Precision Agriculture

Subjects: Agriculture, Dairy & Animal Science
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According to a recent definition of Precision Agriculture (PA), developed by the International Society of Precision Agriculture, the term refers to a management strategy, which uses acquisition, processing, analysis, and combination with other information of temporal, spatial, and other data in order to facilitate decision-making based on the estimated variability.

precision agriculture internet of things big data data analytics blockchain
artificial intelligence cyber-physical systems

1. Introduction

Modern agricultural techniques have been strongly criticized about their negative environmental impacts. Examples [1] of such impacts include:

- Loss of biodiversity among plants and animals caused by monocultures;
- Soil and groundwater pollution due to the use of chemical pesticides and fertilizers;
- Soil eroding at a much faster pace than it can be replenished;
- Fish die-offs;
- Use of water and fossil fuels at unsustainable rates.

In the next few decades, the global population is expected to grow substantially, followed by a subsequent increase in global food demand [2]. The prices of fertilizers and pesticides are also expected to rise. Precision agriculture (PA) (also known as site-specific management, precision farming, prescription farming, etc.) [3] can have an important contribution in addressing the aforementioned challenges. It can also serve as part of an environmentally sustainable agricultural system while still maintaining profitability [4].

2. Information and Communication Technology Solutions for Precision Agriculture

2.1. Data Collection and IoT

Various data collection and IoT technologies (e.g., wireless sensor networks (WSN), geographic information systems (GIS), satellite communications) were adopted within several solutions analyzed for the purposes of this paper. The term GIS refers to computer systems for storing, analyzing, displaying, and managing geospatial data [5].

2.2. Data Analysis and Artificial Intelligence

Various data analysis and AI tools and technologies supporting PA were reviewed for the purposes of this paper, encompassing big data analytics, computer vision, data fusion/reconstruction, recommender systems, evolutionary algorithms, fuzzy logic, granulation/interpolation techniques, machine learning, heuristic/decomposition/denoising/pattern-matching algorithms, semantic processing, predictive models, simulation/visualization tools, and others.

2.3. Data Storage and Distribution

Sharing valuable knowledge and experiences among different actors in agriculture as well as efficient and safe storage options are of vital importance for PA. In this regard, solutions around sharing platforms, cloud storage, blockchain, and other relevant technologies were analyzed for this literature review.

2.4. Multi-Purpose Platforms

Several reviewed PA solutions, encompassing digital platforms, mobile applications, and CPSs, support multiple data lifecycle stages.

3. Summary and Conclusions

A wide variety of ICT solutions for PA exist [6], supporting one or multiple data lifecycle stages. These solutions have been found to underpin PA applications that in turn contribute to substantial environmental and economic benefits (e.g., higher quality crops with higher yield, prevention of pesticides and fertilizers overuse, optimized used of water and other resources, prevention of soil degradation).

Among the different data lifecycle stages, data analysis and AI stage encompassed the largest number of different technological categories. Being a focus point of many different solutions, computer vision was the most popular technological subcategory of data analysis and AI lifecycle stages. Computer vision tools and technologies were mainly used to facilitate classification and detection of crops, to extract useful knowledge for the condition and quality of the crops, as well as to enable effective CPS-based operations. Technologies revolving around decision-support and predictive models were also very popular among the data analysis and the AI solutions. These technologies offer valuable insights into actions farmers should take to increase productivity and efficiency as well as to prevent losses or destruction of crops due to diseases or natural phenomena.

Despite the fact that data collection and IoT stages of the data lifecycle model encompassed only four technological subcategories (WSN was the most popular subcategory), it was the focus point of several solutions. Sensors of various kinds (mostly temperature, moisture, CO_2, and light sensors) were of vital importance for monitoring crops condition and served as inputs to subsequent data analytics/integration/storage/sharing operations. Multispectral satellite imagery was used in many computer vision techniques, and satellite navigation was extensively used for the navigation of the majority of CPSs.

Regarding the papers focusing on storage and distribution lifecycle stages, sharing platforms and cloud storage platforms were very popular, facilitating secure storage and distribution of agricultural data as well as of valuable experiences and knowledge. Blockchain and smart contracts were found to have a great potential in PA, providing immutable and secure data storage and sharing.

Among solutions supporting multiple data lifecycle stages, CPSs were by far the most frequently occurring in the examined bibliography. The use of CPSs in the context of PA can radically change the form of modern farming activities. The reviewed PA solutions enabled several tasks (e.g., seeding, transplanting, weeding, tilling) to be conducted autonomously with minor or no human interaction. Other solutions revolved around dangerous (e.g., due to exposing the farmer to harmful chemicals) and time-consuming activities, which were carried out by CPSs, thus decreasing labor costs and minimizing the risks of health problems.

The proposed categorization method can be used for future research on PA from a single (or multiple) data lifecycle stage(s) perspective(s). Future research may also perform a cost-benefit analysis regarding the use of certain PA-related collection/analysis/storage/distribution technologies described in this review. The developed data lifecycle model can be used in its current form for research works around PA or other technologies encompassing multiple data lifecycle stages. It may also be adapted to meet the specific needs of business or academic members.

In conclusion, ICT solutions act as pillars and facilitators for data management in PA. Diverse ICT tools and technologies support different lifecycle stages in a variety of ways. From the analyzed bibliography, machine vision, CPSs, WSNs, decision-support systems, and satellite navigation were the technologies with the most vital role in PA and data analysis, and AI was the data lifecycle stage receiving the widest support from ICT solutions.

References

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