effectiveness dimension because it would likely face significant opposition from key stakeholders, such as farmers, who may be unwilling to share their data. In addition, the Maximalist option's approach to data governance may not effectively address the problems associated with agricultural data governance. The Maximalist option also received a low score in the feasibility dimension because it would be difficult to implement given the current resource and capacity constraints. It would require significant funding and coordination between various institutions and stakeholders, which may not be feasible in the short term. Furthermore, the Maximalist option may not be sustainable over the long term as it may face challenges in maintaining political and stakeholder support. Therefore, based on the evidence gathered, it is unlikely that the Maximalist option would be the optimal policy for governing agricultural data.

In this research, the policy problem of agricultural data governance has been analyzed, and four main dimensions have been identified: data sharing, the data production cycle, data rights and norms, and smart farming. Based on these dimensions, three policy options have been developed to propose a policy framework that addresses each dimension of the agricultural data policy problem. The proposed policy options range from minimal to maximalist government approaches, with each option providing data safeguards, enablers, roles, and responsibilities for governing agricultural data. After forecasting the outcomes of these three policy options, it has been concluded that the minimalist and moderate approaches are the most feasible options within the policy process, as they not only solve the agricultural data governance problem but also account for new innovations and technological developments. In contrast, the maximalist option fails to provide a realistic and feasible policy solution. Therefore, the proposed two-stage model for agricultural data governance policy recommends the adoption of the minimalist or moderate approach, depending on the specific needs and characteristics of each agricultural sector in the US.

- **Prescription: The Final Step in Agricultural Data Governance Policy Analysis**

The final step in the policy analysis process is to propose a policy option that is most likely to resolve the governance issues of agricultural data in the United States. This step is called prescription, and it focuses on policy choice by considering the reasons for selecting a particular option. In other words, it provides a means of selecting one policy option from among several possible outcomes (Dunn, 2018, p. 190). In the remainder of this chapter, this research will examine which of the two feasible policy options, minimalist or moderate, should be recommended based on the outcomes previously determined in the agriculture sector.

Considering the trade-offs associated with collective action, both the minimalist and moderate policy alternatives are likely to achieve the policy goal[67] of balancing equity and

[67] Policy goal: “A desired outcome of a policy; these goals can be explicitly stated or implicit in the policy and other factors found in its legislative history” (Birkland, 2016, p. 236)

efficiency[68] among the proposed agricultural data governance policy options. These policy alternatives aim to address the lack of data standardization, access, sharing, and use, not only to enhance agricultural practices and productivity, but also to improve crop yields, nutritional quality, and promote sustainable agriculture overall.

The minimalist policy option aims to implement and practice data governance principles based on the United States COP Core Principles effectively. Its purpose is to monitor compliance with the Core Principles in contractual agreements to enable a trusted data-sharing system across the U.S. agriculture sector. On the other hand, the moderate policy alternative for agricultural data governance not only aims to implement and practice data governance Core Principles but also assigns roles and responsibilities for data access and sharing. It also emphasizes the use of data value and promotes sector collaboration.

However, achieving a well-balanced solution between the interests of various stakeholders can be a complex task. Therefore, proposing a specific policy option requires an evaluation to determine the best approach. In governing agricultural data, the aim is to maximize the benefits of sharing and using such data in relation to the costs of not currently utilizing large amounts of unshared agricultural data due to stakeholders' distrust.

Sharing and using agricultural data can significantly improve agricultural productivity and risk management, including adaptation or mitigation of the effects of climate change (OECD, 2019). Data-driven decisions could also enhance international market access and open up new digital trade opportunities, which would benefit agricultural productivity,

[68] Efficiency: “Gaining the most output for a given level of input… [it] is often thought of as getting the same output for less of a particular input, or getting more of something for a constant input.” (Birkland, 2016, p. 233).

profitability, food security, and the overall digitalization of the agricultural sector, leading to data-ization.

To summarize, proposing a policy option for governing agricultural data in the United States necessitates careful consideration of the trade-offs associated with collective action, as well as an in-depth assessment of the costs and benefits of the available policy alternatives. Prescription, the final step in the policy analysis process, focuses on selecting the best policy option based on its potential outcomes.

In this case, the minimalist and moderate policy alternatives are the most feasible alternatives for achieving the policy goal of balancing equity and efficiency in agricultural data governance. The minimalist policy option seeks to monitor compliance with COP principles, whereas the moderate policy option assigns roles and responsibilities for data access and sharing while emphasizing data value and encouraging sector collaboration. Cost-effective analysis and costs and benefits analysis will be used to determine the best approach for governing agricultural data and maximizing the benefits of sharing and using such data in relation to the costs for the agriculture sector in the U.S.

Cost Effective Analysis

Cost-effectiveness analysis (CEA) is a useful method that enables a comparison of policy options not only based on their effectiveness (benefits) measured in units of public goods or services but also on the costs associated with achieving different levels of benefits that may be more effective at a lower cost (Dunn, 2018, p. 217). Therefore, the CEA method can be employed to examine and compare the benefits that the minimalist policy option for agricultural data governance offers in comparison to the moderate policy option and the status quo, which is doing nothing at all. Through this evaluation process, it will be possible to determine the most cost-effective and beneficial policy option for the agricultural sector.

Three criteria are commonly used in CEA. The first is the adequacy analysis, which examines whether a policy option can meet minimal standards of benefit at some maximal cost level. The second criterion, cost minimization, evaluates whether a policy option has the lowest costs for some minimally acceptable level of benefits. Finally, the third criterion, benefit maximization, assesses whether a policy option provides the greatest benefits for some maximally acceptable level of costs. Applying these criteria will enable us to identify the most cost-effective policy option for governing agricultural data in the U.S.

The cost effectiveness of agricultural data governance policy framework will depend on several factors:

- The volume and complexity of the data: The more data that needs to be collected, stored, and managed, the more costly it may be to implement effective governance policy.
- The level of risk associated with the data: If the data is sensitive or valuable, more stringent security measures may be required, which may increase the cost.
- The level of collaboration required: If multiple stakeholders are involved in the data collection and use, it may be more costly to coordinate their efforts and ensure that everyone is following the same data governance guidelines and standards.

- The availability of funding: The availability of funding can play a significant role in the cost effectiveness of agricultural data governance policy framework. If sufficient resources are available, more robust governance measures may be implemented.

An effective agricultural data governance policy should ultimately balance the costs of implementing governance measures with the benefits of ensuring that data is collected, stored, and used in a way that benefits all stakeholders. This balance is crucial to ensure that the policy is sustainable and provides value to the agricultural sector.

The comparison between the two policy options (minimalist and moderate) showed that while policy option II (moderate) may achieve higher overall benefit maximization by allocating more funds, policy option I (minimalist) achieves the minimum standard of benefits of data governance at the lowest cost, making it the most effective choice. The CEA method did not identify any potential problems or unintended consequences of either policy implementation. Implementing a design and strategy to improve data governance and its consumption is a challenging task. Therefore, Policy Option I will be pursued as it will serve as the foundation for Policy Option II. This approach provides a significant benefit and is the most efficient way to implement an agricultural data governance policy solution. Table 23 presents a comparison of the results of the cost-effectiveness analysis.

Table 23 Cost Effectiveness Analysis

Policy	Benefit Maximization	Cost Minimization	Overall Max Benefit and Less Cost
Policy I	Ineffective	Effective	Effective
Policy II	Effective	Ineffective	Effective
No Policy	Ineffective	Ineffective	Ineffective

Costs and Benefits

In this section, the forecasted effects of the minimal and moderate policies are compared to a "status quo" situation, which represents the measures or values of benefits and costs if the policy vacuum scenario for agricultural data governance persists. Maintaining the status quo of agricultural data practices is also considered as one of the possible options.

To begin this process of evaluating policy options for agricultural data governance, it is necessary to identify and categorize the costs and benefits associated with each option. This analysis should consider both direct and indirect costs and benefits that are relevant to the policy options being considered. Additionally, the importance of each factor should be ranked to help determine the relative weight of each element in selecting among the options.

To clarify, estimated direct benefits are primary outcomes of a policy option that directly address the structured policy problem dimensions for the targeted population. On the other hand, estimated indirect benefits are secondary outcomes that are associated with less valued benefits than the flow (access, sharing, and using) of agricultural data governance, but still contribute to solving the agricultural data governance problem on a smaller scale.

Direct estimated benefits refer to the benefits that can be directly attributed to the implementation of a policy option. In the case of agricultural data governance, these benefits would focus on improving access, sharing, and the use of agricultural data. Examples of these benefits could include the development of data-sharing standards, incentivizing farmers, producers to share data, and building a data-sharing infrastructure within agricultural research. The literature review was an effective source for projecting these direct estimated benefits.

Potential indirect benefits of facilitating data-sharing standards, safeguards, and enablers in agriculture include increased collaboration between domain researchers and data scientists, as well as the development of a data-sharing infrastructure within agricultural research. This can lead to increased research investment, and the recovery of unpublished data, which can further support innovation and knowledge creation in the field. These indirect benefits may not be immediately apparent, but can have a significant impact on the overall success of agricultural research and development efforts (Brouder et al., 2019, p. 2).

Table 24 Estimated direct and indirect benefits from a policy framework to govern agricultural data

Benefits	
Direct	**Indirect**
Increased involvement of USDA agencies in developing an effective oversight trustworthy system of COP principles in contractual agreements between farmers and ATPs.	Increase public involvement and strategic abilities on improving IoT-enabled Agricultural (IoTAg) monitoring.

Benefits	
Direct	**Indirect**
Increased level of collaboration for a reliable and trustworthy agricultural data flow, such as farmer-to-ATP coordination mechanisms.	Increase the promotion of a data-literacy culture in agriculture: the ability to read, understand, create, and communicate data for best farming practices using digital technologies.
Increase USDA capacity and procedures for data sharing to trusted academic organizations and researchers with anonymized and aggregated data via the secure data center for research, analysis, and evaluation.	Increase in data-driven public agricultural research approaches based on the availability of public data.
Increase incentives for instituting a data-driven approach for agriculture future decision-making where data can be found, integrated, and used.	Improve agriculture government agencies' strategic abilities to provide technical assistance to farmers, to allocate federal funds, and improve farm program implementation.
Increased USDA involvement and intervention capacity in COP principles violations in contract agreements between farmers and ATPs and appropriate action.	Improved management agencies' ability to store agricultural-related information on the cloud and make it accessible from anywhere, allowing for fast data access and real-time information availability.
Improved USDA capacity to implement registration requirements for private companies acting as data intermediaries.	Reduce waste and inefficiencies in post-production processing and handling in the agriculture sector.
Improved management of USDA organizational capacity to oversee the granting of ATPs' data-transparent	Lowering the risk of climate change and extreme weather events due to the sharing and using of larger amounts of agricultural data.

Benefits	
Direct	**Indirect**
trademark or logo and evaluate its renewal on an annual basis.	
Increase agricultural stakeholders' awareness of the importance of protecting personal farmer information (address, bank, and credit information).	Increasing the resilience and sustainability of food systems to ensure food and nutrition security.
Incentives for promoting a data-driven international trade environment.	
Incentives to form partnerships and alliances with international collaborators and subject experts to create open data platforms in order to make it easier for primary producers, practitioners, and researchers to find agricultural data in their field of interest (collaborative agricultural open databases).	

The digital economy has emerged alongside the flow of data, creating the potential for significant innovation and benefits for users (Howell, 2022, p.1). Data has two distinct characteristics that set it apart from other goods: it is non-competing and displays network effects. This means that a single piece of data has the capacity to provide multiple benefits to multiple applications, and when combined with additional information, its value increases. To fully realize the potential of data, reliable data-sharing solutions must be developed, and this is where data governance comes into play. By ensuring proper data governance, we can unlock the benefits of data while mitigating risks and promoting ethical practices.

These potential benefits can be observed in the wine industry, where having a trustworthy system for contractual agreements in place to access, share, and use data can play a significant role in sustaining a vibrant transatlantic trade relationship between the EU and US wine sectors. This sector is a vital driving force in many rural economies and a significant number of medium and small businesses. Implementing a data governance framework will incentivize government agencies to intervene by collecting, linking, and analyzing data to support the economic vitality and diversity of the wine sectors. For instance, this can involve working on tariffs on wine to achieve a 'zero for zero' wine trade environment (Featherstone, 2021). However, the US wine industry has recently faced challenges due to President Donald J. Trump's administration's imposition of a 25% tariff on French, Spanish, German, and English wines in October 2019, which led to a drop of nearly $500 million in the value of French wine exports to the US in 2020[69].

Direct estimated benefits are essential in evaluating the significance of collaborating with provider users who have access to data and information on pests and diseases to develop research on a single platform. An example to consider is the PlantwisePlus Knowledge Bank[70] and the CABI Digital Library (CDL) platform, which provides access to diagnostic and decision support tools, as well as data sheets, detailed images, and distribution maps[71]. Knowledge Bank users can benefit from improved search capabilities,

[69] Information available at: https://www.decanter.com/wine-news/us-suspends-wine-tariffs-eu-454550/

[70] PlantWise Knowledge Plus is a free online resource that gathers plant health information from across the world. More information available at: https://blog.plantwise.org/2021/08/12/what-is-the-plantwise-knowledge-bank/

[71] Detailed information available at the Plantwise Blog: https://blog.plantwise.org/2022/11/29/plantwiseplus-knowledge-bank-joins-the-cabi-digital-library/

an enhanced mobile experience, and access to key decision-making tools, among other advantages.

Another example of how data governance solutions can incentivize partnerships between public agencies and private companies is the Agmatix initiative[72]. Agmatix is a startup ag-tech company that has developed a single engine to digitize research data, enabling agro-professionals to increase crop yields and quality while minimizing environmental impact. By employing machine learning and artificial intelligence, Agmatix creates statistically and scientifically stronger models and decision support systems, which can aid in the mainstream adoption of big data in agronomy to increase global yields. The Agmatix platform facilitates the development of statistical agricultural models, which can help reduce food waste and support global food security in light of population growth.

Agriculture science can be better translated into practice through the implementation of a data governance framework for the sector. Such a framework can help provide policy makers with access to less fragmented, partial, and biased evidence, allowing for more informed decision-making. Additionally, according to PwC, IoT-enabled Agricultural (IoTAg) monitoring is the fastest-growing technology segment in smart, connected agriculture, with an expected market value of $4.5 billion by 2025 (Columbus, 2021).

The estimated benefits highlighted above illustrate the value of implementing an agricultural data governance policy. Establishing data safeguards and enablers through policy measures will facilitate the advancement of data sharing. Incorporating data governance practices such as workflows and usage guidelines in all federally funded

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[72] Agmatix information available at: https://www.agmatix.com/ag-field-trial-management/

projects, along with coordinating existing and emerging data initiatives, networks, and repositories, and building long-term infrastructure comprising hardware, software, and human resources, will help to curate, preserve, and add value to agricultural data beyond its primary use.

The estimated costs encompass all the expenses that would be necessary to implement either of the two public policy options. Estimated direct costs represent the minimum amount required for each policy option to achieve the desired benefits and outcomes. Although these costs are typically expressed in monetary terms to gauge the advantages and disadvantages of a given policy option, it is impractical to provide precise monetary estimates for each cost category in this research on solving agricultural data governance issues in the U.S. This is due to the fact that agricultural costs are constantly fluctuating, and data accuracy can be inconsistent. Nevertheless, the estimated costs provided are supported by specific examples in the literature. Attempting to determine costs through survey methods or market behavior inferences is a challenging task.

Table 25 Estimated direct, indirect and risk costs in this study

Costs		
Direct	**Indirect**	**Risk**
Capacity building and modernization of organizational digital infrastructure for USAID agencies.	Challenges with ATPs in regulatory compliance with COP principles in contractual agreements and lawsuits,	The fragmentation of the agriculture industry has negative impact on data governance practices
Farmers automation technology subsidies	Poor data quality, data inaccuracy and data	The Department of Agriculture delays

	inconsistency	adopting a modernizing model to implement agricultural data policy changes
Improving the infrastructure, maintenance, and storage capacity for data sharing among USDA agencies.	Lengthy adoption of agricultural digital technology process, lack of expertise, privacy and security issues	Farmers' access to aggregated agricultural data is constrained or limited.
Funding for projects related to data cooperatives or data intermediaries, annual membership, collaborative agriculture organizations, and ATPs businesses.	Challenges in reaching out to small farmers (information distribution about policy changes)	Reduced central location for all agricultural data management offered by ag tech providers
Annual memberships to access and maintain the ADT Trademark or logo.	Negative effects on supply chain coordination	Open-source software has limited accessibility for farmers and other agriculture stakeholders.
Large amounts of unused agricultural data.		
Increase the adoption of AI in the agriculture industry.		
Investment in cloud connectivity technologies for the agriculture sector		

Globally, it is expected that the amount of data generated each day will reach 463 exabytes (Bonner, 2022), highlighting the growing importance of developing sustainable data management processes. Some studies have attempted to quantify the cost of poor data quality. For example, according to a 2016 report by IBM (Redman, 2016), poor-quality data[73] costs businesses $3.1 trillion annually in the United States alone. Sakpal (2021) estimated that poor data quality costs organizations an average of $15 million per year. Moreover, a study by Experian in 2020 found that inaccurate data cost businesses an average of 12% of their annual revenue. These numbers are only estimates and may not be applicable to all organizations, but they give a general sense of the significant financial impact of poor data quality. In addition to revenue impacts, poor-quality data or a lack of data can lead to flawed decision-making and assessments over time (Bonner, 2022). Access and shareability are crucial for data to be useful.

Evaluating risk costs is important when determining which policy option has a lower risk of harm. However, estimating potential consequences and external factors that may affect outcomes is challenging (Aven, 2014, p. 20). Probabilities are conditional (if...then) and based on prior knowledge about the event, such as scientific knowledge, data, assumptions, perceptions, and beliefs (Aven, 2014, p.23). Therefore, probability-based risk assessment costs for an agricultural data policy framework are primarily informed by previous knowledge of agricultural data issues. For instance, in the US agriculture sector, data access and use by others continue to be dependent on individual contractual agreements, aided by one-time trial-and-error data transfer solutions (Cragin et al. 2010). A significant barrier remains the lack of funding for synthesis research using aggregated

[73] Poor quality data can include inaccurate information, incomplete data, non-formatted information, irrelevant content, or even duplicate data.

data. Concerns about data privacy, security, and intellectual property also prevent emerging data-sharing efforts, particularly those involving public-private partnerships.

To assess risk, it's important to measure or calculate expected values or costs, which are known as risk metrics. These can provide valuable information about the level of risk in a specific situation. For example, in the United States, the infrastructure deficit poses a risk to agriculture's ability to comply with "open access" policies. When assessing risk at the macro policy and governance levels, it's important to consider not only the likelihood of a risky event occurring and causing harm, but also the unknown consequences and the potential human reactions, behaviors, and attitudes towards it.

The public's expectations for accessing and using agricultural science to make informed decisions span a wide range of land management, from understanding food's nutritional value for diet modification to vastly improving precision technology application for profitable crop and animal production and environmental protection (Brouder et al., 2019, p. 3). As such, risk is a function of the implementation of public policy. It is important to evaluate the likelihood of potential risks and their associated costs if policy option one or two is implemented.

Uncertainties around funding could raise concerns about the feasibility of functional, hybrid business data models that could complement existing public financing data models through short-term research grants or national funding (Brouder et al., 2019, p. 13). The cost of the envisioned data infrastructure is largely unknown, but undoubtedly, significant investment will be required. Data stewardship, as opposed to simple storage, involves additional workflows and human resources (Bourne, Lorsch, and Green 2015), which further exacerbates cost concerns and uncertainty.

The costs of modernizing agriculture data infrastructure (Ristino & Hart, 2022) and restructuring the USDA to oversee COP principles in contractual agreements are estimated to be directly associated with the minimalist policy option I. Modernizing the USDA will provide a foundation for the moderate policy option II, which aims to oversee agriculture data intermediaries and their processing, storage, analysis, and provision of other data services to farmers and producers. Estimated remaining costs in USDA modernization, such as the formation of an agricultural data governance board for policy option II to promote secure and safe agricultural data flow between data intermediaries, farmers, and producers, are lower. By modernizing USDA agencies, the agricultural sector will witness increased innovation, implementation of digital technologies and tools, food security, sustainability, and a digitally transformed sector.

Findings

The analysis presented dismisses the status quo as an unrealistic alternative, as it fails to provide any benefits while increasing costs and risks associated with the loss of data literacy and informed decision-making. Policy option I is the best scenario, given the government's allocation of funds in the agricultural sector, as it offers the greatest benefit for cost. The cost and benefits analysis supports its implementation, as it will enhance the stewardship and ownership of agricultural data, providing stakeholders with a better understanding of the implications of ongoing technological innovations in the sector. However, budget constraints may limit the scope of this option.

Policy option II builds upon the foundation of policy option I and can potentially provide additional benefits. However, it may not necessarily result in reduced costs compared to policy option I. A more comprehensive analysis that takes into account potential entry barriers and the potential for diminishing returns on investment may be necessary to fully understand the economic impact of policy option II. Currently, both Cost-Effective Analysis and Costs and Benefits do not provide a clear picture of this impact. Policy option I appears to be the most viable scenario in terms of costs and benefits.

The CBA further supports this conclusion, as it confirms that maximizing efficiency and minimizing costs will be critical to the successful implementation of data governance in the agricultural sector. By adopting a comprehensive approach to data stewardship and ownership, farmers and producers can minimize risks while maximizing outputs, all while maintaining accurate records for regulatory compliance.

In summary, the evidence suggests that policy option I provides the best balance of benefits and costs for the agricultural sector, with policy option II serving as a logical extension of policy option I. By adopting a forward-thinking approach to data governance and management, the government can lay the groundwork for a sustainable and secure agricultural future, while farmers and producers can enjoy the benefits of increased data literacy and informed decision-making.

Conclusion

In the era of the Fourth Industrial Revolution, data is no longer just a byproduct of agricultural activities; it has become a valuable commodity in its own right. As the agriculture sector undergoes digital transformation, there is a growing need for a comprehensive data governance policy framework that can facilitate the secure and efficient management of agricultural data.

The analysis of the agricultural data governance policy problem and the three policy options presented in this dissertation highlight the need for modernizing the agricultural data infrastructure in the U.S. agriculture sector. The core of this research lies in identifying a significant policy problem, specifically the lack of a comprehensive agricultural data governance policy. Through this research, the aim was to ask the appropriate questions to address this issue from a policy perspective, and propose potential solutions that can be effective in facilitating the digital transformation of the agriculture sector.

The objective of an agricultural data governance policy framework is to promote data sharing and reuse in the sector while protecting personal data and privacy. A policy framework for cross-sector data sharing can establish clear rules, such as obtaining consent and safeguarding personal data, promoting responsible data sharing. This framework encourages innovation and competition while ensuring that data is used for the greater good of agriculture in the U.S.

This research recommends implementing policy options to establish a secure and safe flow of agricultural data between data intermediaries, farmers, and producers. This initiative will serve as a foundation for sector innovation, increase the implementation of digital technologies and tools, and promote food security, sustainability, and a digitally transformed sector.

In addition, providing guidelines and objectives for agricultural data governance and management will empower farmers and producers to make informed decisions based on data analysis, resulting in increased productivity and economic growth. In summary, modernizing agricultural data infrastructure and potentially implementing policy options I and II are crucial for sustaining and growing the agricultural sector. These policies will improve data stewardship and ownership, enhance sector innovation and efficiency, and advance food security, sustainability, and the digital transformation of the sector.

One of the key contributions of this doctoral research is the proposal of a two-step policy, which represents an innovative approach to addressing the challenges posed by the Fourth Industrial Revolution and the digital transformation of the economy in the agriculture policy subsystem. This policy recommendation represents an attempt at policy innovation that has the potential to facilitate the adoption of new technologies and promote sustainable agriculture practices. By proposing this new approach, this research is offering valuable insights into how policymakers can adapt to the changing technological landscape and ensure that the agricultural sector is well-positioned to thrive in the future.

Moving forward, the next recommended step would be to conduct a stakeholder assessment in the agricultural sector to identify opportunities and challenges related to implementing an agricultural data governance policy. This assessment will allow for a better understanding of the needs and concerns of stakeholders, including farmers, producers, and data intermediaries. Based on the findings of the assessment, a collaborative process can be initiated to engage stakeholders in discussions and agreements of cooperation to facilitate the implementation of an agricultural data governance policy. This will require a multidisciplinary approach, involving policymakers, industry leaders, and academia to ensure that the policy is effective, beneficial, and aligned with the digital transformation of the agriculture sector.

By highlighting the importance of a data-driven approach to agriculture and the potential benefits of using data as an additional product in this sector, this study hopes to contribute to the ongoing conversation surrounding agricultural data governance and encourage further research and policy development in this area. This research underscores the need for policymakers and stakeholders to prioritize modernizing the agricultural sector and developing a robust data governance policy framework to ensure the future of food security and economic development.

In conclusion, it is necessary to implement an agricultural data governance policy that promote responsible data use, foster transparency and trust, and facilitate innovation and growth in the sector.

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Appendix: Tables for the Application of Forecasting Policy Analysis Methods

Attached below are the Excel tables that were used in our forecasting analysis work.

Forecasting–Prediction Policy Analysis: Policy options addressing the dimensions of the policy problem

		Addressing the policy problem dimensions								
Policy Options for Ag-DG	**Data governance legal dimensions (Chen, 2021)**	**Farmer and public trust in data sharing (0.4)**	**Data rights and norms for privacy and confidentiality (0.2)**	**Data production cycle, Oversight, accountability (0.2)**	**Smart Farming-Sector digital transformation (0.2)**	**Policy adoption time**	**Policy adoption budget**	**Sum**	**Total**	**% problem response**
Option 1: Minimalist	**Safeguards**	1	0	1	0	1	1	4	6	
	Enablers	1	1	0	0	1	1	4	6	
	Institutional roles and responsibilities	1	1	1	0	1	1	5	6	
Option 1 consolidated		HIGH	MEDIUM	MEDIUM	UNDER SERVED	HIGH	HIGH	13	18	72%
Option 2: Moderate	**Safeguards**	1	1	1	1	0	1	5	6	
	Enablers	1	1	1	1	1	1	6	6	
	Institutional roles and responsibilities	1	1	1	1	0	0	4	6	

Option 2 consolidated		HIGH	HIGH	HIGH	HIGH	LOW	MEDIUM	15	18	83%
Option 3: Maximalist	**Safeguards**	1	1	1	1	0	0	4	6	
	Enablers	1	1	1	1	0	0	4	6	
	Institutional roles and responsibilities	1	1	1	1	0	0	4	6	
Option 3 consolidated		HIGH	HIGH	HIGH	HIGH	UNDER SERVED	UNDER SERVED	12	18	67%

Policy Process Feasibility Analysis

	Policy Process Feasibility Dimension									
Policy Options for Ag-DG	**Incidents**		**Interests and Ideas**		**Institutions**		**Inter-Unit diffusion**		**Industrialization**	
Option 1: Minimalist	Incidents that create windows for new ideas	HIGH	Collective action problems	MEDIUM	Institutions that allow policy responses to occur	HIGH	Political economy/fiscal incentives	MEDIUM	Agriculture Sector Digital transformation	UNDER SERVED
	Incidents of non-technical communication		Advocates of change or stasis		Institutional strategies to optimize the use of institutions for policy response		Globalization ("global supply chains effect")			
			Powerful ideas to mobilize, frame, and determine policy change							

	Policy Process Feasibility Dimension									
Policy Options for Ag-DG	**Incidents**		**Interests and Ideas**		**Institutions**		**Inter-Unit diffusion**		**Industrialization**	
Option 2: Moderate	Incidents that create windows for new ideas Incidents of non-technical communication	HIGH	Collective action problems Advocates of change or stasis Powerful ideas to mobilize, frame, and determine policy change	LOW	Institutions that allow policy responses to occur Institutional strategies to optimize the use of institutions for policy response	HIGH	Political economy/fiscal incentives Globalization ("global supply chains effect")	HIGH	Agriculture Sector Digital transformation	HIGH
Option 3: Maximalist	Incidents that create windows for new ideas Incidents of non-technical communication	MEDIUM	Collective action problems Advocates of change or stasis Powerful ideas to mobilize, frame, and determine policy change	HIGH	Institutions that allow policy responses to occur Institutional strategies to optimize the use of institutions for policy response	UNDER SERVED	Political economy/fiscal incentives Globalization ("global supply chains effect")	MEDIUM	Agriculture Sector Digital transformation	HIGH

Coding of Benefits and Costs

			Qualitative Y				Numeric Y			Weighted Numeric		
BENEFITS I (DIRECT)	**Importance Rank**	**Rank Weight**	**Option 1**	**Option 2**	**Status Quo**	**Weighted Rank**	**Option 1**	**Option 2**	**No policy**	**Option 1**	**Option 2**	**No policy**
Increased involvement of USDA agencies in developing an EFFECTIVE OVERSIGHT trustworthy system of COP principles in contractual agreements between farmers and ATPs	1	1.25	high	medium	none	22.5	3	2	0	67.5	45	0
Increased level of collaboration for a reliable and trustworthy agricultural data flow, such as farmer-to-ATP coordination mechanisms	2	1.25	medium	high	none	21.3	2	3	0	42.5	63.8	0
Increase incentives for sharing public data	3	1.25	medium	high	none	20	2	3	0	40	60	0
Increase incentives for instituting a data-driven future decision-making approach where data can be found, integrated, and used	4	1.25	medium	high	low	18.8	2	3	1	37.5	56.3	18.8
Increased USDA involvement and intervention capacity in COP principles violations in contract agreements between farmers and ATPs and appropriate action	5	1.25	high	high	none	17.5	3	3	0	52.5	52.5	0

Improved USDA capacity to implement registration requirements for private companies acting as data intermediaries.	6	1.25	low	medium	none	16.3	1	2	0	16.3	32.5	0
Improved management of USDA organizational capacity to oversee the granting of ATPs' data-transparent trademark or logo and evaluate its renewal on an annual basis	7	1.25	low	low	none	15	1	1	0	15	15	0
Increase agricultural stakeholders' awareness of the importance of protecting personal farmer information (address, bank, and credit information).	8	1.25	high	high	none	13.8	3	3	0	41.3	41.3	0
Incentives for supporting a data-driven international trade environment	9	1.25	medium	medium	none	12.5	2	2	0	25	25	0
Incentives to form partnerships and alliances with international collaborators and subject experts in order to make it easier for primary producers, practitioners, and researchers to find agricultural data in their field of interest.	10	1.25	medium	high	none	11.3	2	3	0	22.5	33.8	0
BENEFITS II (INDIRECT)												

Increase public involvement and strategic abilities on improving IoT-enabled Agricultural (IoTAg) monitoring	11	1	medium	high	low	8	2	3	1	16	24	8
Increase farmer participation in best farming practices for using digital technologies (data literacy)	12	1	medium	high	low	7	2	3	1	14	21	7
Increase in data-driven in public agricultural research approaches based on the availability of public intent data	13	1	medium	high	low	6	2	3	1	12	18	6
Improve agencies' strategic abilities to allocate federal funds to specific agriculture programs	14	1	low	medium	none	5	1	2	0	5	10	0
Improved management agencies' ability to store agricultural-related information on the cloud and make it accessible from anywhere, allowing for fast data access and real-time information availability	15	1	medium	high	low	4	2	3	1	8	12	4
Reduce waste and inefficiencies in post-production processing and handling	16	1	medium	high	low	3	2	3	1	6	9	3
Lowering the risk of climate change and extreme weather events	17	1	medium	high	none	2	2	3	0	4	6	0

Increasing the resilience and sustainability of food systems to ensure food and nutrition security	18	1	medium	medium	low	1	2	2	1	2	2	1
MAX	**18**	1	MIN									
COSTS I (DIRECT) (Policy Option Implementation - 1 the most important)												
Capacity building trainings and modernization of organizational digital infrastructure for Department of Agriculture agencies.	1	1.25	medium	high	none	22.5	2	3	0	45	67.5	0
Farmers automation technology subsidies	2	1.25	medium	high	none	21.25	2	3	0	42.5	63.8	0
Data storage infrastructure and maintenance	3	1.25	medium	medium	low	20	2	2	1	40	40	20
Data Cooperatives or Intermediaries annual membership	4	1.25	medium	low	high	18.75	2	1	3	37.5	18.8	56.3
ADT Trademark or logo for one-year	5	1.25	medium	low	high	17.5	2	1	3	35	17.5	52.5
Large amounts of unused agricultural data	6	1.25	low	low	high	16.25	1	1	3	16.3	16.3	48.8
AI investment in agriculture	7	1.25	low	high	none	15	1	3	0	15	45	0
Interconnectivity (IOT - Central Servers)	8	1.25	medium	high	low	13.75	2	3	1	27.5	41.3	13.8
COSTS II (INDIRECT)												
Challenges with ATPs in regulatory compliance with COP principles in contractual agreements and lawsuits	9	1	low	medium	medium	10	1	2	2	10	20	20

Poor data quality, data inaccuracy and data inconsistency	10	1	low	medium	mediu m	9	1	2	2	9	18	18
Lengthy adoption of agricultural digital technology process, lack of expertise, privacy and security issues	11	1	medium	high	low	8	2	3	1	16	24	8
Challenges in reaching out to small farmers (information distribution about policy changes)	12	1	medium	high	none	7	2	3	0	14	21	0
Negative effects on supply chain coordination	13	1	medium	low	high	6	2	1	3	12	6	18
COSTS III (RISK)												
The fragmentation of the agriculture industry has negative impact on data governance practices	14	1	medium	medium	low	5	2	2	1	10	10	5
The Department of Agriculture delays adopting a modernizing model to implement agricultural data policy changes	15	1	medium	medium	low	4	2	2	1	8	8	4
Farmers have restricted or limited access to aggregated agricultural data	16	1	medium	medium	low	3	2	2	1	6	6	3
Ag Tech providers reduce the offer of a centralized location for all agricultural data management	17	1	medium	medium	low	2	2	2	1	4	4	2

Farmers have restricted access to open-source software	18	1	medium	medium	low	1	2	2	1	2	2	1
MAX	18	1	MIN							91	119	79