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REVIEW

Geomatic tools used in the management of agricultural activities: a systematic review

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Abstract
Managing agricultural activity encompasses technology, geographic information, spatial data and geomatic tools as support techniques. In this framework, agricultural mapping is an essential geomatic application due to its importance in managing food systems. This research aims to analyze the state of knowledge of geomatics tools and their applications in agriculture through a systematic review of scientific documents and methodological approaches, highlighting the use of geomatics in agricultural mapping to evaluate trends in agriculture management. The study methodology consists of a scientific base of publications on geomatics and its applications in sustainable agriculture, with a quantitative analysis of production and its approaches. Subsequently, PRISMA establishes a systematic review in search of the subject's methods, applications and trends. The results show that of the total data analyzed, 60% corresponds to general agricultural mapping for crop/water/soil mapping using satellite images. Twenty percent for land use and coverage, considering the georeferencing that contributes to agricultural territorial planning. Nine percent consider geomatic key for agricultural cadastre (plot management). In addition, 6% corresponds to precision agriculture and 5% to watershed management. The most predominant geomatics tools are: Geographic Information System (GIS), Global Positioning System (GPS), unmanned aerial vehicle (UAV) and remote sensing (RS). Also, among the most used geomatic techniques in agricultural cartography, photogrammetry in crop phenology and multispectral analysis in the optimisation and monitoring of agricultural production stand out. Studies show that the geomatic application promotes sustainability practices such as crop rotation, seeds dispersed and germinated by animals, agricultural irrigation through rivers/basins/streams, family gardens and generation of employment sources. The geomatics use is of great utility/potential for the acquisition and generation of geospatial data accurately, with time and cost savings that contribute to the decision-making of city councils, public cadastral administrations, enterprises, educational institutions and agricultural foundations.

Keywords Agricultural mapping · Geomatics · Cadastre · Agricultural land · Sustainability

Abbreviations

AC	Agricultural Cadastre
ANOVA	Analysis of Variance

Extended author information available on the last page of the article

AM	Agricultural Mapping
ALULC	Agricultural Land Use and Cover
DEM	Digital Elevation Model
FAO	Food and Agriculture Organization of the United Nations
GEE	Google Earth Engine
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning Systems
IoT	Internet of Things
LAS	Land Administration System
LiDAR	Light Detection and Ranging
LPIS	Land Parcel Information System
LULC	Land use/Land Cover
MODIS	Medium-Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
SDG	Sustainable Development Goals
PCA	Principal Component Analysis
PA	Precision Agricultural
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PS	Photogrammetric survey
SS	Satellite survey
TS	Terrestrial survey
RPAS	Remotely Piloted Aircraft Systems
RS	Remote Sensing
RTK	Real-Time Kinematic
SISI	Italian Soil Information System
SNAP	Sentinel Application Platform
SRIT	System of Rectification of Images of Remote Detection
SRTM	Shuttle Radar Topography Mission
SVM	Support Vector Machine
UAV	Unmanned Aerial Vehicle
WGS	World Geodetic System
WMS	Web Map Service
WM	Watershed Management

1 Introduction

Agriculture is important to the planet's food security (Calicioglu et al., 2019; Vasylieva, 2019). It represents a strategic role in the availability and contribution of food needs in the face of a growing global population demand (i.e., 9.73 billion inhabitants by 2050) (FAO, 2017; Said Mohamed et al., 2021). It is necessary to optimise spatial and geographical technologies to address the problems of food security, production and sustainable environmental response to the effects of global change. In this sense, it is worth answering: How is geomatics supporting agricultural management activities at the dawn of the twenty-first century? Growing demographics and climate change are challenges that affect agricultural production, reflected in a possible global food crisis (Xia et al., 2022). What sustainable management of agriculture requires (Song et al., 2009). In other words, substantial improvements are required in the agricultural system with information on the dynamics of soil properties and activities (e.g., treatments that maximise crop health and productivity) (Morrison-Whittle et al., 2017), water (e.g., irrigation systems) (Zhuo & Hoekstra, 2017), crop (e.g., resource optimisation) (Zuo et al., 2021) and farmer (e.g., monitoring of agricultural processes and practices). These activities must be linked to fulfilling the Sustainable Development Goals (SDG-2, 6, 12, 13 and 15) (Naciones Unidas, 2023).

Furthermore, sustainable agricultural management involves obtaining information on urban–rural areas and spatial distribution of land use and land cover (LULC) (Ni et al., 2021). In this context, using geomatic tools is important for urban–rural planning and territorial ordering, as they help in decision-making related to land tenure management, agricultural investment and tax collection (Shirzad et al., 2022). The environmental evaluation mitigates losses due to pests and conserves biodiversity (El Hoummaidi et al., 2021). Food security allows access and spatial detection of productive lands (Viana et al., 2022). Moreover, in agricultural production, geomatics improves crop management (Karthikeyan et al., 2020).

Geomatics is a multidisciplinary approach that manages, analyses and processes georeferenced spatial and land surface data (Ajmar et al., 2015; Barrile et al., 2018; Gomarasca, 2009; Kamel Boulos et al., 2001). Geomatics tools are important in geoscience, geographic information, spatial distribution and remote sensing technology. With prospective applications in monitoring real-world scenarios (Jurado et al., 2022). Furthermore, its use in multidisciplinary research provides highly precise graphic, multi-temporal, geometric data that generates thematic maps, improves information and contributes to decision-making. In applications of management practices agricultural, geomatics has evolved, as shown in the timeline of Fig. 1. From the use of base cartography for crop identification and control in the transition period of agricultural expansion (Anderson, 1990) to the use of Geographic

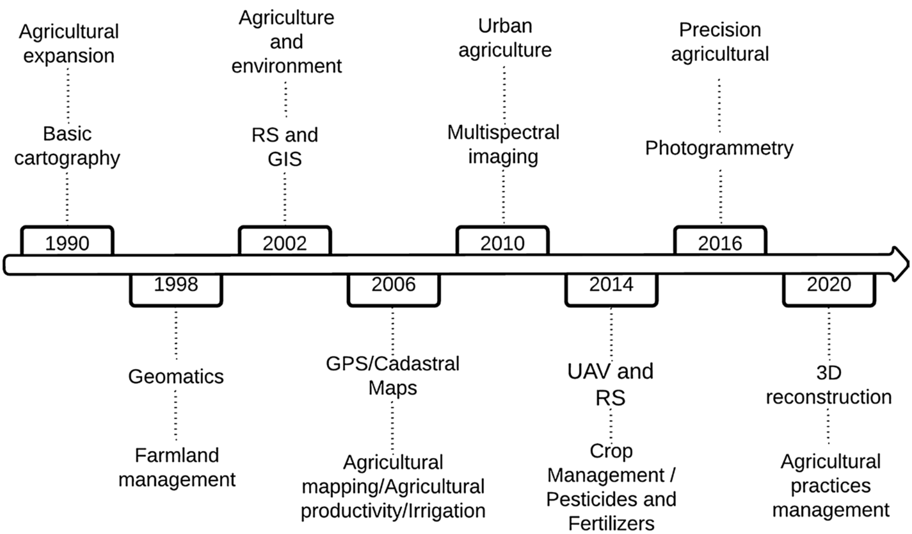

Fig. 1 Timeline of the relationship between geomatics and agricultural management

Information System (GIS) tools to analyze and compare the dynamic conditions of cropping systems and agricultural land management (Aguilar Rivera et al., 2013; Reichert et al., 1998; Stubert et al., 2020; Suresh & Sivasankar, 2014). Remote sensing (RS) complements the interrelation between environmental conservation and agricultural practices (Khawlie et al., 2002; Zini et al., 2002). Subsequently, other spatial tools appeared, such as satellite data and Global Positioning System (GPS) used for mapping, agricultural productivity and irrigation efficiency (Banik et al., 2006; Konecny, 2002; Mena et al., 2007; Rao, 2004). In the last decade, geomatic tools and techniques, such as photogrammetry (D'Urso & Marino, 2016), unmanned aerial vehicles (UAVs) (Costa et al., 2012), multispectral images, orthophotos and 3D reconstruction (Jurado et al., 2022; Tang et al., 2020), have been used in agricultural management practices contributing to precision agriculture and geosystem mapping (Alves et al., 2011; Ballesteros et al., 2014; Bannari et al., 2021; Jurado et al., 2018).

A strategy that improves agricultural management in crop management is precision agriculture (PA) (Far & Rezaei-Moghaddam, 2018; Modica et al., 2020). PA is a management strategy based on information technology that uses advanced data analysis techniques for decision-making, improves crop productivity and reduces environmental impacts (Sishodia et al., 2020). This strategy requires spatial information on crops and soils to adapt agricultural techniques to the conditions of the territory (Bannari et al., 2021). It uses innovative sensors and methods such as photogrammetry, high-resolution RS, UAVs and multispectral sensors (Herrero-Huerta et al., 2014; Jurado et al., 2018). These techniques base their importance on the management of spatial–temporal changes in agricultural processes reflected in the mapping (e.g., thematic maps) (Belcore et al., 2021), such as digitalisation of farms and cartography of pest infestation (Del-Campo-Sánchez et al., 2019). In addition, mapping of small agricultural areas (Sedina, 2017), identification of abandoned agricultural lands (Hearn, 2021; Lasanta et al., 2015) and suitable soils for various crops (Dadhich et al., 2017) to improve the yield profitability of agricultural production, and preserve the environment (Raeva et al., 2018). Agricultural mapping is oriented to crops' cartography based on classification methods. These methods consider the level of data processing, multi-temporal, vegetation water content, types, distribution, plots and numbers of crops, which originates crop maps with very good classification accuracy (Gomarasca et al., 2019).

In addition, agricultural mapping highlights its importance in the planning and executing of agricultural systems based on plots with geographically referenced information on unique and well-defined territorial units, such as the agricultural cadastre of urban and rural areas (Tomić & Roić, 2018). An agricultural cadastre is a basic tool for agricultural management (Hanus et al., 2018). To generate an agricultural cadastre, the information of the owner farmer, surface area, crop type and parcels is relevant, providing cadastral maps with crop delimitation functions and cadastral limits (Blanco et al., 2019; Cay & Iscan, 2011). In addition, it presents data such as records and property rights, land use, cultivation, restrictions and responsibilities of farmers, which vary depending on the administration and legal system of countries (Yìldiz et al., 2018). Technological advances (e.g., GPS, UAV and RS) and the availability of geographic information tools (e.g., GIS) provide opportunities for various cadastral applications such as monitoring agriculture in maize, rye and grassland through remotely piloted aircraft system (RPAS). Furthermore, obtaining thematic cadastral maps of the normalized difference vegetation index (NDVI), thermal and multispectral show the productivity of nutrients in the fields (Sedina, 2017). Another cadastral application is the territorial ordering of agricultural space affected by rapid urbanisation through GIS, textural characterisation and image segmentation for cadastral fiscal purposes of taxes applicable to any region (Ruiz-Lendínez, 2020).

Alternatively, the functionality of GIS and its integration with other tools (e.g., RS and GPS), methods, models and technological techniques analyze the space–time of LULC by agricultural activity (AL-Taani et al., 2021; Pollino et al., 2021) through UAV images (Ballesteros et al., 2014) and produces agricultural cadastral maps for decision-making related to land management (AL-Hameedawi et al., 2017; Herrera-Franco et al., 2022). In addition, it evaluates the impact of farming constructions in agroforestry landscapes (Cillis et al., 2020) and manages resources in soils affected by salinity, degradation and shifting agriculture (Venkataratnam et al., 2002). It reduces the risk of groundwater contamination by controlling and managing agricultural anthropogenic contamination in watersheds (Bera et al., 2021) and identifies and monitors agricultural protection sites to sustain the territory (Schaefer & Thinh, 2019).

Geomatic tool applications have been used in different agricultural activities. For example, in Andhra Pradesh (India), using RS and GIS techniques, they mapped coastal agricultural areas affected by sea level rise to propose mitigation plans associated with the effects of climate change (Nageswara Rao et al., 2011). Rice cultivation systems were also evaluated based on spatiotemporal maps of fertilisation patterns, yield and spatial interpolation. The Moderate-Resolution Imaging Spectroradiometer (MODIS) is an important indicator for determining the status of these crops (Pandey et al., 2015).

In Port Said Governorate (Egypt), they mapped the quality and characteristics of the soil, using a GIS and RS platform to increase the precision of physiographic maps, achieving the potential suitability of crops (AbdelRahman & Arafat, 2020). In Karbala Province (Iraq), the harvest quality of wheat crops was evaluated based on remote sensing indicators reflected in NDVI maps and the detection of changes in crops that represent agricultural areas and their quality (Sbahi et al., 2021). Furthermore, in Boscoreale (Italy), they provided a botanical atlas that determines the morphological and oenological characteristics of vineyards, using approximation photogrammetry and very high-resolution cameras to analyze the variations in size and shape of the grape (D'Urso & Marino, 2016). Another study examined agave crops in Mexico through UAV and photogrammetric processing, differentiating agave plants from weeds and other elements. These techniques and geomatic tools allowed control and monitoring of the crop (Calvario et al., 2017). In the humor depression (Romania), they determined the quantity of alfalfa hay crops harvested in an agricultural area by acquiring images by UAV to increase the yield of these agricultural exploitations, reducing work times and eliminating weather restrictions (Copăcean et al., 2020).

Geomatic studies merge geomatic tools applied to agricultural processes with space–time analysis for decision-making in agricultural management. Additionally, these case studies show the feasibility of using geomatics tools to map agricultural areas, evaluate cropping systems, identify productive soils and contribute to sustainable food production. This study complements research gaps in applying geomatic tools in agricultural mapping, agricultural LULC, agricultural cadastre, precision agriculture and watershed management. This systematic study raises the research question: (1) How do geomatics tools strengthen agricultural management?, (2) What geomatics tools contribute to agricultural mapping and agricultural management?

The objective of this research is to analyze the state of knowledge of geomatics tools and their applications in agriculture through a systematic review of scientific documents published in Scopus and Web of Science (WoS) databases and methodological approaches, highlighting the use of geomatics in agricultural cartography for the evaluation of trends in agricultural management. The rest of the study consists of Sect. 2, which shows the methodological approach composed of three phases that denote the scientific basis of the publications, analysis of scientific production, research topics, trends and systematic review protocol. Section 3 presents the evolution of the themes, relationship-contribution of geomatics in the agricultural cadastre/cartography and the most used geomatic tools in various agricultural management activities. Section 4 discusses the application of geomatics tools in agricultural management issues. Finally, Sect. 5 presents the conclusions and future research.

2 Materials and methods

This analysis focuses on bibliometric applications and systematic review regarding the scientific publications of the Scopus and WoS databases, generated in scientific history, to detect the main characteristics of geomatic applications for sustainable agriculture. Figure 2 presents the phases of the study: (i) scientific base of publications regarding geomatics and agricultural management, (ii) analysis of scientific production trends and (iii) systematic review protocol.

2.1 Scientific base of publications related to geomatics and agricultural management

In agriculture, geomatics has been used for various processes such as the geographic location and distribution of crops (Escandón-Panchana et al., 2024; Kussul et al., 2015), the improvement of agricultural practices that contribute to food security of the sectors and decision-making in agricultural management (Doumit, 2017; Uca Avci & Sunar, 2015). In this context and considering the study's research question, this phase carried out a bibliographic search on the Scopus and WoS platforms, indexed, multidisciplinary

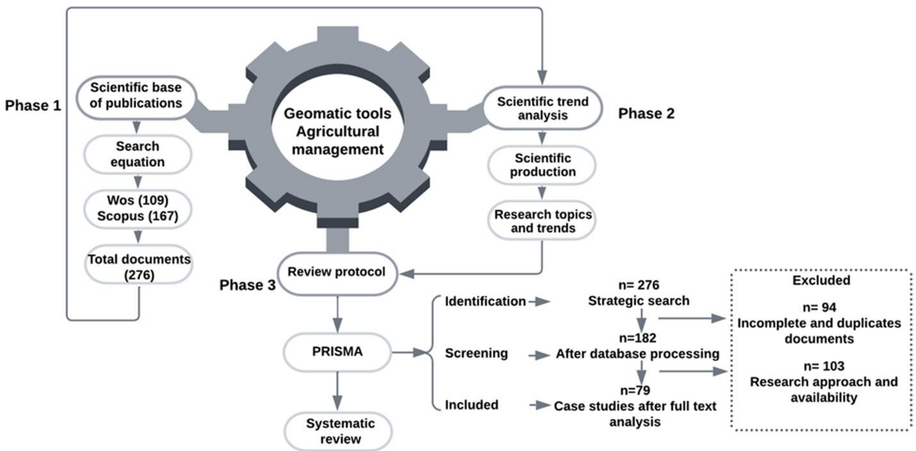

Fig. 2 Phase diagram of methodology

scientific databases, more complete with publication metadata and impact indicators (Mongeon & Paul-Hus, 2016; Pranckutė, 2021). The search considered the terms “geomatic” and “agriculture” based on the equation: TITLE-ABS-KEY [geomatic* AND (agricultural OR agriculture)]. This search was conducted in December 2022 and obtained 276 records, Scopus (167) and WoS (109).

According to the study focus, the Mendeley software exported the references to systematise the information and continue with the inclusion and exclusion criteria (Bornmann & Haunschild, 2015; El Chami et al., 2020).

3 Analysis of scientific production trends

This phase consists of a bibliometric analysis, which allows the exploration of the scientific contribution, intellectual structure of the area of specific knowledge and the trends of this field of research (Donthu et al., 2021; Ellegaard & Wallin, 2015). This section considered three steps: (i) fusion of the databases (Scopus and WoS) from the search through the statistical program RStudio, version R-4.1.2 (Guleria & Kaur, 2021; Martens et al., 2017). This program allows statistical meta-analysis to be carried out through R packages or codes (Forliano et al., 2021). Databases selected for their scientific standards are merged using the “mergeDbSources” function due to metric support (Dzogbewu et al., 2023). (ii) Cleaning of the database through filter tools and conditional formatting using the Microsoft Excel Office utility (Tsay & Yang, 2005; Van Nunen et al., 2018). This program finds and eliminates duplicate records, obtaining relatively reasonable and accurate data (Zhong & Lin, 2022). In addition, polynomial regression was used to evaluate the annual production of publications. (iii) Analysis of the conceptual structure through the Bibliometrix tool allowed the analysis of research trends in the field of study and the evolution of its themes (Derviş, 2020; Forliano et al., 2021). Bibliometrix is a tool that helps import bibliographic data from databases for quantitative research analysis (Olaleye et al., 2023). Build data matrices and scientific maps for the analysis of themes over time.

4 Systematic review protocol

This phase adapted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodologies and bibliometric analysis to answer the research question of this study (Herrera-Franco et al., 2023; Page et al., 2021; Tricco et al., 2018). PRISMA is a methodological strategy that selects studies for systematic reviews and meta-analysis and consists of various stages, such as developing eligibility criteria and obtaining data synthesis (Girma & Kuma, 2022; Ortiz-Martínez et al., 2019). The systematic review highlights three sections:

1 Identification, obtained 276 documents from the merger of the Scopus and WoS databases. Subsequently, cleaning the database eliminated eight incomplete records and 86 duplicate documents (i.e., 94 documents deleted), obtaining 182 papers in this phase.
2 Screening, this phase analyzed the full text of 182 documents. The inclusion criterion was the use of geomatic tools in agricultural management. Furthermore, the exclusion

criteria availability of records and research approach discarded 10 and 93 papers, respectively (i.e., 103 documents excluded). A total of 79 articles remained for the synthesis. The discarded documents were related to other research topics, such as hydrology, coastal flooding risks and drainage projects.

3 This phase included 79 documents reviewed that were related to the subject of study, such as Agricultural Mapping (AM), Agricultural LULC (ALULC), Agricultural Precision (PA), Agricultural Cadastre (AC) and Watershed Management (WM), all associated with the application of geomatic tools. The documents were synthesised considering their important sections through the variables: year, author, objective, study variables, design method, geomatic tools, statistical method, geomatic relationship and agricultural activity, sustainability and results. A narrative synthesis approach was applied to explain the results (Wood et al., 2016).

5 Results

5.1 Analysis of scientific production trends

The research associated with applying geomatics in agricultural management has increased in the last two decades. Figure 3 shows the number of publications per year, highlighting the increase in documents in the last five years of scientific production. These events could be related to the interest in the acquisition and management of spatial data by the agricultural sector, which proves to be a potential research topic. In addition, the total number of citations reflects a variable increase in the last decade. It highlights a significant increase in 2014 due to the latest advances in image processing applied to monitoring and mapping in various contexts. For example, In the United States and European Union countries such as France, UAV image processing using digital photogrammetry and automated dense image matching techniques have been used for orthoimage production, map generation, and 3D building modeling (Nex & Remondino, 2014). In Italy, multi-temporal image processing was applied through a dense point cloud, mesh for creating orthomosaics and digital elevation model (DEM) for mapping and monitoring in precision agriculture (Lambertini et al., 2022). In addition, there are other recent advances in image processing using artificial

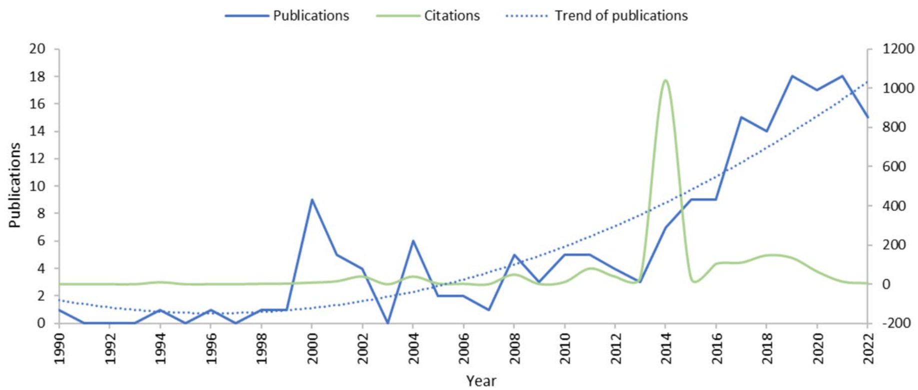

Fig. 3 Scientific production, citations and trend of publications related to geomatics and agricultural management, period 1990–2022

intelligence techniques such as machine and deep learning, support vector machine (SVM) and computer vision for the diagnosis of breast cancer (Sadoughi et al., 2018), improvements in the industry related to sustainable food production (Kakani et al., 2020) and detection of defects on railway tracks (Wei et al., 2019).

5.1.1 Evolution of themes

This analysis uses two-time intervals: 1990–2017 and 2018–2022. These intervals select through trial and error. Figure 4a shows the change in the terminology of some topics in time intervals: geomatics incorporates GIS, land use incorporates agriculture and precision agriculture includes photogrammetry. In the first period, a large part of the research covers the management of activities related to agriculture, such as soil identification, use and cover of agricultural land, seasonality and monitoring of crops and land consolidation through geomatics as a tool for application, generating thematic maps and cartography of farmland. The second period presents the intensification of geomatic studies related to agricultural management practices such as suitability of farmland; precision agriculture based on photogrammetry, orthophotos and multispectral images; agricultural land use and anthropic cover.

Also, Fig. 4b shows that the motor theme has a high degree of density and centrality with articles associated with: "geomatic", which includes GIS and remote sensing tools in evapotranspiration, groundwater and soil quality studies, "precision agriculture" with geomatic techniques and tools such as UAV, computer vision, DEM and photogrammetry, "agriculture" and its applications in LULC, monitoring, planning and classification of agricultural soils; and "LiDAR" which includes subthemes of forestry studies, while the emerging issues focus on "pollution", "land consolidation" and "rural development". However, the niche theme presents "environment" as a topic of high development and its importance in studies related to hydrological and environmental models. Finally, the basic issues of high relevance and low density are the themes based on "NDVI", which determine changes in forest cover, water bodies and agricultural land.

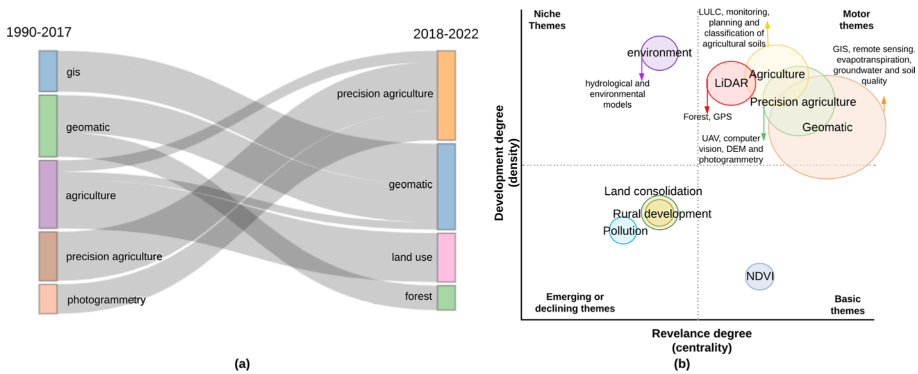

Fig. 4 Strategic map. **a** Evolution of themes 1990–2022. **b** Diagram of density and centrality of topics. *LULC* land use and land cover, *LiDAR* light detection and ranging, *GPS* global positioning system, *GIS* geographic information system, UAV unmanned aerial vehicle, *DEM* digital elevation model, *NDVI* normalized difference vegetation index

5.2 Contribution of geomatic tools in managing the urban and rural agricultural cadastre

Geomatic tools constitute technologies for mapping and monitoring agriculture without having contact with crops. Photogrammetric and cartographic techniques allow the integration and manipulation of spatial, flexible and feasible databases for the planning of agricultural cadastre projects. Using satellite images contributes to the design of thematic maps, urban land use and cadastral survey (urban and rural). The GIS application contributes to managing spatial data and property registration processes, property boundaries, cadastral parcels and land use rights on farmland. RS contributes to the identification, mapping, monitoring and spatiotemporal changes in the registry and property rights.

In urban agriculture cadastre planning, geomatics integrated road infrastructure, water management, drainage, land reorganisation and improvement of the farm landscape. In addition, it improves working conditions in rural areas, rearrangement of rural settlements, organisation of stationary establishments (e.g., barn, hayloft, sandpit and stone yard) and management of water resources.

Figure 5 presents the important variables (1–11) that intervene in the urban and rural agricultural cadastre, with the most used geomatic tools (a–j) and their relevant processes. This information contributes to the registration of agricultural properties, land tenure and tax collection that depend on the regulations of each country. In this context, geomatics identifies and analyses the geosystems involved in the agricultural cadastre to contribute to food production through arable land, increase livelihoods for rural areas through employment and efficient management strategies and sustainable farmland for food security.

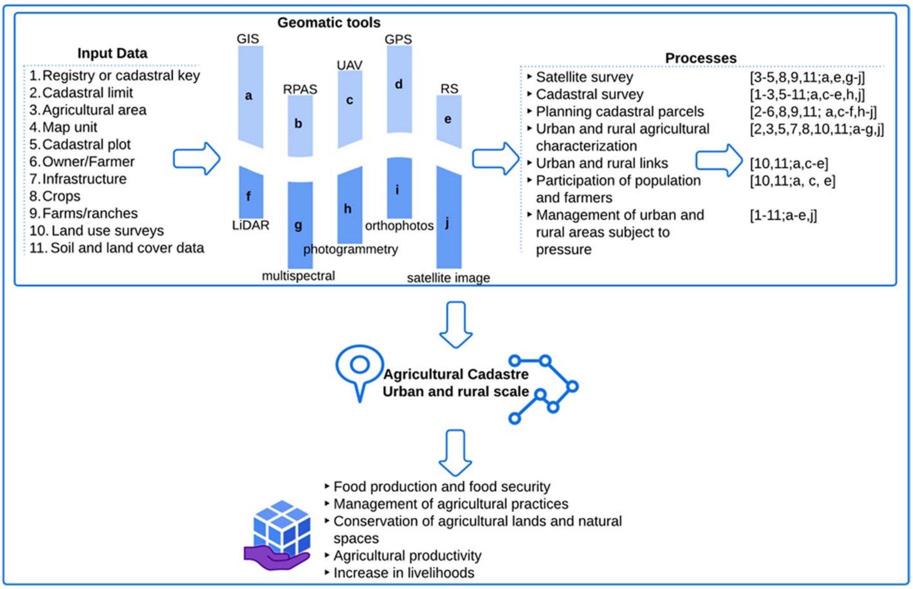

Fig. 5 Contribution of geomatics in the urban and rural agricultural cadastre. GIS geographic information system, *RPAS* remotely piloted aircraft system, *UAV* unmanned aerial vehicle, *GPS* global positioning system, *RS* remote sensing, *LiDAR* light detection and ranging

According to the studies analyzed in this review, there are three common types of cadastral survey: photogrammetric survey (PS) using remotely piloted aircraft systems, satellite survey (SS) and terrestrial survey (TS). Forty-five percent of the studies identify that PS through the use of UAV achieves a high potential in detecting urban and rural agricultural areas with positive impacts on spatial planning, territorial planning, tax collection, registration of agricultural properties, food security and agricultural productivity. Thirty-five percent determine that SS achieves acceptable precision through satellite images, with positive aspects in agri-environmental monitoring, classification and conservation of agricultural lands. In addition, 20% of the studies use TS for traditional agricultural practices. Most studies agree that the risk of PS and TS is related to limited access to agricultural land due to natural or anthropogenic activity. Furthermore, the risks of SS could be the resolution and availability of images.

In addition, geomatic tools have been applied in various urban and rural agricultural cadastre studies. For example, in Türkiye, Yìldiz et al. (2018) recorded agricultural land based on the land management system (LAS) by generating spatial data with GPS and photogrammetry. For the acquisition of satellite images or orthophotographic maps, topography used RS and GIS. This study classified agricultural land, property records of agricultural areas for rural agricultural cadastres, and implementation of agricultural policies. Also, in Poland, Puniach et al. (2018) applied UAVs to update cadastral records of areas affected by agricultural landslides. UAV allowed for obtaining elevation models and orthophoto maps. Taszakowski et al. (2018) transformed the old Austrian urban and rural cadastre into a digital cadastral map through legal-geodetic processes. GIS allowed the vectorisation and calibration of urban (buildings) and rural areas (agricultural plots).

5.3 Geomatics–agriculture relationship

The nexus between geomatics and agriculture improves agricultural production yield, quality and estimation through technologies such as UAV images of different agricultural activities. In addition, this relationship highlights the importance of agricultural monitoring in

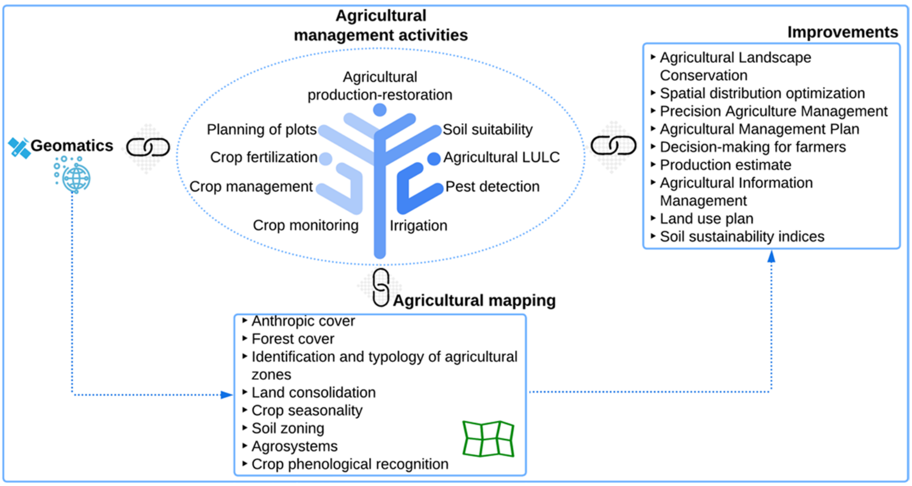

Fig. 6 Relationship between geomatics and agriculture

developing smart agricultural systems, which implies pest management, fertilisation and irrigation implementation. Also, this duality provides a digital mapping of agricultural LULC, highlighting dominant crops and recession agriculture in various sectors. Geomatic-based agricultural mapping obtains accurate data on urban and rural agricultural areas using crop types and parcel concentration statistics. Figure 6 presents a scheme that combines agricultural management activities (e.g., irrigation, planning of plots and soil suitability) with agricultural mapping issues (e.g., crop seasonality, land consolidation and soil zoning), which allows improvements in management and agricultural management plans that contribute to the management of decision makers.

5.4 Descriptive analysis of the systematic review

The PRISMA method allowed the analysis of 79 documents related to case studies focused on geomatic tools' use in agricultural management. Figure 7 summarises the distribution of these studies into five themes with their respective number of documents (*n*) and predominant variables related to the agricultural activities of the included studies. Agricultural mapping represents the topic with the largest number of case studies and associated variables, such as identifying farming areas and crops' seasonality and vegetation.

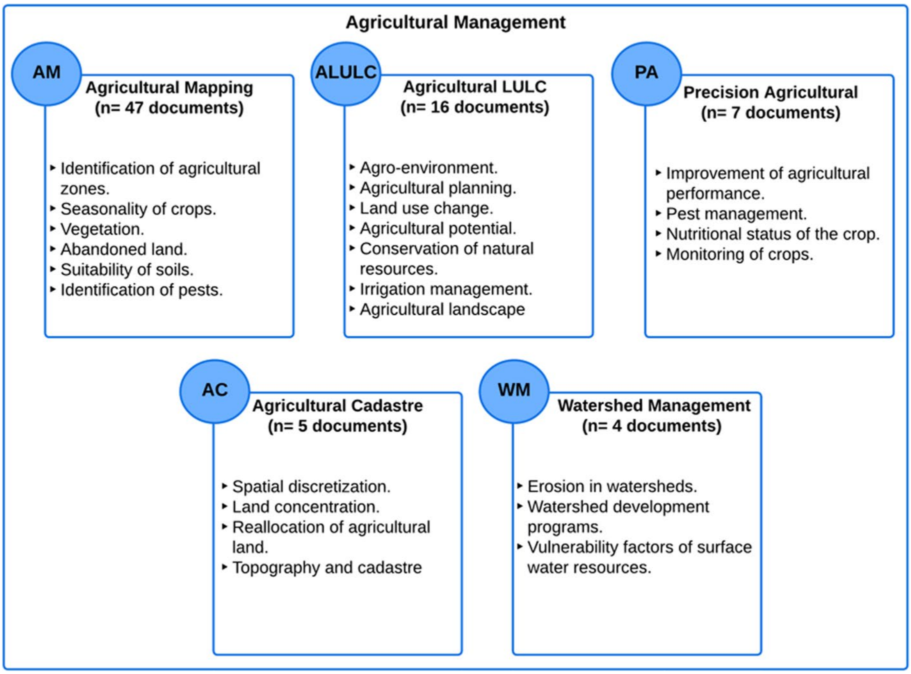

Fig. 7 Main themes of agricultural management and related variables. *AM* agricultural mapping, *ALULC* agricultural land use and cover, *PA* precision agricultural, *AC* agricultural cadastre, *WM* watershed management

Table 1 Studies related to agricultural mapping

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Italy/Campania district/Costa Viola/Reggio Calabria/ Lamole/ Piedmont/ Bova Superior	Sentinel 2	Geodetic GNSS and RTK	DJI Phantom 4 Pro, DJI Matrice 210 V2 and DJI Matrice 600 Pro	Agisoft Photoscan, Bing Maps, WMS, ERDAS Imagine, QGIS 3.14.0, ESRI ArcGIS, PostGIS and Geoserver	Nikon D810 metric camera, Optris PI450, multispectral Tetracam µ-MCA06, LiDAR Rangefinder, autonomous tractors and SISI	PCA, multivariate analysis and descriptive statistics	Fruits: grape, olive and citrus	Crop restoration programs	(Barrile et al., 2022; Belcore et al., 2021; Costantini et al., 2016; D'Urso & Marino, 2016; Modica et al., 2014, 2020; Tucci et al., 2019)
India/Patan District/ Andhra Pradesh/ Bhadarabad/ Dhar/Jhabua	LIS II, III and Landsat 8	GPS	–	ArcGIS, MOD 13Q1 and ERDAS Imagine	SRTM and satellite vegetation sensors	Descriptive statistics, regression analysis and kurtosis	Grain: wheat and rice. Sugar cane	Water collection measures	(Arunima et al., 2015; Dadhich et al., 2017; Nageswara Rao et al., 2011; Pandey et al., 2015)
Egypt/ Port Said/South Beheira/West Nile Delta/ El-Sharkia	RapidEye2015, Sentinel 2, Landsat 8	GPS	–	ENVI 5.1, ERDAS Imagine 14, IDRISI 19.0.2 and ArcGIS 10.5	SNAP and SRTM	Regression analysis, descriptive statistics and geostatistics	Vegetables and fruit trees	Crop rotation. Agricultural irrigation through the river and groundwater. Fish farming activities improve soil properties	(A. E. AbdelRahman & Arafat, 2020; AbdelRahman et al., 2022a, 2022b, 2022c, 2022d)

Table 1 (continued)

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Mexico/Jalisco/Huasteca/Guerrero	Landsat MSS, 8 and SPOT	–	Phantom 4	ILWIS 3, ENVI 5.1, ESRI ArcGIS 9.2, PostGIS, GeoServer and GeoBase L9	RGB sensor, Apogee PS-100 spectroradiometer and MAPIR Survey 3W camera. GEE	Descriptive statistics	Agave and sugar cane. Grain: maise and beans	Seeds are dispersed and germinated by animals	(Aguilar Rivera et al., 2013; Calvario et al., 2020; Fernandez-Ordoñez et al., 2014; Olvera-Vargas et al., 2022; Vázquez et al., 2015)
Spain/Tarazona de la Mancha/Sabina Forest/Madridejos	-	U-blox LEA-6H-0-002, GNSS-RTK and GPS Leica 1200	Microdrone md-400 and microdrone md4-200	Apero-MicMac and Agisoft PhotoScan	Photon 320 thermal camera and Canon Ixus HS115 automatic	Regression analysis and ANOVA	Grape, maise and onion	Water management for irrigation in rural areas	(Ballesteros et al., 2014, 2018; Del-Campo-Sánchez et al., 2019; Ribeiro-Gomes et al., 2016)
Iraq/Wasit/Karbala/Ain al-Tamur	Landsat ETM, 8 and Sentinel 2	–	–	ArcGIS 10.4.1 and ERDAS Imagine 14	–	Analysis of variance, geostatistics and descriptive statistics	Olive trees and palm trees. Grain: wheat, barley and maise. Vegetables: onion and garlic	Local production generates jobs	(Al Waeli et al., 2020, 2021; Sbahi et al., 2021)

Table 1 (continued)

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Brazil/ Chapada dos Veadeiros/ Londrina	Landsat TM, 5 and 8	GPS	–	SPRING 4.3.3	SRTM and Thematic MapperTM sensor	Cross tabulation	Coffee	Modern agricultural and livestock activities preserve the biome and rural landscape	(Silva et al., 2018; Trabaquini et al., 2010)
Chile/Maule region/Lolol, Pumanque, Chépica, Santa Cruz, Palmilla, Peralillo	Landsat	GPS Trimble GeoExplorer Series 2005	–	PCI Geomatics	WGS84	Regression analysis and descriptive statistics	Grapes, blueberries and fruit species	Local production generates jobs	(Mena et al., 2007; Retamales et al., 2015)
France/Vallées et Coteaux de Gascogne	NOAA	–	–	SIGPAC	–	PCA and descriptive statistics	Pastures and groves	Grasslands generate food for livestock	(Blanco et al., 2019; Marie et al., 2014)
Canada/Quebec	NOAA-AVHR, Landsat TM	–	–	ERDAS Imagine, MAPAQ Geoextra and GeoCOMP	–	Data interpolation and regression analysis	Wheat	–	(Reichert et al., 1998; Viau et al., 2000)
Poland/Poznań	Landsat ETM	–	–	Corine Land Cover, World_ Imagery	–	Nonparametric log-probabilistic	–	–	(Ruiz-Lendínez, 2020)

Table 1 (continued)

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Romania/ Humor Depression	–	–	DJI Phantom 4 Pro	Leica Cyclone Model	–	Descriptive statistics	Alfalfa	Grasslands generate food for livestock	(Copăcean et al., 2020)
Netherlands	SPOT, Envisat and Radarsat	GPS	–	QOPT	–	Descriptive statistics	Potato, wheat, maise and pastures	–	(Moll & Wouters, 2001)
Jordan/Mujib	Landsat OLI-TIR, Quick Bird,	GPS	–	GIS CropWat	–	Descriptive statistics	Vegetables, cereals, fruit trees and olive trees	–	(Al Rawashdeh, 2019)
Czech Republic	–	–	RPAS eBee	ArcGIS and ENVI	MultiSPEC 4C sensor, ThermoMAP camera and Pix4D software	Descriptive statistics	Maise and rye	–	(Sedina, 2017)
Senegal/Haute Casamance	–	GPS	–	Kronostat 1.01, GIS	–	Descriptive statistics	–	Seed storage for crop restoration	(Mballo et al., 2021)
Arabia/ Hadramawt/ Yemen	–	GPS	–	Arc Hydro GIS and ERDAS Imagine 8.6	PCGeomatica 9.0	Logistic regression analysis	–	–	(Harrower, 2008)

GNSS global navigation satellite system, *WMS* web map service, *SISI* Italian soil information system, *SNAP* sentinel application platform, *ANOVA* analysis of variance, *GEE* Google earth engine, *NOAA* national oceanic and atmospheric administration, *WGS* world geodetic system, *SRTM* shuttle radar topography mission, *PCA* principal component analysis

5.4.1 Agricultural mapping (AM)

This topic presents 47 studies, all of which use RS, GPS, UAV and GIS geomatic tools in agricultural mapping, and one study uses LiDAR to extract phenological information from the vegetation. These studies apply statistical methods in data classification and elaborating thematic maps that are accurate or close to reality. Table 1 presents the studies focused on agricultural cartography distributed by the scientific contribution of countries (according to the frequency of studies) with their respective geomatic tools and predominant statistical methods such as regression analysis, principal component analysis (PCA) and descriptive statistics. In addition, it shows the types of frequent crops. It highlights sustainability practices in various countries, focused on the SDGs (2, 6, 12, 13, 15).

Agricultural LULC (ALULC)

This theme comprises 16 studies that use RS and GIS geomatic tools to analyze LULC by agricultural activity. In addition, a study used a multispectral camera for the classification of agricultural characteristics of crops. Table 2 presents studies focused on the identification and spatial representation of land use for analyzing anthropic activities and agricultural management. Descriptive statistics such as standard deviation, mean and analysis of variance are the predominant statistics in these studies.

5.4.2 Precision agricultural (PA)

This theme analyses seven studies focused on agricultural precision using geomatic tools such as RS, GPS, UAV, GIS and the photogrammetry geomatic technique, of which four studies use multispectral cameras for intelligent agricultural management. Table 3 presents the studies evaluating the quality and precision of farming fields.

5.4.3 Agricultural cadastre (AC)

Table 4 presents five studies that use RS and GIS to analyze the agricultural cadastre, of which two studies use georadar and sensors for plot planning, and one study applies LiDAR for the detection and digitisation of farming areas. Descriptive statistics is the predominant statistical method.

5.4.4 Watershed management (WM)

Table 5 presents four studies that use RS, GPS and GIS in watershed management for agricultural intervention.

6 Quantitative synthesis

Figure 8 shows the quantitative synthesis of the systematic review, considering the variables geomatic tools, statistical, crop, sustainability and documents of the studies associated with the five themes of agricultural management. In AM studies, Italy stands out for using geomatic tools (100%) considered in this study (i.e., RS, GPS, UAV and GIS). In addition, Spain and Iraq excel in fruit, pastures and vegetable crops (Fig. 8a). In ALULC studies, Mexico and India stand out for the statistical methods considered in their studies and Nigeria for their crop interest (Fig. 8b). In PA, Spain considers all the geomatic tools (Fig. 8c). In the AC theme,

Table 2 Studies related to agricultural LULC

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
India/Bengaluru/Tiptur/Mumbai/Pune/Luppi/Hunasgi Taluk	CartoSat-2, LISS III and IV	GPS	–	ArcGIS, QGIS, ArcINFO and Geomatic	HRMX multispectral camera, Software: Domain, FloraMap and LPIS	Descriptive statistics, multicriteria analysis and support vector machine	Cereals and coconut	Natural fertiliser of crop and forest litter	(Banik et al., 2006; Ramadasa et al., 2022; Rana & Kharel, 2019; Ravan et al., 2004)
Mexico/Oaxaca/Marques de Comillas Chiapas/Tecolutla	Landsat 5, 7 and 8	–	–	Geoda, ArcGIS and QGIS 2.18.25	Grass 7.0.4	Hydrographs, sedimentograms and confusion matrix	Maise and barley	–	(Moreno et al., 2021; Sandoval-García & Cantú-Silva, 2022; Tapia Silva & Lopez Flores, 2017)
Italy/Costa Viola	–	RTK-GNSS	–	PostgreSQL-PostGIS and Corine Land Cover	Aerial laser scanner	Stratified random sampling	Grape	Local development through agriculture, history and tourism	(Modica et al., 2017)
Venezuela/Anzoátegui	Terra and Aqua	–	–	IDRISI	–	Descriptive statistics	Cassava, peanuts, maize and sorghum	Home gardens	(Olivares-Campos et al., 2019)
Cameroon/Logone	Landsat MSS and SPOT	GPS	–	IDRISI	MapINFO	Descriptive statistics	Rice and pastures	Hydrological rehabilitation	(Mouafo et al., 2002)
Cuba/Zaza River Basin	–	–	–	GIS	SRTM	Descriptive statistics	–	–	(Ramírez et al., 2019)
Romania	Landsat 8	–	–	GIS and Corine Land Cover	–	Multifactorial analysis	–	–	(Simon, 2017)

Table 2 (continued)

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Mozambique/ Nacala Corridor	Terra and Aqua	–	–	MODIS Land Cover Type MCD12Q1	ERDAS Imagine	Descriptive statistics	Pastures	–	(Pollino et al., 2021)
Nigeria	Landsat TM and HJ-1	–	–	GlobeLand30 and GEE	Sentinel Site Database	Logistic regression analysis	Grain: maize, beans and rice. Fruits and vegetables	–	(Arowolo & Deng, 2018)
France	–	–	–	GIS	Sensors	Descriptive statistics	Pastures	Grasslands allow livestock development	(Vannier, 2012)

LPIS land parcel information system, *RTK* real-time kinematic, *GNSS* global navigation satellite system, *SRTM* shuttle radar topography mission, *GEE* Google Earth engine

Table 3 Studies related to precision agricultural

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Italy/Emilia-Romagna	–	GNSS-RTK	Drone Mod. 3DR and DJI Matrice 210 Commercial Off-The-Shelf	Open-source Quantum GIS	MicaSense multispectral camera and DJI Zenmuse Z30 sensor	Descriptive statistics	Wheat	Less use of fertiliser and pesticides	(Chiappini et al., 2020; Lambertini et al., 2022; Orsini et al., 2019)
Spain/Albacete, Castilla La Mancha	Double dual-frequency antenna with L2C	L2C geodetic GPS	Quad mini V 20	GIS	GNSS, Tetracam Mini-MCA and FieldSpec 3 ASD spectro-radiometer	Descriptive statistics	Grape	–	(Herrero-Huerta et al., 2014)
Czech Republic/Vysoké Sedliste	–	–	Drone eBee by senseFly	PostFlight Terra3D	Multispectral camera—multiSPEC 4c, the senseFly thermoMAP camera and Pix4Dmapper	Descriptive statistics	Maise and rye	–	(Raeva et al., 2018)
Morocco/Béni-Mellal	–	Leica 500-RTK	DJI Phantom-4 Pro+ V2.0	GIS	Pix4Dmapper	Descriptive statistics	–	Mountains allow the installation of hydroelectric plants for irrigation	(Bannari et al., 2021)

GNSS global navigation satellite system, *RTK* real-time kinematic

Table 4 Studies related to agricultural cadastre

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Türkiye/Agalar Village	QuickBird, Ikonos-2, Landsat 7 and SPOT 5	–	–	GIS	NetCad	Descriptive statistics	Sugar beet, grain and pastures	–	(Cay & Iscan, 2011; Cay et al., 2004)
Italy/Lago di Garda	RS	–	–	GIS	–	Descriptive statistics	–	–	(Zini et al., 2002)
Romania/Labasint Village, Sistarovat	–	–	–	Leica Cyclone	LiDAR backpack, 4MP cameras, light sensor, georadar and Leica Pegasus	–	Pastures	Use of grasslands for livestock	(Simon et al., 2021)
France	–	–	–	GIS	DEM, GROOV' Space	Probability sampling	–	Application of hydrological models	(Lagacherie et al., 2022)

DEM digital elevation modeling

Table 5 Studies related to watershed management

Countries	Geomatic tools					Statistical method	Crop	Sustainability	References
	RS	GPS	UAV	GIS	Others				
Canada/Quebec	Satellite	–	–	IDRISI	–	Hydrographs and sedimentograms	Maise and barley	–	(Duchemin et al., 2001)
Tunisia	SPOT-H and Landsat-Tja	Pronav GPS 100	–	SRIT	ArcINFO	Descriptive statistics	–	–	(Pouliot et al., 1994)
India	Satellite	GPS	–	ArcGIS 9.0	–	PCA	–	Soil regeneration	(Ramachandran & Ramakrishna, 2006)
France/Gimone	–	–	–	QGIS	Weather France radar	Regression analysis	Wheat, soybeans and maize	–	(Grimene et al., 2022)

SRIT system of rectification of images of remote detection, *PCA* principal component analysis

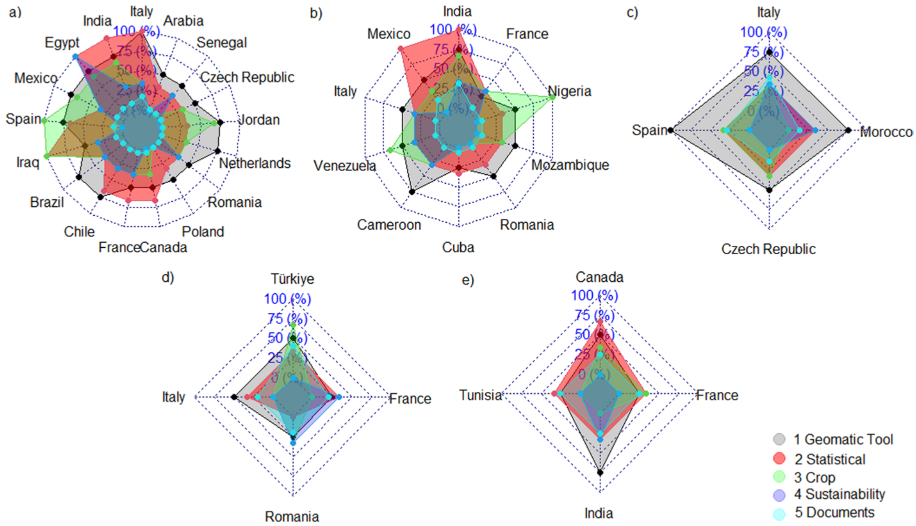

Fig. 8 Quantitative synthesis of the systematic review. **a** agricultural mapping (AM), **b** use and cover of agricultural land (ALULC), **c** precision agricultural (PA), **d** agricultural cadastre (AC) and **e** watershed management (WM)

Turkey attaches importance to pastures and vegetable crops (Fig. 8d). And in WM studies, India uses 75% of geomatic tools. Canada uses 75% of statistical methods in their studies (Fig. 8e).

7 Discussion

This review analysis highlights the contribution of geomatics tools in managing urban/rural agricultural cadastres. It focuses on innovative results such as precision, spatial resolution and image processing in geospatial detection of crop areas, mapping, intelligent monitoring, agricultural property management, property boundary accuracy and cadastral parcels. Furthermore, these geomatic tools are essential for agricultural territorial planning and management activities. They allow farmers to obtain relevant information about areas and spatial distribution of crops necessary for decision-making within the framework of territorial-economic-agricultural-environmental development.

The application of geomatics in agriculture supports the use of GIS in topics of interest associated with agricultural management (Fig. 3a) (Pouliot et al., 1994; Viau et al., 2000). Countries such as Italy, Iraq, Spain and Brazil have more frequently used GIS and other geomatic tools (e.g., Landsat and Sentinel satellites, airborne remote sensing, UAV, GPS, RPAS and multispectral sensors) in AM studies, which explore vegetation for crop quality assessment (Belcore et al., 2021; Jurado et al., 2018; Sbahi et al., 2021; Sedina, 2017) and detection of pest infestation level (Del-Campo-Sánchez et al., 2019). These studies obtained high crop precision, optimal routes, strategic irrigation points, agricultural intervention areas and time–cost savings in agri-environmental activities. Similarly, other studies in India and Egypt used GIS, Landsat satellites, and the Shuttle Radar Topography Mission (SRTM) in AM associated with soil suitability to identify suitable crop areas and provide farmers with planning strategies (AbdelRahman & Arafat, 2020; AbdelRahman et al., 2022b, 2022c; Dadhich et al., 2017). These studies achieved high precision in estimating biomass and soil suitability for crops (i.e., approximately 66% suitable soils), in contrast to moderate global soil degradation (44%) due to soil salinisation, compaction and chemical contamination (FAO, 2023b). On the contrary, other studies in Canada and Chile used GPS and satellites (e.g., LIS II-III and NOAA) in AM linked to crop seasonality to determine patterns and dynamics of agricultural productivity (Blanco et al., 2019; Pandey et al., 2015; Viau et al., 2000). These studies obtained agrometeorological prediction mechanisms against the impacts of climate change.

Additionally, applying geomatics in AM through multispectral satellite images obtains thematic maps for detailed analysis of viticultural and crop yields (e.g., olive, citrus and blueberry) (Costantini et al., 2016; D'Urso & Marino, 2016; Retamales et al., 2015). On the contrary, other studies use the textural characterisation and segmentation of aerial images for the detection, automatic counting and quality of crops (e.g., grain such as wheat, corn, rice and barley; vegetables such as onion, potato and garlic; fruits such as coconut), in urban and rural areas (Al Waeli et al., 2021; Ballesteros et al., 2014, 2018; Calvario et al., 2020; Moll & Wouters, 2001; Ribeiro-Gomes et al., 2016; Ruiz-Lendínez, 2020). Also, some studies related to AM denote that applying geomatics in agriculture promotes sustainability improvements in agricultural management, such as agricultural restoration through crop rotation techniques for barns that store seeds, food (Mballo et al., 2021), farming projects that offer opportunities to work and improve environmental conditions in the region (Al Waeli et al., 2021; Ghaderi et al., 2020; Gitinavard et al., 2021).

Regarding the studies related to ALULC, in Cuba, Mexico and Mozambique, they applied GPS, satellites (e.g., SPOT, MODIS Terra and Aqua), and multispectral cameras for agricultural management and evaluation of impacts on local agroecosystems (Moreno et al., 2021; Pollino et al., 2021; Silva et al., 2018). These studies obtained changes in land use due to anthropic activities, urban expansion and forest-agricultural-pasture cover. Similarly, other studies in countries such as Romania and India applied geomatics (GIS, Landsat 8 satellites and geomatics software) in the identification and spatial representation of arable land, forests and grasslands, with sustainable practices that identify areas of water scarcity to establish action plans with sustainable crop patterns (Ramadasa et al., 2022; Simon, 2017). According to FAO (2023a), these action plans must integrate technology, research and development with local knowledge to obtain adequate statistics; geospatial maps focused on the agricultural production system. In addition, studies associated with ALULC prioritise the distribution and extent of agricultural areas with pasture crops (Mouafo et al., 2002; Vannier, 2012) and grain (e.g., maize, beans and rice) (Arowolo & Deng, 2018).

Studies related to PA in countries such as the Czech Republic, Spain and Morocco used geomatic tools (RS, GPS, UAV and GIS) and photogrammetry in precision agriculture to improve agricultural yield and crop monitoring (Bannari et al., 2021; Chiappini et al., 2020; Lambertini et al., 2022; Musci & Dabove, 2020; Orsini et al., 2019; Raeva et al., 2018). These studies managed to reveal the texture and relief characteristics of the agricultural land for the fertilisation of crops. On the contrary, studies in Italy integrated geomatic tools for intelligent pest management agricultural management systems (Chiappini et al., 2020; Musci & Dabove, 2020).

Few studies relate CA to geomatic tools (use of DEM, GIS and LiDAR) in countries such as France, Turkey and Italy. These studies analyzed the connection between parcels in agricultural land reallocation projects, achieving greater parcel concentration, with sustainable practices such as detecting grasslands for livestock that contribute to the farm space's conservation of flora and fauna (Cay & Iscan, 2011; Lagacherie et al., 2022;

Simon et al., 2021; Zini et al., 2002). Other studies integrate CA and agricultural mapping using geomatic tools such as RS, GIS, UAV, and GPS measurements for cadastral registry assignment, identification and plot boundaries, calculation of agricultural properties, improvements to agricultural management, and agricultural landscape spatial discretisation (Cay et al., 2004; Lagacherie et al., 2022; Modica et al., 2020; Vannier, 2012). In addition, some studies extract topographic-cadastral data of farm areas to evaluate their agricultural performance, establish agrotourism development strategies (Lambertini et al., 2022; Simon et al., 2021) and control agro-environmental regulations for sustainable agriculture (Zini et al., 2002).

WM-related studies in countries such as Tunisia, India and France integrate geomatic tools with geographic databases and create agricultural GIS to improve the management and planning of irrigation water, watersheds and natural resources (Grimene et al., 2022; Naboureh et al., 2021; Pouliot et al., 1994; Ramachandran & Ramakrishna, 2006).

Recent studies focus on technological advances in the use of the spectroradiometer, multi-copter drones, autonomous tractors, multispectral topographic cameras, sensors, satellites for spatial distribution and recognition of phenological stages of crops, georeferenced surveys in precision agriculture, areas suitable for cultivation, optimisation agricultural production and sustainable soil management (AbdelRahman et al., 2022a, 2022b, 2022c, 2022d; AbdelRahman et al., 2022a, 2022b, 2022c, 2022d; Barrile et al., 2018; Olvera-Vargas et al., 2022).

Finally, agricultural management has emerged with the development of geomatic tools. It implies high performance through information management practices, which contributes to decision-making and the ability to manage sustainable agricultural processes (Kim et al., 2023).

8 Conclusions

The studies analyzed within the framework of geomatics tools in agricultural management cover statistical methods such as exploratory analysis, regression, descriptive statistics and principal component analysis, with precise and reliable results in agricultural planning processes. Sixty-percentage of the studies analyzed with PRISMA are related to geomatics and agricultural cartography, specifically in agricultural activities such as identification, suitability, seasonality, pedology and monitoring of agricultural areas. GIS, GPS, UAV and RS are the most used geomatics tools in agricultural mapping. The predominant geomatic techniques are photogrammetry in the phenology of crops such as grapes and olive trees and multispectral analysis in optimising and monitoring agricultural production. Furthermore, the most frequent tool in the application of agricultural management activities is GIS.

29.3% of the studies analyzed highlight the improvement of agricultural management through the application of geomatics tools in the spatial resolution/precision and processing of satellite images (e.g., Sentinel-2), demonstrating effectiveness in the measurement of various properties of crops-water-soil. Geomatics allows the production of thematic maps related to identifying, classifying, yielding, spatial distribution and monitoring crop growth. Also, it is of great help to farmers in automating agricultural practices such as the identification of pests, diseases and strategic irrigation points. It is crucial to optimise planting and harvesting routes for grains such as wheat and maise in Mexico and France; vegetables such as onion and potato in Spain and Netherlands; fruits such as grapes and olive trees in Italy, Chile and Spain; and coconut in India. Geomatics contributes to saving time and costs in agro-environmental activities. In addition, it strengthens the agricultural cadastre by digitising and processing data/images at the parcel scale in various planning and decision-making processes in the urban–rural sphere. In this context, countries in Europe, Africa, Asia and Latin America use geomatics tools to identify, register and manage agricultural properties, land tenure security, land value and taxes for innovative crop management approaches. Also, the dynamics of changes in LULC due to agricultural activity in communes and urban sectors require that territorial policies consider the agricultural cadastre for the local development of the sectors.

This study demonstrates that the application of geomatics promotes sustainability practices in agriculture. They are focused on less use of fertilisers and pesticides to improve food security (SDG-2) and prevent the effects of climate change (SDG-13). They also include the efficient use of water resources for agricultural irrigation (SDG-6) and the rehabilitation of degraded soils (SDG-15). Furthermore, it highlights that improvements in the agricultural system in rural and urban areas increase the quantity and quality of local production, generating employment and economic development in these sectors (SDG-12). The study's limitations are based on the number of publications associated with geomatic duality and agricultural cartography, according to the topics addressed in agricultural management. Therefore, research in the areas of systematic reviews is relevant:

- Systematic reviews aimed at sustainability practices in the relationship between geomatics and agriculture with specific data from successful case studies.
- Spatiotemporal analysis through GIS and artificial intelligence techniques such as deep learning to understand the evolution of potential agricultural production areas and their future behavior.
- Intelligent monitoring using geomatics tools, genetic algorithms and the Internet of Things (IoT) to improve agricultural practices focused on food production.

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