# Next Generation Cross-Sectoral Data Platform for the Food System

Donika Xhani*

*University of Twente, Drienerlolaan 5, 7522 NB Enschede, the Netherlands*

**Abstract**

The food system is a complex network encompassing various stakeholders, including primary producers, manufacturers, retailers, and consumers. Across all the stages of the food supply chain, a significant amount of data is produced, offering valuable insights crucial for ensuring the delivery of safe, high-quality, and cost-effective products to meet the needs of a growing global population. Recommender systems are commonly used in the food domain but often lack personalization, leading to generic recommendations. Enhancing user experience through explainability offers transparent reasoning behind recommendations, fostering trust and informed decision-making. Semantic reasoning can be enhanced through ontology-based user profiles. Moreover, the increased data sharing in the food sector has raised privacy and security concerns, prompting the development of privacy-preserving data platforms. This PhD project aims to address these challenges by (1) utilizing ontologies for enhancing semantic interoperability, (2) employing eXplainable Artificial Intelligence (XAI) methods and semantic reasoning for enhancing the transparency of recommender systems, and (3) designing a privacy-preserving data platform that facilitates data sharing while ensuring the protection of sensitive information.

**Keywords**

Food supply chain, ontology, recommender system, data platform, explainable AI

## 1. Introduction

The food system comprises a multitude of participants across the supply chain: (1) primary producers such as cultivators, farmers, and aquafarmers, (2) food producers such as breeders, processors, and packers, (3) retailers such as distributors, supermarkets and restaurants, (4) logistics such as transporters, shippers and carriers, and (5) consumers [1]. Throughout every stage of the food supply chain, a substantial volume of data is produced, offering valuable insights to those managing the processing and distribution of food items from production to consumption [1]. Effective management of this food data plays a vital role in ensuring the delivery of safe, high-quality, and cost-effective products to meet the needs of a growing global population [1, 2].

A guidance for achieving appropriate data management is the FAIR principles [3], which ensure Findability, Accessibility, Interoperability, and Reusability of the data [4], and present huge opportunities in the scientific community [5]. However, ensuring interoperability (the "I" in FAIR) by representing the semantics using ontologies remains a demanding task [5, 6].

In the food domain, recommender systems are commonly used for recommending different food items or recipes in accordance with the user's preferences, nutritional goals, or dietary restrictions. Current food recommendation systems face several limitations such as the lack of personalization by often relying on generic suggestions rather than taking into account user's preferences, dietary constraints, cultural heritages, and health-related needs [7].

Enhancing user experience can be achieved through explainability, which offers transparent and understandable reasoning behind specific recommendations [8, 9]. This empowers users to make informed

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*Corresponding author.

d.xhani@utwente.nl (D. Xhani)

https://people.utwente.nl/d.xhani (D. Xhani)

0000-0003-2536-0574 (D. Xhani)

decisions and builds trust [9, 7, 8]. For instance, explaining that a lactose-free dish is recommended because it aligns with the user's dietary needs of not eating milk-based products. For example, in this case, the recommender system can give this explanation:*"This meal was suggested because it aligns with your lactose-free dietary requirements*" provides clarity and reinforces trust in the system [7]. For this purpose, the recommender system can rely on eXplainable Artificial Intelligence (XAI) models which refers to techniques used for making the Machine Learning (ML) models interpretable and comprehensible by humans [**?** ].

XAI can be implemented by using post-hoc approaches which refer to the application of XAI models on top of the black-box output generated from a ML model [8]. For explaining the decision-making and the output of a food recommender system, it is crucial to comprehend which are the important features i.e., by doing feature extraction by using the SHAP model, and to have textual explanation for creating personalized explanations [8]. Semantic reasoning of the food recommender system can be enhanced by the usage of ontologies by enabling ontology-based user profiles, which can help the algorithms understand user preferences, dietary needs and culinary aspects [7].

The increase of data sharing among the actors and sharing of personal data and health data has led to increased awareness of privacy and security concerns. Privacy-preserving data platforms are systems that facilitate data sharing while ensuring the protection and security of sensitive information [11, 12]. Such platforms enable users to make well-informed food decisions while safeguarding their sensitive data, thereby enhancing the security and reliability of the user experience [7].

This PhD project aims to dive into these areas: (1) the usage or design of ontologies for enhancing semantic interoperability in the food supply chain, (2) the usage of XAI methods and semantic reasoning for explaining the decision-making of the recommender systems and the generated output, and (3) the design of a privacy-preserving data platform.

## 2. Research Questions

The development of this future food system inspires the following Research Questions (RQ) that will be carried out throughout the PhD.

The main RQ is:

**How to design a next-gen cross-sectoral data platform that ensures semantic interoperability, privacy-preserving, and provides Explainable AI solutions?**

The sub-research questions are:

1. How to enhance semantic interoperability and explainable artificial intelligence (XAI) in food supply chains or food recommender systems?
2. What privacy-preserving techniques are most effective for protecting sensitive agricultural data?
3. What architectural models are best suited for integrating cross-sectoral data while maintaining privacy and interoperability?
4. What are the specific needs and requirements of the various stakeholders in the agricultural sector?
5. What are the potential applications and benefits of the platform in real-world agricultural scenarios?

## 3. Methodology

The methodology used in this PhD project is the Design Science methodology [13]. The Problem Investigation phase is used to identify what is the state-of-the-art regarding existing ontologies and knowledge graphs in the agri-food domain, XAI techniques that are used in food recommenders, and privacy-preserving techniques. The Treatment Design phase is used to identify (1) requirement analysis, (2) adopting existing web technologies frameworks, (3) designing a semantic web technologies-based recommender, and (4) modeling of a reference architecture for next-gen privacy-preserving data

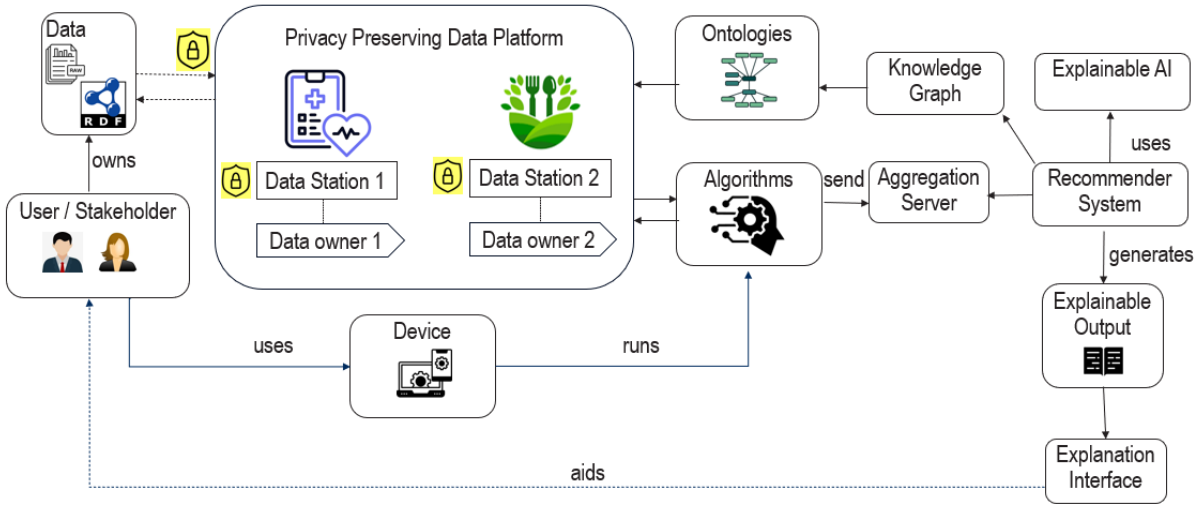


**Figure 1:** Conceptual Model of the proposed solution

platform. The Treatment Validation phase is used for (1) validating the used semantic web technologies, (2) using the single case mechanism method in a case study for validating the prototype, and (3) using the expert opinion method for validating the reference architecture models.

## 4. Conceptual Model

Figure 1 illustrates the primary components of the proposed solution, which addresses our research questions in the following manner. The privacy-preserving data platform ensures that each stakeholder retains ownership of their data and can selectively permit access to it. Each data station is managed by a data owner and is accessible via specific algorithms. The platform leverages ontologies to guarantee semantic interoperability. Additionally, the recommender system generates explainable recommendations, thereby assisting users in obtaining informed and transparent outcomes.

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