DOI 10.15302/J-SSCAE-2022.01.008

Strategic Issues of Monitoring and Information Services of Agricultural Water and Land Resources in China

Zha Yan [1, 2], Wu Wenbin [1, 2], Yu Qiangyi [1, 2], Liang Shefang [1, 2], Lu Miao [1, 2], Qian Jianping [1, 2], Tang Huajun [1, 2]

1. Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China
2. Key Laboratory of Agricultural Remote Sensing, Ministry of Agriculture and Rural Affairs, Beijing 100081, China

Abstract: Rational development and utilization of agricultural water and land resources are crucial for national food, ecological, and resource security, owing to the high value of cropland and water resources. Therefore, it is vital to obtain timely and accurate information on the quantity and utilization of these resources for national stability and socio-economic development. In this study, we have summarized the status quo and problems of agricultural water and land resources monitoring and information services in China and expounded the framework of a monitoring and information service system. We proposed the following strategic goals: realizing automatic, intelligent, and unmanned monitoring of agricultural resources and environment and marketing the monitoring information services. These goals can be achieved by increasing the efficiency and outcomes of water and land use and optimizing the spatial allocation of agricultural land and water resources. Moreover, we analyzed the technological routes for agricultural water and land resources monitoring in relation to deep integration of information technology and agriculture and proposed specific projects from the aspects of infrastructure construction, core technology development and integration, and information services. Furthermore, we proposed the following policy suggestions: (1) strengthening the top-level design, (2) enhancing scientific and technological innovation, (2) building a sharing platform for agricultural resource monitoring, (4) deepening the interaction of government, industry, universities, research institutes, and users of agricultural resources, and (5) promoting high-level talent training. Our study is expected to provide a theoretical reference for the development of agricultural water and land resources monitoring in China.
Keywords: agricultural water resources; land resources; resource monitoring; information services; satellite, aerial, and ground integration

1 Introduction

Water is an important strategic resource that supports sustainable economic and social development, and farmland is the most fundamental requirement for agricultural production. Both have multiple functions, including food supply and ecological regulation. Rational development and utilization of agricultural water and land resources are directly related to national food safety, ecological security, and resource security. Therefore, it is vital to obtain timely and accurate information on the quantity and utilization of agricultural water and land resources for national stability and socio-economic development. Developed countries have monitored agricultural water and land resources for more than 50 years, with close coordination among legislation, standards and monitoring and a complete monitoring system. In recent years, government and researchers have focused on information infrastructure and digital agriculture, and actively developed sensors, artificial intelligence (AI), unmanned aerial vehicle (UAV), mobile

Received date: December 03, 2021; **Revised date**: January 14, 2022
Corresponding author: Wu Wenbin**,** researcher of Institute of Agricultural Resources and Regional Planning of Chinese Academy of Agricultural Sciences. Major research fields include agricultural land use and agricultural remote sensing. E-mail: wuwenbin@caas.cn
Fund program: CAE Advisory Project "Research on Smart Agriculture Development Strategy" (2019-ZD-05)
Chinese version: Strategic Study of CAE 2022, 24(1): 064–072
Cited item: Zha Yan et al. Strategic Issues of Monitoring and Information Services of Agricultural Water and Land Resources in China. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2022.01.008

Internet, and other cutting-edge technologies. By relying on abundant data resources, such as ground surveys, statistics, and remote sensing, developed countries have combined information technology with model simulation to establish a full-fledged monitoring and information service system for water and land resources, and the environment [1]. Moreover, they have kept surveys, assessments, and information open and transparent to ensure a high degree of monitoring data sharing and orderly information release.

At present, China has inadequate agricultural water and cropland resources with spatial mismatch of grain production, and water and land resources, as well as extensive resource utilization patterns, which are strong constraints to agricultural production [2,3]. With agricultural boom, there has been an increase in prominent problems related to agricultural ecological environment and high costs of environmental resources in China. Therefore, agricultural development is facing restraints at the level of resources as well as environment. To obtain timely and accurate information on the quantity and utilization of agricultural water and land resources and to rapidly establish a unified and efficient modern monitoring network system, China has issued a number of relevant policies and implemented the remote sensing monitoring One Map project, ecological environment protection information project, and national water resource monitoring capacity building project in the last five years. This was done to support the development of agricultural water and land resources, and environmental monitoring, and to maintain the quality of monitoring data, promote the sharing of monitoring information, and improve the level of monitoring information services [4,5]. According to the *General Plan for Construction of Natural Resources Survey and Monitoring System (2020)*, a unified national natural resources survey, assessment, and monitoring system will be built by 2023, forming laws and regulations, standards, technologies, and quality management systems for natural resources surveys and monitoring [6]. Based on the *Outline of the Digital Rural Development Strategy* and the *Development Plan for Digital Agricultural and Rural (2019–2025)*, remote sensing monitoring and other technologies will be used to establish a national agricultural and rural data platform, providing data support for promoting green agricultural and rural development [7–9].

Compared with the conventional manual ground measurement and survey of agricultural water and land resources, satellite remote sensing, UAV, Internet of Things, cloud computing, big data, and other technologies can quickly obtain real information of water and land resources in a large range, and accurately grasp dynamic changes, so as to calculate the quantity of resources, locate geographical distribution, and verify ownership. Accordingly, they are conducive to achieving the regulatory objectives of early detection, early prevention, and severe crackdown, and providing a scientific basis for the “three red lines” in water resources management and the red line for farmland control. With regard to digital economy and Intelligent Plus era, for the purpose of promoting information technology application in agricultural water and land resources monitoring and information service, we analyzed current development of agricultural water and land resources monitoring in China and summarized the problems in data, technology, and application. In addition, we studied the development goals and technology development routes of each stage before 2050 and put forward suggestions for infrastructure construction, core technology R&D and integration, and information service, with the expectation that they will provide basic reference for high-quality development of agricultural water and land resources monitoring in China.

2 Analysis on development of agricultural water and land resources monitoring and information services in China

2.1 Current development

2.1.1 Agricultural water and land resources monitoring network takes shape at provincial, municipal, and county levels.

China started agricultural environmental protection in the 1970s. In 1983, the former Ministry of Agriculture established the Environmental Monitoring Center and built an agricultural environmental monitoring network. At present, a three-level agricultural environmental monitoring network system has been established, with the General Environmental Monitoring Station of the Ministry of Agriculture and Rural Affairs as the leader, all provincial-level agricultural environmental monitoring stations as the principal part, and some major municipal and county-level monitoring stations as the bases. The national monitoring network of soil environmental quality of the original location of agricultural products and the state-controlled monitoring network for agricultural non-point source pollution have been established to conduct data surveys and provide timely updates, monitor pollution variation tendencies in real time, and release annual reports on statistical information every year, to significantly improve basic support capacity. Specifically, the national long-term fixed-point monitoring network of soil heavy metals in

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the original location of agricultural products includes 152 000 long-term fixed-point monitoring sites. To analyze the main methods of agricultural non-point source pollution in six areas (northern plateau and mountain area, southern mountainous and hilly area, northeast plain area, Huang–Huai–Hai plain area, Southern plain area, and northwest plain area), with wheat, corn, rice, vegetables, and other major crops as the focus, a state-controlled monitoring network for agricultural non-point source pollution was established in 30 provinces, involving 273 state-controlled monitoring sites for farmland non-point source pollution (including 182 state-controlled monitoring sites for surface runoff and 91 state-controlled monitoring sites for underground leaching) [10].

2.1.2 Satellite, aerial, and ground integrated monitoring is an important technology in agricultural water and land resources monitoring.

Conventional ground surveys and sampling monitoring methods waste time and labor, and are difficult to carry out in a large area and easily interfered with by human factors. At present, agricultural water and land resources surveys and monitoring are supported by technologies, such as ground surveys, remote sensing, and mapping. Furthermore, high-resolution remote sensing, Beidou satellite navigation, agricultural UAV, precision operation of agricultural machinery, and their supportive application platforms have been developed to provide new types of technological support for agricultural water and land resources monitoring in a wide range. For example, agricultural water and land resources monitoring based on satellite (satellite remote sensing), aerial (UAV remote sensing), and ground (ground sensor network) integration has played an important role in agricultural resources surveys, crop yield estimations, and agricultural disaster monitoring and assessments [11–13]. A stereoscopic observation system for agricultural remote sensing based on aerospace, aviation, and ground remote sensing platforms has been built with multi-platform, multi-sensor, high temporal-spatial resolution, and high spectral resolution to effectively relieve remote sensing for agricultural applications from the constraint of insufficient information sources. In addition to the development of information technology and expansion of agricultural application demands, the application range of satellite, aerial, and ground integrated monitoring has also extended from optical remote sensing data to radar and hyperspectral data; from traditional crop monitoring to resources, disasters, and environment monitoring; and from China to the world. For example, during the third National Land Survey launched in 2017, high-resolution satellite remote sensing technology was applied in multi-scale and high-precision image acquisition and interpretation of information on changes in cropland, forest, grassland, water, wetland, and other natural resources in all county areas. In addition, it clarified the national land resources, improved land resources survey and statistics, and established an all-weather, all-coverage remote sensing monitoring, and rapid updating mechanism. In 2021, Chinese scientists integrated and optimized more than 10 sets of global/regional remote sensing cropland mapping data and cropland area statistics data at the national, provincial, and municipal levels, and developed global cropland integration mapping products with a resolution of 500 m in 2010 [14].

2.1.3 Information service platform for agricultural water and land resources ushers an era of rapid development.

All relevant departments have built big-data platforms for the management and service of agricultural water and land resources. For instance, the Ministry of Agriculture and Rural Affairs applied satellite remote sensing, UAV monitoring, mobile acquisition terminals, and multi-source data resources in real-time monitoring of cropland conditions and built a comprehensive monitoring and supervision platform for national farmland based on satellite, aerial, and ground integration technology, to support the storage and management of big data on cropland nationwide and carry out monitoring on land use change, planting structure, and non-agricultural and non-grain cropland areas. Meanwhile, the Ministry of Water Resources built a water and soil conservation monitoring and management platform to monitor water and soil conservation conditions in key areas in real time, transformed the former problem-oriented passive supervision pattern to the target-oriented active supervision pattern, and significantly improved the precision management level of regional water and land resources. In 2020, the Chinese Academy of Agricultural Sciences and 12 other scientific research institutions completed the high-precision digital soil database covering the whole territory of China and applied remote sensing, geographic information system, global positioning system, AI, human–computer interaction, and other modern information technologies in integrating soil survey data over the past 40 years and simulating soil types and spatial distribution characteristics based on the physical and chemical properties of soil, with a precision of 100 meters. These provided a basis for the systematic study of spatial-temporal evolution of soil and environment in China and offered basic data for agricultural, natural resources, and environmental departments at all levels, extending to national projects, such as well-facilitated farmland construction, cropland protection, and soil fertility improvement [15].

2.2 Existing problems

2.2.1 Insufficient monitoring data acquisition capability and low monitoring precision and timeliness

Data are the basis for monitoring, analyses, decision-making, service, and application of agricultural water and land resources. China features diverse landforms such as frequent cloudy and rainy weather, complex cropping systems, and highly dynamic agricultural production. Due to this, many major technological difficulties exist in the information acquisition of agricultural water and land resources, resulting in a low information acquisition guarantee rate. First, there are inadequate data acquisition elements. Currently, there are still more population parameters, such as cropland environment, planting type, planting structure, and productivity, but less information on individual parameters such as plant shape, organ, and form and physical and chemical parameters, such as soil, crop nutrition, and quality, which cause extensive management of water and land resources. Second, data acquisition is not sufficiently precise. Specifically, it is difficult for a single satellite sensor or platform to obtain continuous spatial-temporal data, and aerial remote sensing development attaches more importance to hardware platforms than to software systems, which underutilizes the application potential of civil UAVs. The terrestrial Internet of Things is underdeveloped and applied at initial stage. Moreover, there are still many problems with remote sensing monitoring, such as mixed pixels, atmospheric correction, and scale conversion [16]. In addition, multi-source data integration and conversion technology are lagging. With insufficient agricultural information acquisition technology for satellite, aerial, and ground integration, agricultural water and land resources monitoring is mainly static (based on a single time point/period), with a low spatial resolution, lack of dynamic monitoring capacity of spatial-temporal changes in long time series, and insufficient monitoring timeliness [17,18]. Third, information acquisition equipment is underdeveloped. New-type water and land resource-purpose sensors (such as biosensors) and communication and transmission technologies of different information acquisition equipment slow advances, which seriously restricts the efficiency of field information acquisition, and there are obvious deficiencies in low-cost convenient information processing equipment and acquisition, diagnosis, control, and operation of integration equipment.

2.2.2 Insufficient coupling and integration of agricultural water and land resources simulation model

Based on modeling theories and methods, simulation models for monitoring agricultural land resources can be divided into geographic and economic models. The former focuses on the influence of environment factors, while the latter lays emphasis on the choice and decision-making behaviors of human factors. The formation and changes in agricultural water and land resources are affected by both natural and human factors, which are comprehensive, complex, and dynamic. In view of the changes in agricultural water and land resources and the related human–nature coupling system, a coupling and integration study was conducted based on multidisciplinary knowledge models [19,20]. In particular, an integrated model, which combines coupled geo-ecological and socio-economic models, is the development direction of agricultural water and land resources monitoring model. If crop growth model is combined with agricultural economic model, a simulation analysis can be conducted on the spatial pattern of major crops in the future [21]. Attention should be paid to the challenges in coupling studies regarding agricultural water and land systems. First, the study of coupling scale and speed should be strengthened. Along with advances in interactions between changes in agricultural water and land resources, long-distance coupling effect has become more extensive. Due to the multi-scale, multi-factor, and cross-level coupling of agricultural water and land systems, attention should be given to the potential influence of interactions among agricultural production, social economy, ecological environmental, and human characteristics in adjacent regions, remote distance, or even worldwide. Subsequently, a large coupling research framework should be established to optimize the allocation of agricultural soil and water resources [22–24].

2.2.3 Low efficiency of monitoring information sharing and information services of agricultural water and land resources

In China, the monitoring tasks of agricultural water and land resources are implemented by many departments such as the Ministry of Agriculture and Rural Affairs, Ministry of Water Resources, Ministry of Ecology and Environment, and Ministry of Natural Resources. Each department has built its own big data platform for agricultural water and land resources information management and service, but with overlapping monitoring and repeated data collection. As a result, multi-level departments are collecting local data, but the specialized local data hardly support overall judgment through simple data exchange and sharing, making a lot of monitoring data inefficient or even idle. Although relevant laws and regulations require all departments to share monitoring data, there is no monitoring information or data-sharing mechanism at the national level. As a result, there is no basis for all departments to

DOI 10.15302/J-SSCAE-2022.01.008

coordinate cross-department data sharing, which restricts the efficiency of existing monitoring data [25].

2.2.4 Lack of industrial and national standards for agricultural water and land resources monitoring

Water and land resources surveys and monitoring should be strictly and scientifically based on water and soil environment quality standards. China has 189 water quality monitoring standards and 43 soil quality standards [26], including the *Environmental Quality Standards for Surface Water (GB 3838—2002)* and *Technical Specifications for Soil Environmental Monitoring (HJ/T 166—2004)*. Although there are many monitoring methods and standards, there are no uniform rules for detection methods. Specifically, standards data are disordered and there are inconsistencies between technical standards and specifications for environmental monitoring issued by different departments, which affect the integration and assessment of monitoring information. In addition, owing to the lack of scientific basis for formulating monitoring methods, there is a low consistency between quantity, type, and actual conditions. With social progress and information technology development, agricultural water and land resources monitoring standards should be improved and updated to make the monitoring standards system more scientific, systematic, and practical [27].

2.2.5 Insufficient talent reserves for agricultural water and land resources monitoring

Satellite, aerial, and ground integrated monitoring technologies have gradually become an important technical means of agricultural water and land resources monitoring in China. Although it has a wide application range, it has high requirements for the comprehensive quality of environmental monitoring workers. In China’s agricultural environment monitoring system, there is only a small proportion of professional technicians with low professional quality and unreasonable talent structure, and interdisciplinary talents in agriculture and information technology are scarce. In addition, the system has inadequate grassroots teams that are engaged in agricultural water and land resources monitoring, with a lack of strict and professional new technological training. In terms of stability, personnel quantity, and quality, the monitoring and information service teams cannot meet the development requirements of environmental monitoring in the new era.

3 Framework of monitoring and information service system of agricultural water and land resources

In the framework of monitoring and information service systems of agricultural water and land resources (Fig.1), a satellite, aerial, and ground integrated observation system was built to focus on monitoring the quantity, quality, and spatial-temporal dynamic changes in water and land resources and ecological environment. The agricultural water and land resources monitoring and information service platform is established to support agricultural production guidance, decision-making services, and management; improve quantitative, digital, and intelligent monitoring and supervision levels; and ensure efficient utilization and green development of agricultural resources.

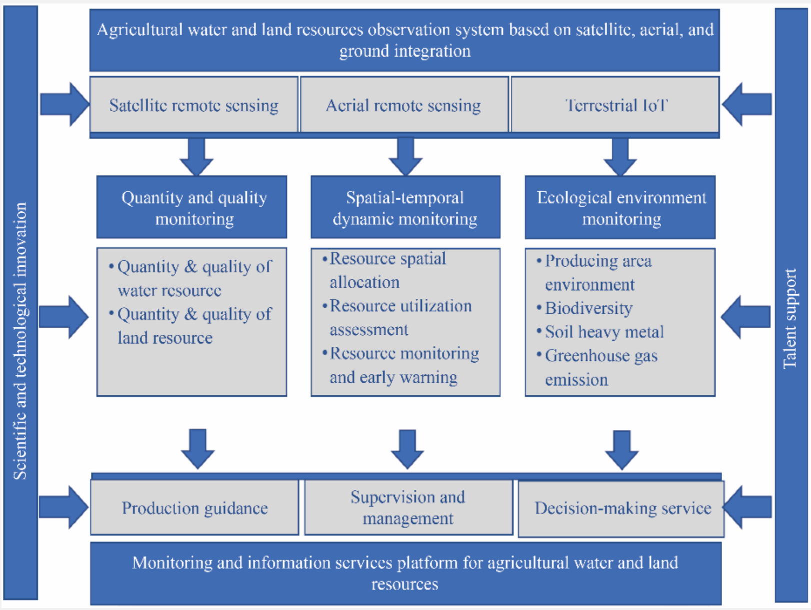

Fig. 1. Framework of the monitoring and information services system of agricultural water and land resources.

In the satellite, aerial, and ground integrated observation system of agricultural water and land resources, on-orbit satellite (remote sensing, navigation, communication) resources are applied in multi-type, multi-sensor, multi-satellite joint monitoring. China's existing multi-scale remote sensing data are shared and networked, and joint positioning, interactive communication, stable transmission, and linkage control between UAV and mobile vehicle platforms are developed. New types of smart soil sensors and smart irrigation water quality and quantity sensors are developed to gradually build an agricultural water and land resources monitoring network integrating satellite remote sensing, UAV remote sensing, and ground sensor network. A stereoscopic monitoring network for agricultural water and land resources (including business operation and capability monitoring networks) is established to improve the coverage, acquisition, calculation, and service levels of agricultural water and land resource monitoring data [28].

In terms of the quantity and quality of agricultural water and land resources monitoring, the agricultural water and land resources observation network is used to determine the grade, health condition, productivity, and quality of cropland and changes in surface/groundwater resources, total water resources and quality, annual average river runoff, dynamic changes in water storage of lakes and reservoirs, and groundwater level.

With respect to the spatial-temporal dynamic monitoring of agricultural water and land resources utilization, agricultural water and land resources allocation technology is developed based on the research progress of agricultural resource carrying capacity, and early warning and assessment of agricultural water and land resources utilization are implemented. The allocation pattern and implementation path of agricultural water and land resources in five major grain-producing areas are proposed to expand the monitoring and information service scope of agricultural water and land resources. The monitoring and early warning system and spatial optimum allocation system for agricultural water and land resources are established in an all-round manner to ensure sustainable economic and social development.

In terms of ecological environment monitoring for agricultural water and land resources, the input and output of agricultural resources of well-facilitated farmland are assessed according to the construction verification basis of well-facilitated farmland, to define the red line of agricultural water and land resources to be maintained in China. Furthermore, a nationwide security project of agricultural water and land resources is carried out to monitor cropland soil pollution, non-point source pollution, groundwater level, and the environment of the original location of agricultural products nationwide, further controlling agricultural water consumption, promoting fertigation technology, improving the utilization efficiency of agricultural water and fertilizer, increasing the proportion of green agricultural inputs, reducing cropland pollution, and improving cropland quality.

With regard to the monitoring and information service platform of agricultural water and land resources, efforts should be made to develop the big data capacity for agricultural water and land resources monitoring; acquire multi-target, large-zone, long-term massive monitoring data of agricultural water and land resources; and conduct data cleaning, integration, query, mining, analysis, and visualization. A blockchain technology-based agricultural water and land resources monitoring data sharing and management system is developed to efficiently connect intelligent sensing equipment and big data platforms for monitoring systems. Interunit, interdepartmental, and interregional monitoring data for agricultural water and land resources are open and shared to form an operational system covering platform and specific application services.

4 Strategic issues in agricultural water and land resources monitoring and information services in China

4.1 Development ideas

Food safety is the foundation of national economic construction and social stability. Ecological security is a prerequisite for sustainable development, and resource security guarantees a healthy ecological environment and stable grain yield. In the next 30 years, the development of agricultural water and land resources monitoring and information services in China will focus on the major demands of food safety, ecological security, and resource security and adhere to the new concept of green development, to achieve the development goals of automatic, intelligent, and unmanned monitoring of agricultural resources and environment and marketing of the monitoring information service. Agricultural resources and environment sensors, intelligent big data of agricultural resources, agricultural Internet of Things, and other key generic technologies are developed in the pattern of "independent innovation + introduction of achievements". Efforts will be made to promote the industrial application of monitoring technology and information services and form a resource monitoring and information service industry system with stereoscopic monitoring, digital design, precision operation, and intelligent management to significantly improve

DOI 10.15302/J-SSCAE-2022.01.008

resource utilization rate and labor productivity.

4.2 Staged goals

By 2025, China will build a satellite, aerial, and ground integrated monitoring network of agricultural water and land resources, establish unified big data standards and specifications for agricultural resources and environment, and develop One Map of agricultural resources and environmental elements and ownership to cover at least 80% of agricultural water and land resources. By then, efforts would have been made to verify 1 billion *mu* (1 *mu* ≈ 666.7 m^2) of well-facilitated farmland, dynamically monitor the utilization of water and land resources, and assess the input and output of agricultural water and land resources in well-facilitated farmlands to ensure stable grain productivity of well-facilitated farmlands in China (above 5×10^8 t). The barriers to resource monitoring data in the agricultural sector will be overcome to promote the sharing and application of survey and monitoring results and achieve data sharing within and outside agricultural business operation departments.

By 2035, a theoretical and technical system to improve the comprehensive utilization efficiency of agricultural water and land resources will be established. Specifically, the quality of cropland in key areas will be surveyed and monitored annually, with a monitoring coverage of agricultural water and land resources of no less than 90%. A land resource security project will be carried out to define the red line of cropland resources. Based on the monitoring information, the allocation pattern and the implementation path of agricultural water and land resources in the five major grain-producing areas in China will be proposed to optimize the spatial allocation of agricultural resources. Agricultural water and land resources monitoring information services will be market-based and socialized.

By 2050, the monitoring coverage of cropland soil pollution, non-point source pollution, groundwater level, and environment of the original location of agricultural products will reach 100%, indicating the achievement of the goal of modern agricultural governance. Agricultural water consumption will be effectively controlled, and fertigation technology will be promoted all way round to realize the goal of green agricultural development. Application systems of agricultural water and land resources monitoring and assessment, government services, supervision and decision-making will be established to form the management pattern of data-based supervision, service, and decision-making.

4.3 Technology roadmap

From 2025 to 2050, technological R&D, integration, and demonstration will focus on quantity and quality monitoring of agricultural water and land resources, spatial-temporal dynamic monitoring of agricultural water and land resources utilization, and ecological environment monitoring of agricultural water and land resources in an attempt to improve the utilization rate and productivity of agricultural water and land resources, optimize spatial allocation of resources, and enhance intelligent monitoring and service level of water and land resources (Fig.2).

By 2025, emphasis will be on smart soil sensors, smart irrigation water sensors, agricultural resources big data, cognitive computing, and other key generic technologies. Efforts will be made to develop standards and specifications for monitoring data acquisition, monitoring patterns, big data management, and application of agricultural water and land resources and compile an open and shared directory of agricultural water and land resources monitoring data. The satellite, aerial, and ground integrated monitoring system of agricultural water and land resources will be built to form a sensor equipment system represented by the satellite, aerial, and ground integrated mobile monitoring platforms.

By 2035, the smart land technology R&D will be strengthened by focusing on key intelligent technologies, including land resources surveys, assessment, planning, and supervision. A big data platform for agricultural water and land resources monitoring will be built to ensure the cleaning, integration, querying, operation, mining, analysis, and visualization of massive monitoring data of agricultural water and land resources.

In 2050, breakthroughs will be made in big data analysis of water and land resources and blockchain application technology, and agricultural water and land resources monitoring data sharing and management systems will be developed based on blockchain technology. Intelligent sensing equipment for monitoring systems and big data platforms will be efficiently connected through smart contract management. Interunit, interdepartmental, and interregional monitoring data for agricultural water and land resources are open and shared.

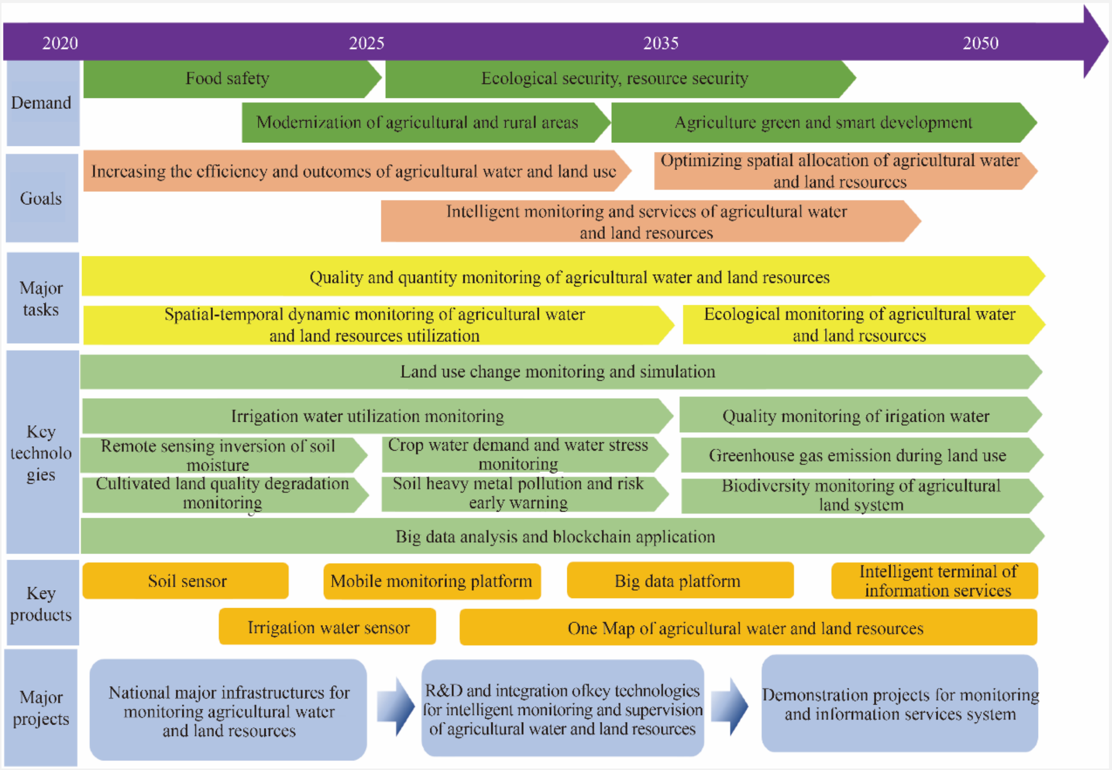

Fig.2. Roadmap of monitoring and information services of agricultural water and land resources.

4.4 Suggestions for major projects

4.4.1 National major infrastructures for monitoring agricultural water and land resources

A satellite, aerial, and ground integrated monitoring system of agricultural water and land resources shall be developed, covering smart soil sensors; smart irrigation water sensors; satellites, aerial, and ground integrated mobile monitoring platforms; and other sensor equipment to build a national monitoring network. Efforts shall be made to build a big data platform for monitoring agricultural water and land resources and develop a monitoring data sharing and management system of agricultural water and land resources based on blockchain technology to efficiently connect intelligent sensor equipment of monitoring systems and big data platforms, build agricultural water and land resources monitoring infrastructures, and establish an integrated service platform for agricultural water and land resources monitoring data openness and sharing in support of specific application services.

4.4.2 R&D and integration of key technologies of satellite, aerial, and ground integrated monitoring of agricultural water and land resources

An agricultural water and land resources monitoring technology system shall be established, including precipitation-crop yield impact simulation monitoring, irrigation water consumption monitoring, remote sensing inversion of soil moisture, field crop water demand and water stress monitoring, cropland irrigation and drainage water quality monitoring, and agricultural water resource utilization risk assessment. Smart land technology innovation shall focus on breakthroughs in land resource monitoring technologies, such as land use change monitoring and simulation, cropland quality degradation monitoring, heavy metal soil pollution and risk warning, cropland inputs and high-intensity utilization monitoring, monitoring of greenhouse gas emissions in land use activities, and agricultural land system biodiversity monitoring. Big data analysis; blockchain application; and satellite, aerial, and ground integrated monitoring technologies shall be developed to make agricultural water and land resources monitoring more scientific, systematic, and precise.

4.4.3 National business operation monitoring and information service system of agricultural water and land resources

Efforts shall be made to develop standards and specifications for monitoring data acquisition, monitoring patterns, big data management, and application of agricultural water and land resources; and compile an open and shared directory of agricultural water and land resources monitoring data. Data co-construction and sharing shall be

DOI 10.15302/J-SSCAE-2022.01.008

conducted among units, departments, and central and local governments, and the demonstration and application capacities of digital agricultural technologies, equipment, and systems shall be enhanced. A national business operation monitoring and information service system of agricultural water and land resources shall be established to provide data on agricultural water and land resources to governments at all levels and provide dynamic monitoring information of agricultural water and land resources to relevant parties as auxiliary decision-making services.

5 Suggestions for countermeasures

5.1 Strengthening overall planning and expanding investment channels

Top-level design and planning of agricultural resources surveys and monitoring should be strengthened to effectively solve major and urgent problems. The demands of relevant management departments should be integrated into survey and monitoring plans. The existing fund channels for financial budget should be effectively used, and financial support at all levels should be reasonably increased to meet demands for satellite remote sensing monitoring, Internet big data monitoring, agricultural resource management systems, and other infrastructure and equipment, and improve the comprehensive capacity to use relevant big data. Multi-party and multi-input operation mechanisms should be established based on public-oriented service functions and support from market resources. Attempts should be made to include the funds required for agricultural resources surveys and monitoring into financial budgets at all levels through communication and coordination. Existing survey and monitoring projects should be optimized and integrated to focus on major survey and monitoring tasks.

5.2 Strengthening infrastructure construction to promote innovation and application

In view of the urgent demands and weaknesses of agricultural resources monitoring development, information and communication technology should be applied in the field of agriculture to consistently improve infrastructure for agricultural water and land resources monitoring and information services and accelerate sustainable construction of hardware and software infrastructures. Innovative breakthroughs should be made in advanced basic theories, key generic technologies, and system integration, such as research on the application of AI, blockchain, big data, mass data management, and stereoscopic display in surveys and monitoring. Emphasis should be on key generic technologies, such as multi-source information acquisition and digital analysis, big data storage and efficient processing in agriculture, dynamic monitoring and early warning of agricultural resources, quantitative simulation, and intelligent decision-making models. Scientific research institutions, universities, and enterprises should be encouraged to form innovation alliances to reasonably determine the benefit distribution mechanism, jointly research and develop environmental monitoring equipment, and improve localization levels.

5.3 Building an important monitoring and sharing platform of agricultural resources

Agricultural resources and environment monitoring involve departments in charge of agriculture and rural areas, water resources, natural resources, ecological environment, meteorology, and forestry and grass. It is suggested that the National Development and Reform Commission should take the lead in establishing a multi-source data co-construction and sharing mechanism based on top-level design. The barrier-free channels for transferring agricultural resource monitoring data should be established among different departments. The functions of access control and system monitoring should be graded based on different users, data, and services. A monitoring data sharing platform of important agricultural resources should be set up to form networked agricultural data and build a database. After the integration of local institutions, resource accounting and data sub-platforms should be established at provincial, municipal, and county levels to interconnect and share with national data platforms, with the aim of ensuring smooth and efficient operation of agricultural resources accounting system.

5.4 Integrating various parties to deepen coordinated development of government, industry, universities, research institutes, and users of agricultural resources

An innovation platform integrating government, industry, universities, research institutes, and users of agricultural resources should be established based on scientific research and industrial advantages of multidiscipline, multi-field and multi-department. To solve key scientific and technological issues in regional or industrial development, the government, enterprises, universities, research institutes, and monitoring units should work together to promote original breakthroughs and coordinated development of theory, technology, systems, and equipment. In terms of mechanism, a reasonable operation pattern that considers the interests of all parties should be developed to explore a long-term sustainable development path and build a two-way integration mechanism of scientific and technological innovation and industrial application.

5.5 Strengthening team building by introducing and cultivating talents

Based on existing teams and organization, various units should give full play to their professional advantages and implement survey and monitoring tasks to maintain a rigorous and orderly operation. It is suggested that the existing survey and monitoring workers should be integrated through institutional reform. The working mechanism should be optimized to form professional support teams for agricultural resources survey and monitoring and gradually realize a new agricultural resources survey and monitoring pattern for national surveys, local testification, and data distribution and sharing. Attention should be paid to cultivating interdisciplinary professionals in theory, technology, methods, and application of agricultural resources monitoring and management. Social forces should be introduced to develop market-oriented surveys and monitoring teams. Research workers from research institutes and universities should be actively absorbed in surveys and monitoring to give full play to their professional expertise and knowledge. In addition, innovative Chinese talents and teams should be encouraged to develop in-depth cooperation with world-class universities and institutions in digital agriculture, agricultural remote sensing, and information technology.

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