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# AgroAPI platform: An initiative to support digital solutions for agribusiness ecosystems

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A B S T R A C T

Agriculture is directly related to the Sustainable Development Goals (SDGs) proposed by the United Nations. Digital transformation in agriculture is an important trend for sustainable practices and governance. In recent years, various sensors have been used in agriculture to collect large volumes of data that allows faster and more complex analysis. This paradigm shift has led to data-driven agricultural management, which aids farmers in the decision-making process. Digital platforms for data storage, organization, and management are important tools used by companies to generate better solutions for end users. However, there are challenges related to the acquisition time and retrieval of scalable and accurate data. To address these challenges, this paper presents the AgroAPI platform that provides access to data and models for the agricultural sector through Application Programming Interface (API). This is an initiative from the Brazilian Agricultural Research Corporation (Embrapa) and its partners. The AgroAPI's APIs focus on agricultural productivity, indication of planting dates, soil classification, weather, bio-input catalog, and vegetation indices obtained from satellite images. This study showed that the AgroAPI platform, its available APIs and the applications developed with them contribute to reaching SDGs, particularly those related to agriculture.

## 1. Introduction

The growing demand for more nutritious, equitable, functional and sustainable food systems, and the intensification of extreme weather events, pandemics, conflicts, and rural exodus are important challenges for agriculture worldwide in the 21$^{st}$ century [1]. Additionally, projections of population growth and consumption patterns indicate that at least a 70% an increase in food production is required to meet demands by 2050. Some of the 17 Sustainable Development Goals (SDGs) launched by the United Nations (UN) can be met by actions directly related to agriculture [2]. Digital transformation in agriculture, the main subject of this work, represents an opportunity to help eradicate hunger (SDG 2), mitigate the effects of climate change (SDG 13), increase agricultural production (SDG 12), facilitate sustainable use of water (SDG 6), promote actions to improve the conditions of smallholders (SDG 10) and increase access to information (SDG 9) [3].

However, important challenges remain in terms of rural connectivity infrastructure, computing platforms for integrated data access, training in digital technologies, and public policies. According to a literature review conducted by Berchin et al. [4], public policies in Brazil focus on the contribution of family farming to food security. The way in which farmers perceive benefits of technification likely influences their decision to adopt technologies. Bolfe et al. [5] conducted a survey with Brazilian farmers regarding use of digital technologies, and their applications, challenges, and future perspectives. Results indicated that 84% of farmers interviewed use at least one digital technology with some perception of increased productivity. Of the farmers interviewed, 95% wanted to learn more about new technologies. Studies conducted in South America, analyzed issues surrounding the adoption of digital agriculture in Brazil, Argentina, Uruguay, and Chile [6]. The results indicated that the Global Positioning System (GPS), mapping tools, mobile applications, and remote sensing were the most commonly adopted technologies. The main barriers to technology adoption identified were the are cost, lack of training, limited number of service providers, and lack understanding of the benefits of digital agriculture.

Digital transformation in agriculture is a promising alternative to address these difficulties by increasing technification, gathering data, automating tasks, and generating useful information for data-driven

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decision-making by farmers [7]. Digital agriculture involves communication, information, and data analysis that enables rural producers to plan, monitor, and manage both the operational and strategic activities of agricultural production. There are continuous technological advances that contribute to digital agriculture, such as mobile devices [8], Internet of Things - IoT [9,10], big data [11], computer vision [12], cloud computing [13], artificial intelligence [14], and remote sensing [15]. The integration of these technologies and development of new applications has the potential to transform and positively impact the agricultural sector. However, those involved in this agricultural revolution must consider a responsible innovation process with regard to environmental, social and sustainability issues, as discussed by Rose and Chilvers [16]. Furthermore, Rotz et al. [17] reported social benefits of digital agriculture and argued that policy, programming, and legislation can help to consider the potential implications of these digital technologies for agricultural work and rural communities.

The use of IoT, that is, sensors that are connected to the internet and transmit data, associated with increased network coverage in the field influenced agricultural management models [18,19]. A higher number of sensors on farms, results in a greater volume of data that must be transmitted, stored, validated, treated, and integrated into applications to be accessed by different actors in agribusiness. Considering the large volume and complexity of data, computational technologies are increasingly needed in all steps, from data collection to end-user applications, in order to perform tasks that exceed human processing capabilities. Additional challenges must be considered, such as data standardization, interoperability, information security, and the proposal and adoption of regulatory laws. Researchers have been working towards solutions for these issues, such as proposing standards for data interoperability, more effective security protocols, user-centered design, and creation of digital platforms [20].

These platforms play an important role in storing, processing, and exchanging data from devices, operating as an intermediary interface layer (middleware) [21,22]. Recently, many platforms are based on the APIs model, which are a manner of exposing software in a standardized way, enabling communication between different computer systems [23]. APIs are therefore considered fundamental to digital transformation in organizations, because they facilitate integration of information systems and reduce both costs and time [24–26]. Although invisible to end users, APIs are responsible for the resources currently present in many applications [27]. Solutions based on digital platforms have been developed and used by various actors in agricultural innovation ecosystems. The use of APIs in agricultural applications has also been increasing with solutions for different areas (e.g. precision agriculture [28], and climate data [29]), targeted to improve interoperability and data exchange.

APIs enable developers to access a diverse range of data and services, to build applications, or to provide new services for different agricultural management Information Systems. Initiatives involving the development of API platforms to foster innovative ecosystems in agriculture have emerged in several countries. In France, the API-AGRO platform was proposed in 2013 by a consortium of institutions. The API-AGRO platform promotes secure sharing of data and algorithms through APIs, which connects public and private institutions [30,31]. The Department of Primary Industries and Regional Development (DPIRD) the Government of Western Australia is responsible for a data platform obtained via a web API, that includes information on weather, organisms, soil, and radar. Web APIs (https://www.agric.wa.gov.au/web-apis) are designed to share data that are collected and maintained by DPIRD during research, development, and outreach activities with both national and international partners. In Japan, there is an initiative to develop an "Agricultural Data Collaboration Platform" (Wagri) that provides useful data and enables data sharing. Wagri acts as a hub to link various data sources and services, thus promoting greater harmony between different players in agribusiness. Wagri provides APIs for soil data, market conditions, and weather, which present commercial data in an accessible format.

In light of the previous studies, an important question arises: how can digital agriculture help to achieve the SDGs? To address this question, this paper presents the AgroAPI platform (www.embrapa.br/agroapi) focused on the digital agriculture market as an innovation and business strategy. This platform allows access to information and models generated by the Brazilian Agricultural Research Corporation and its partners. The AgroAPI presented here also shows contribution to the SDGs provided by solutions that explores the platform's APIs.

## 2. Materials and methods

An API platform such as AgroAPI provides a connection between API producers and consumers. API producers develop, manage, and publish APIs, whereas API consumers build applications for end users that access information provided by the APIs. Therefore, an API platform requires an interface for the internal public (API producers at Embrapa) and another for the external public (API consumers).

Several software solutions have incorporated the concept of an API platform. There are few benchmarks [32] for API management software in the scientific literature; therefore, we used reports from Gartner [33] and Forrester Wave [34] as the main benchmarks to assess the features, strengths, and weaknesses of leading API management platforms. The *WSO2 API Manager* met the following main criteria defined by Embrapa:

- The open-source model and self-managed solution offer flexibility for customization.
- More affordable deployment and operation costs.
- Quality features to create and manage APIs.

*WSO2 API Manager* has three main components named *API Gateway*, *API Publisher*, and *API Subscriber*, which are common to most API software management. *API Publisher* is aimed at the organization's internal audience, whose principal responsibilities are the creation, exposure, and management during the lifecycle of an API. *API Publisher* has a dashboard to monitor statistics related to the use of APIs. *API Subscriber* (also known as *API Store*) is the interface visible to the external public, which enables listing and searching of available APIs, as well as the capacity for users to subscribe to an API. *API Gateway* is a core component, operating as a single point of access to all of a provider's APIs. The role of *API Gateway* is strategic, as it centralizes responsibility for several non-functional aspects common to all APIs, such as security, access control, traffic control, and monetization. Consequently, API developers can focus solely on business domain-specific aspects.

After the WSO2 API Manager selection process, we followed these steps to structure the AgroAPI platform:

- Determination of specific requirements for the AgroAPI's business model.
- Ensuring defined requirements are fully met with *WSO2 API Manager* and determining where additional customization is required.
- Implementation of the necessary customizations.
- Definition of computing infrastructure such as servers, databases, and internet domains.
- Deployment of the *WSO2 API Manager* in a staging environment and enabling the required components.
- Testing of the functionalities of the WSO2 API Manager and the implemented customizations.
- Choice and implementation of Agritec API to be the first API available in the API Store.
- Deployment of the AgroAPI Platform in a production environment.

The end-to-end process from the conception of an API to its use by a consumer is shown in Fig. 1. Access to *API Publisher* is restricted to Embrapa's internal users. It provides tools for API design if necessary, but

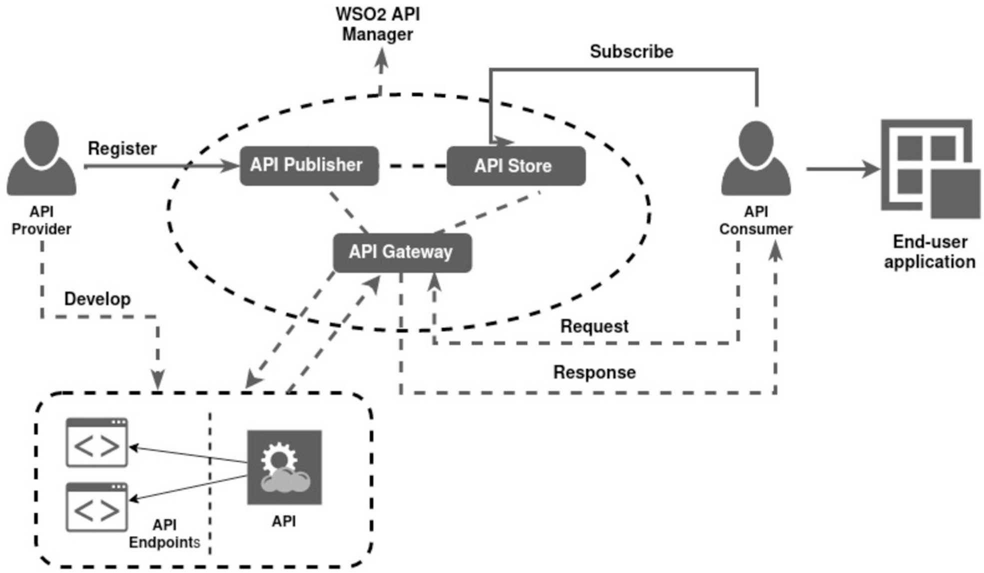


**Fig. 1.** Operation of the main components of AgroAPI, considering the role of API providers and consumers.

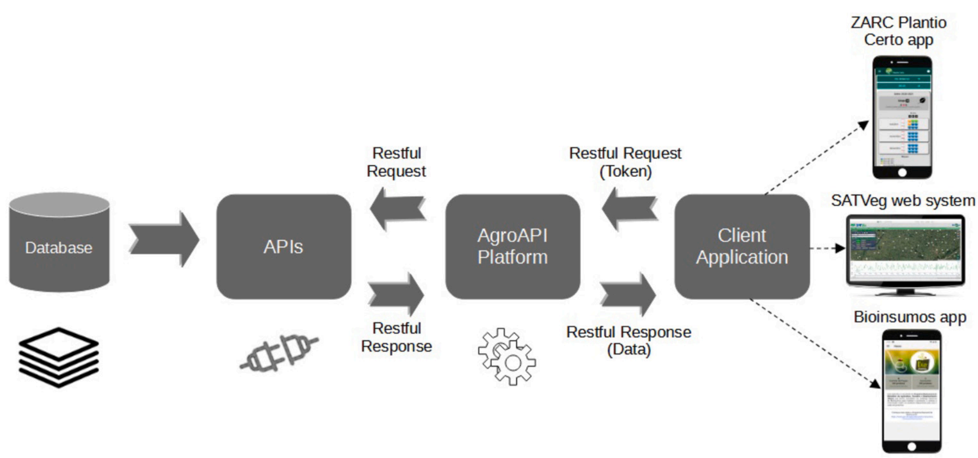


**Fig. 2.** API workflow for client application requests, including examples of digital applications developed using the AgroAPI APIs.

also allows the registration of fully-designed APIs. One of the mandatory pieces of information in API creation is the API root endpoint, which defines the base address (Uniform Resource Locator, URL) from which all API endpoints can be accessed. When registering an API, subscription tiers for the API must be defined. The platform's business managers can define both paid and free subscription tiers. The prices of paid subscriptions are usually defined by the number of API requests. When an API is created, it becomes visible in the *API Store*. From there, calls to the public address are managed by the platform. *API Gateway* is responsible for directing requests for the API URL to a destination at the API endpoint (usually internal to the organization). By acting as a proxy, *API Gateway* is also responsible for the API's security mechanism, such as token validation, blocking Structured Query Language (SQL) injection, and preventing Denial of Service (DOS) attacks. *API Gateway* also triggers the logging of all requests that are later available in the API Manager Analytics tools. These tools are used to monitor usage, traffic, and billing. Final consumers of an API must be registered users on the AgroAPI platform, which is open to the public. Once registered to the platform, a user can then subscribe to a specific API by choosing a subscription tier. If users select a paid subscription, an approval workflow is undertaken by platform administrators before access is granted. If users select a free subscription, access is instantaneous. Once the user subscribes to an API and configures an access key, they can make requests to the API and build end-user applications that utilize the API.

The *WSO2 API Manager* has other components used in the AgroAPI, such as *Key Manager*, *Traffic Manager*, and *API Manager Analytics*. These components are responsible for authentication, authorization, API traffic regulation, the application of security policies, providing billing information, and providing dashboards to monitor the consumer use of APIs. The diversity of data and services provided by the platform involves a wide range of concepts. In the future, we consider using an agricultural ontology or taxonomy to provide domain knowledge. Ngo et al. [35], for example, present a proposal for this.

## 3. Results

The AgroAPI platform facilitates API access to several types of information including crop production, remote sensing, soil classification, and climate. Most APIs have a similar workflow as it can e seen in Fig. 2. Data is provided from the API following a user input (parameters and a token). The API searches for data that is stored in internal databases, runs agricultural models, and returns results in JavaScript Object Notation (JSON) format to the client application.

Digital applications developed from APIs integrate a set of solutions for farmers. These solutions can be used directly by farmers or through companies that provide services across various segments of the agricultural and livestock chain. Farmers can authorize access to production and property data and then receive quantitative information that helps

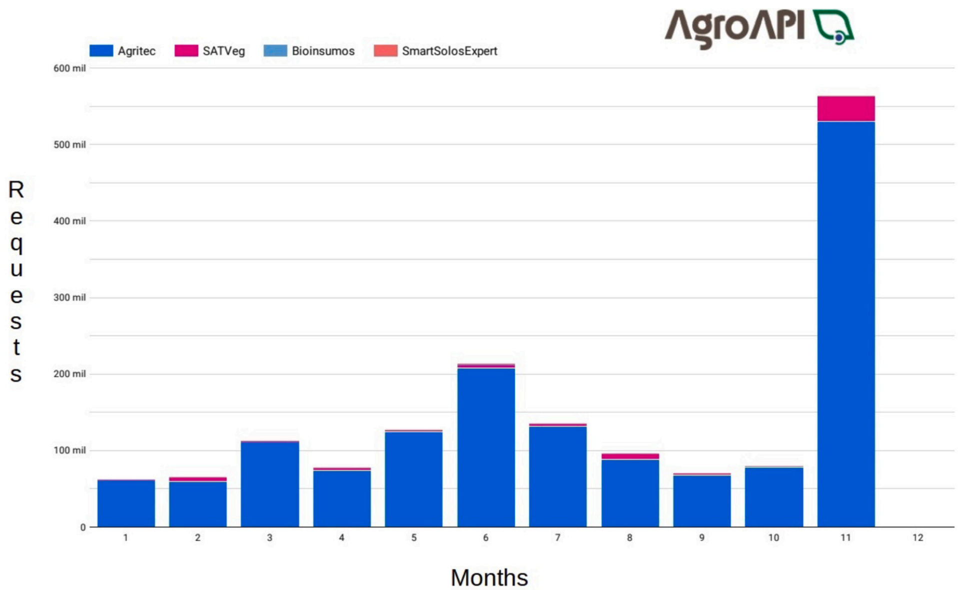


**Fig. 3.** Active users requests per month in 2022, except December (in processing), for each of the APIs within the AgroAPI platform.

them in decision-making, such as agricultural credit, productivity monitoring, and weather forecasts.

The AgroAPI platform is monitored daily and a dashboard is generated with several interactive graphs and tables. We show results of this monitoring in terms of active users per month in Fig. 3. The results indicate that Agritec was the most used API in 2022.

Public and private organizations carried out platform validation across 2022. Through a business model that allows platform maintenance, each company can use data to develop new services to meet client demands. These organizations realize that their digital solutions developed from APIs hosted on the AgroAPI platform are beneficial for information acquisition and data quality.

### 3.1. Agritec

Agritec, the most widely used API, provides information for planning, monitoring, and management of agricultural production [36]. This API allows a user to determine planting dates in Brazil according to the probability of production loss from adverse weather events. Data are provided for a 10-day period and show three levels of production loss risk (20%, 30%, and 40%). Results from Agritec indicate the “ideal” planting time according to the Agricultural Climate Risk Zoning (ZARC), a public policy in Brazil [37]. This API also provides the most suitable cultivars for a given location according to the National Register of Cultivars from the Ministry of Agriculture, Livestock, and Supply.

The Agritec API also allows productivity estimates for rice, beans, corn, soybean, and wheat crops. Estimates are calculated using empirical regionalized models, which are based on a municipal-scale database of cultivated areas and a national agro-meteorological monitoring system. Agritec also provides the water balance and weather conditions before and during crop planting, as a sub-product of the productivity forecast.

One example of an application with economic impact is the Zarc Plantio Certo app, which supports risk management and production planning. It is primarily used by producers and agents in the credit chain and agricultural insurance.

### 3.2. SATVeg

The System of Temporal Analysis of Vegetation (SATVeg) [38] is a web system that provides access to temporal profiles of the normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) across South America. The NDVI and EVI profiles provided by SATVeg are stored in an internal database [38] and are based on images collected from MODIS (Moderate Resolution Imaging Spectroradiometer), specifically the MOD13Q1 and MYD13Q1 products [39]. MODIS provides images every 16 days, with a spatial resolution of 250 m and geometric, radiometric, and atmospheric correction. Currently, these data comprise a time series of approximately 22 years.

The SATVeg API was created based on SATVeg time series visualization and analysis tools. The API facilitates searching for temporal NDVI and EVI profiles for a user-defined location (single geographic coordinate or polygon). This API also allows the raw time series to be edited based on interpolation after elimination of values corresponding to missing data or the presence of clouds (pre-filtering), and smoothing procedures using the FlatBottom [40], Wavelet–Coiflet4 [41], and Savitsky–Golay [42] methods. The API makes it possible to obtain a time series of vegetation indices so that the user is not obliged to use the SATVeg web system. Thus, new digital solutions can be developed using this data.

The main service provided by the SATVeg API is the runtime retrieval of important historical information about crops that have been harvested in the user’s region of interest, consolidated in an EVI or NDVI profile from a large dataset of satellite images. In addition to the crops harvested in each location since 2000, users can also identify crop cycles where higher and lower biomass production occurred, thus determining possible positive or negative impacts on yield.

Because of its diverse applications, the SATVeg API has a diverse set of users, such as agricultural companies that perform general monitoring of crop evolution, government agencies that monitor land use in different regions, and banks and financial companies that provide rural credit to producers. SATVeg is mainly used by clients that need to monitor and analyze the dynamics of land use and land cover in South America based on time series of EVI and NDVI vegetation indices.

### 3.3. SmartSolos expert

The SmartSolos Expert API provides a system for soil classification with the aim of improving the quality of soil data in Brazil. Soil profiles are classified to the fourth level of the Brazilian Soil Classification System (BSCS), which is the official taxonomic system for soil classification in Brazil [43]. The user inputs dozens of soil attributes and the system returns a soil classification according to the BSCS.

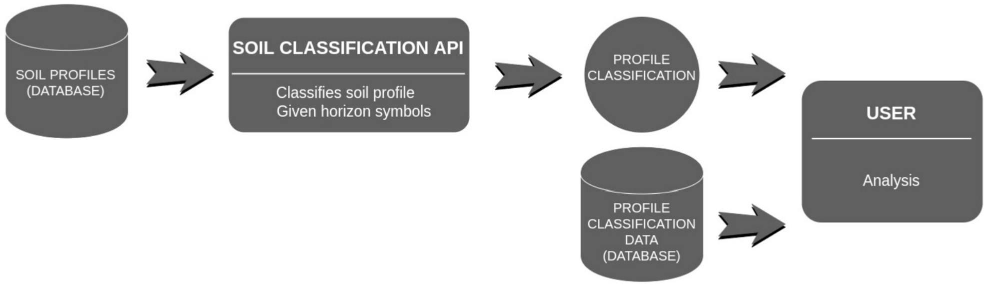


**Fig. 4.** Soil profile classification analysis.

Fig. 4 shows how a user can compare the soil classification obtained by the API to previously registered classifications made by domain experts. If these classifications differ, the SmartSolos Expert API helps to identify the data errors.

The SmartSolos Expert API simplifies identification of data inconsistencies and soil classification. It also guides necessary data changes, allowing for more reliable data curation. Vaz et al. [44] analyzed 94 soil profiles using this API. Approximately 55% of the profiles required data treatment, and almost 40% required changes in classification, which shows the importance of data curation.

The SmartSolos Expert API is available at no cost and aims to support the users, mainly scientists, in soil classification and data curation. Based on analysis of soil data with this API, suggestions for improvements to the BSCS were made to relevant parties. The SmartSolos Expert API also contributes to data organization. During API development, many issues were identified in available soil datasets, such as data redundancy, missing data fields for relevant soil information, and possible simplification of data processing and retrieval. Suggestions have been documented for representation of soil data that would facilitate interoperability and computational processing.

### 3.4. Bioinsumos

The Bioinsumos API provides information about inoculants and products for pest and weed control and is registered at the Ministry of Agriculture, Livestock and Supply [45]. These products are conceptualized as bio-inputs for organic agriculture and other productive systems.

API is organized into two parts: inoculants and biological products. In the inoculants group, those that have been tested and approved for various crops are listed, with an indication of accredited suppliers. The data obtained through this API include the identification number and date of product registration; Employer Identification Number, company name, and Federation Unit of the supplier; type of fertilizer, species, guarantee, physical nature, and crops applied to the product.

A detailed list of products for pest control is presented in the part of the API that handles biological products, with the following data: registration number, holder and trademark of the product, active ingredients, class, toxicological classification, and environmental classification of the product.

The Bioinsumos API helps suppliers and users of biological inputs to find safe products with known provenance; this is useful for the development of applications aimed at producers who seek more sustainability. One of the applications that considers environmental aspects is the Bioinsumos app, which allows rural producers to consult a catalog of 580 biological products available in Brazil to combat more than 100 pests and weeds. In addition, these biological products increase nutrient absorption, which favors the growth of vegetal species. This API is available to the public at no cost.

## 4. Discussion

The AgroAPI platform provides systems that can be embedded in third-party digital solutions. This study highlighted four APIs: Agritec, SATVeg, SmartSolos Expert, and Bioinsumos. All of these APIs are the results of research, development, and innovation projects conducted by Embrapa and its partners.

The AgroAPI platform and corresponding APIs contribute to reaching the SDGs, especially Goals 9 and 17. Goal 9 is related to industry, innovation, and infrastructure, and aims toward sustainable and resilient infrastructure to support economic development, encourage innovation, increase the number of research and development workers, and increase access to financial services and information and communications technology. Goal 17 is related to partnerships and aims to share knowledge and promote co-operation in science, technology, and innovation. All the APIs provided by AgroAPI aim to share knowledge and make technologies available to support sustainable agriculture.

Agritec API is based on ZARC, which supports national policies for agricultural risk according to climate zoning. Agritec API maps well to Goal 13, which considers climate action. Agritec supports decision-making and provides farmers with technical orientation. The solutions built with Agritec API have the potential to enhance productivity and agricultural profitability. Thus, this API is also related to Goals 8 and 12, which consider decent work, economic growth, and responsible consumption and production. Goal 8 contains targets for achieving higher productivity through technological upgrading and innovation, while Goal 12 seeks the adoption of sustainable practices.

The SATVeg API provides strategic information regarding vegetation characteristics in South America. This API supports national policies on land use and land cover, which are important for the conservation, restoration, and sustainable use and management of terrestrial ecosystems. Goal 15 targets life on land. The SATVeg API also helps in development planning and may be used to protect natural heritage, which is part of Goal 11 for sustainable cities and communities.

The SmartSolos Expert API provides a system for Brazilian soil classification, according to the current official taxonomic system. This helps to curate soil data and improve its quality. This API builds knowledge of soils, which is essential for the sustainable management of this natural resource. Goal 12 focuses on responsible consumption and production, whereby sustainable management of natural resources is targeted. Soil quality is also considered in Goal 2, which aims to eradicate food poverty.

The Bioinsumos API provides useful information to producers for pest and weed control. It also contributes to Goal 12 because it aims to minimize adverse impacts on human health and the environment, whilst also promoting sustainable practices. Public access to information is also addressed by Goal 16, which is related to promotion of just, peaceful, and inclusive societies.

Other SDG targets are achieved by the solutions proposed in this study, but we have highlighted here some of them. It is clear that the AgroAPI platform and its APIs contribute to the achievement of the SDGs.

## 5. Conclusion

In this article, we describe the AgroAPI and the four APIs provided within the platform. The applications have benefited farmers, scientists, technicians from co-operatives, technical assistants, and rural extension agencies, as well as the banking and insurance sectors.

The AgroAPI platform facilitates new business opportunities for its users. The API platform promotes institutional innovation and has several benefits such as:

- Promotion of information system integration and sharing of data and services;
- Improvement of the interface with mobile devices;
- Increases in capacity to obtain and disseminate agricultural data and information;
- Stimulation of partnerships with other companies; and
- Facilitation for the company and its partners to achieve better results.

APIs can drive innovation in agricultural ecosystems by integrating new actors and promoting the co-development of novel applications in digital agriculture. The management of APIs is improved with an API platform such as AgroAPI. We have shown that this initiative contributed to the achievement of the SDGs.


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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The APIs analyzed for this study can be found on the [AgroAPI Platform] [www.embrapa.br/agroapi].


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