

Article

A Collaborative Sensing System for Farmland Water Conservancy Project Maintenance through Integrating Satellite, Aerial, and Ground Observations

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Abstract: More and more attention has been paid to farmland water conservancy project (FWCP) maintenance in China, which can reallocate water resources in a more rational and efficient manner. Compared with the traditional survey such as field survey, FWCP maintenance can be improved efficiently with geospatial technology. To improve the level of FWCP maintenance in China, a collaborative sensing system framework by integrating satellite, aerial, and ground remote sensing is put forward. The structure of the system framework includes three sections, namely the data acquisition, the operational work, and the application and service. Through the construction and operation of such collaborative sensing system, it will break through the limitation of any single remote sensing platform and provide all-around and real-time information on FWCP. The collaborative monitoring schemes for the designed FWCP maintenance can engage ditch riders to maintain more effectively, which will enable them to communicate more specifically with smallholders in the process of irrigation. Only when ditch riders and farmers are fully involved, irrigation efficiency will be improved. Furthermore, the collaborative sensing system needs feasible standards for multi-source remote sensing data processing and intelligent information extraction such as data fusion, data assimilation, and data mining. In a way, this will promote the application of remote sensing in the field of agricultural irrigation and water saving. On the whole, it will be helpful to improve the traditional maintenance problems and is also the guarantee for establishing a long-term scientific management mechanism of FWCP maintenance in developing countries, especially in China.



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1. Introduction

Irrigation is crucially important in sustaining global food production, as nearly 40% of crop production takes place on irrigated land worldwide. Additionally, about 70% of global freshwater use is consumed by irrigation, using a great majority of freshwater than for industry and other human activities [1–3]. With the growing water needs of human societies, the constraining effect of the availability of water resources on global food security is very obvious. The approaches that conserve water or use it more efficiently other than increasing human appropriation of water resources by expanding agriculture or more withdrawals for irrigation should be adopted [4].

Farmland water conservancy projects, including reservoirs, agricultural ponds, sluices, pump stations, hydropower stations, culverts, etc. are constructed to alleviate the discrepancy between water demand and water supply during the crop growing season, and play an increasingly important role in agricultural production. During the period of 2011–2015,

the rural infrastructure construction in China has promoted the sustainable development of agricultural economy and influenced the economic society and ecological environment [5] through increasing water use efficiency (WUE) and ameliorating the temporal and spatial distribution of the streamflow. In addition to investments, comprehensive policies should be formulated to maintain irrigation infrastructure and carry out monitoring system construction for scientific and reasonable water use [6]. Specifically, farmland water conservancy project (FWCP) maintenance should include monitoring and protecting farmland water conservancy facilities, planning irrigation water use, irrigation water dispatch and schedule management, irrigation efficiency and WUE evaluation, etc. Maintaining FWCP needs timely spatial distribution information of FWCP, crop planting structure, crop growth, irrigated area and irrigation water consumption, and other information, which is expected to satisfy water demands, minimize operating costs and energy consumption, and finally improve WUE. Whereas, FWCP has the characteristics by a large scope, complex spatial distribution, small and trivial especially in China. When maintaining FWCP, the traditional survey such as field survey leads to some problems, i.e., slow collection speed, poor timeliness, long time needed, and high labor cost (Figure 1). Ultimately, hydrological uncertainty and the high cost of irrigation infrastructure improvements cannot encourage farmers, ditch riders, and irrigation-dependent communities to invest in water conservation measures [7].



Figure 1. Traditional survey for FWCP maintenance in China.

With the development of geospatial technology, remote sensing, geographic information system (GIS), and global positioning system (GPS) have been widely used in the dynamic monitoring and management of soil erosion, agricultural WUE, agricultural water consumption, etc. [8,9] and can improve FWCP maintenance efficiently. The usage of a decision support system (DSS) can assist ditch riders in planning and implementing water delivery operations more efficiently. As a logical arrangement of information including

mechanism models, irrigation data, GIS, and graphical user interface (GUI), information on water demand in an irrigated area can be organized and then the available water supplies will be scheduled to efficiently fulfill the demand. Yet, without comprehensive real-time observation information, the model in a DSS still has large discrepancies with the actual practice on a hefty sum of laterals [10]. Fortunately, remote sensing technology can provide comprehensive objective information through analyzing electromagnetic radiations reflected or emitted by surface objects. Currently, satellite remote sensing and unmanned aerial vehicles (UAVs) remote sensing are popular in maintaining FWCP respectively, though there has been poor coordination and integration of multi-source big data and practical applications need improvement [11–14]. The integration of satellite remote sensing, UAVs, and ground observations can make up for the deficiency of single observation scale or dimension, causing remote sensing big data to form the coordination and interaction in the spatial and temporal scale, dimension and multiple parameter information acquisition, and build a three-dimensional monitoring network [15–17]. When considering FWCP maintenance, satellite remote sensing has the advantages of large coverage and space continuity, which can realize the full coverage monitoring of an irrigated area. UAVs have the characteristics of high precision and time continuity, being used to supplement the lack of satellite remote sensing information and realize the monitoring of irrigation and water conservancy projects in key regions. The ground observations mainly refer to the probes and field survey, which are often used to realize the acquisition of information of FWCPs in key positions and provide precision information to verify the satellite and aerial remote sensing. The no. 1 Central Document, issued by the Chinese Central Government in 2021, stated that big data should be combined with cloud computing, Internet of Things, and other modern technologies to promote the informatization and business level of FWCP construction and management for rural revitalization [18]. Developing a FWCP maintenance platform based on the satellite-aerial-ground sensing system can achieve full coverage on the irrigated area, including key regions, important growing periods for crops, routine monitoring on the full cycle of crop, emergency maintenance, etc. It will be helpful to improve the traditional maintenance problems and is also the guarantee for establishing the scientific long-term management mechanism of FWCP maintenance. The real-time of scientific mechanism can be provided with an active regulation and thus, high-quality service can meet FWCP maintenance. Furthermore, a demonstration project could increase the level of awareness among ditch riders on the potential of multi-source remote sensing data and improve irrigation performance through promoting the use of such technologies. Apart from making out the process of irrigation (which is directly related to the field of water resource), it is also very important to learn the factors of crop growth and the associated stresses [19]. A multi-source collaborative sensing network system integrating the established satellite, aerial, and on-the-ground observations will be in a position to achieve high-precision and high-efficiency of dynamic observation of farmland resources under complex conditions. Only such a system, including biological, water, landscape, and other technologies, could set up an ecological land consolidation technology system and minimize the construction and follow-up maintenance costs as much as possible [20].

To improve the level of FWCP maintenance in China, a collaborative sensing system architecture is proposed by taking advantage of space remote sensing, aerial remote sensing, and ground platform observation with diverse spatial-temporal observation information. Then, the service of such collaborative remote sensing system in maintaining FWCP is analyzed at length. Finally, the methods and technologies for realizing such FWCP maintenance system are discussed briefly.

2. The System Architecture Proposed

With the growing population, increasing urban and industrial water demand, and contrary pollution effect, the efficient use of fresh water is becoming increasingly important in China. The water resources for farm irrigation in northern China mainly come from groundwater, while the irrigation in southern China commonly uses surface water.

Nowadays, the main type of irrigation in China is still conventional flooding irrigation (furrow irrigation). Though drip irrigation can accurately control the timing and amount of irrigation and is popular in developed countries, little effort has been made to implement it in soil cultivation systems in China [21]. In addition, China, the largest rice producer in the world, needs one half of all freshwater use under a continuously flooded condition to meet the rice requirement. To lessen the water shortage and improve the water use efficiency, more attention has been paid to optimizing irrigation and management, i.e., seasonal continuous flooding, alternate wetting and drying irrigation, continuous soil saturation, improved rice cultivation system, etc. for achieving more water-efficient irrigation [22]. Greenhouse gas emissions could be reduced by 37% and water productivity increased by 34% through certain optimized irrigation and management [23]. One fact that smallholder farming dominates Chinese agricultural landscape dispersedly makes water use efficiency lower. A comprehensive decision support system can effectively help farmers adopt optimized irrigation and management through collaborative information [24]. Therefore, timely and objective monitoring information of FWCP and the corresponding irrigation decision-support will encourage farmers to collaborate effectively for water sustainability in China.

When considering such information flow from multi-resource remote sensing data, the framework of the collaborative sensing system for FWCP maintenance is proposed through integrating satellite, aerial, and ground observations in order to maintain FWCP digitally and intelligently (Figure 2). The structure of the sensing system framework includes three sections. The operational conditions and abnormal information on FWCP should be sensed omni-directionally and in real-time. Information derived from integrating satellite, UAVs, and ground observation can meet such requirement. The data acquisition section firstly proposed would provide standardized spatial-temporal databases through standardizing multi-source heterogeneous data and afford the necessary data for the system's functions. The projected databases will include input modules on the water demand and the supply network. In this section, the basic information database and FWCP base should be standardized completely to support maintenance, where Table 1 lists the relevant elements of the bases. The second section is on the operational work namely. This section is the hub of the platform to connect the background databases and realize the man-machine interaction. The crop condition analysis, irrigation water requirement (IWR) analysis, water consumption analysis, WUE, risk assessment and contingency plans, and other functions can be realized by analyzing the monitoring data. Finally, the human-computer access interface on the basis of the Web Service architecture would be built with a visual display and human-computer, that is, an application and service section. This section mainly displays the spatial-temporal distribution status of FWCP and real-time water consumption and supports the query of the emergency plan.

Table 1. Elements referred to two databases in the system.

Item	Elements
Basic information database	Irrigated area, soil permeability and types, water depth, depth to the groundwater table, impermeable soil layers, cropping patterns, crop types, meteorological data, etc.
FWCP base	Lateral canal, main canal, irrigation service area, canal length, irrigated area, main canal layout, lateral canal layout, wells, drains, pump station type, pump head, service life of pump, the hydroelectric conversion coefficient of the pump station, FWCP maintenance criteria, etc.

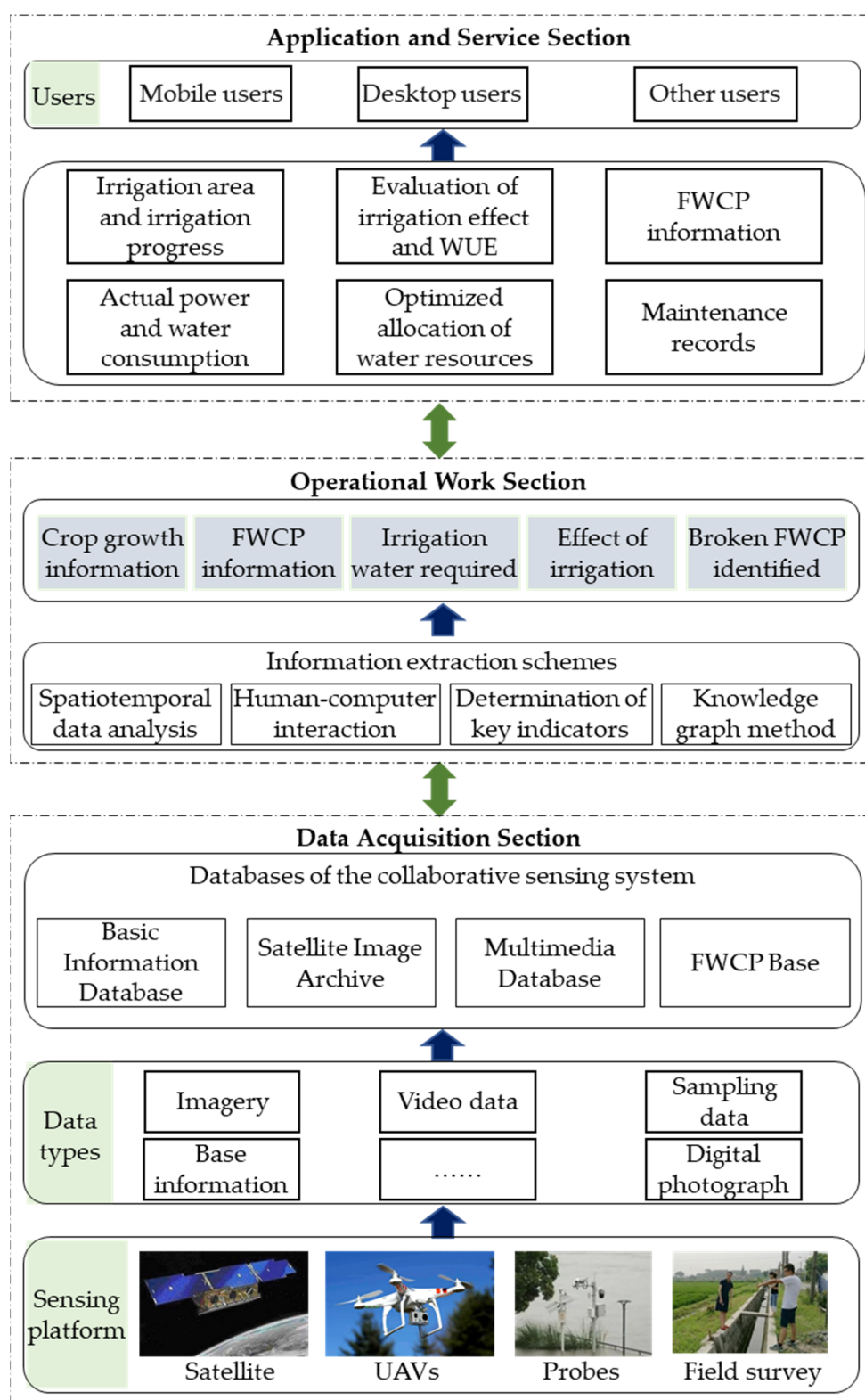


Figure 2. Architecture of collaborative sensing system for farmland water conservancy project maintenance.

In general, the system will fulfill the integration of the existing basic spatial data and various sensing data to supervise visually according to the hierarchical information management requirements. Using technologies such as remote sensing, GIS, GPS, location image and internet plus, the dynamic perception, rapid research and judgment, and real-time alarm of the operating status of FWCP will be realized. The flow rates of water

diversion and drain discharge can be measured directly, and thus all canal spills could be worked out indirectly. All of these will be reported online. A GUI is the framework for linking the three sections and can provide the users with the ability to access data and output for the system.

3. Maintenance Service Analysis of the Collaborative Sensing System

The objective of FWCP maintenance is to make irrigation more efficient during the crop growing season. Through employing remote sensing big data for irrigation estimation, the main information such as irrigation signal or irrigation mapping, irrigation amount, and seasonal timing of irrigation is very useful to evaluate the quality of FWCP maintenance [25]. Generally, the spectral patterns of a single image can be satisfied to distinguish between irrigated and non-irrigated areas, while assessing the spatial-temporal variations of irrigation patterns needs using time series images over a time period (e.g., the crop growth period) [26]. When monitoring crop growth conditions, the temporal frequency of key image acquisition should be high, a suggesting frequency is 1–3 days of revisits, and spatial resolution requirements should be in the range of 1–10 m to meet the minimum management unit. In addition, the challenge in mapping irrigation across large areas is especially obvious in fragmented landscapes with small irrigated and cultivated fields, where the spatial scale of observations counterposes the need for high frequency temporal acquisitions [27]. Satellite remote sensing is good at studying three aspects, identifying the irrigations locations, quantifying the amount of irrigation water supplied or the amount of water quantified to reduce the crop water stress, at large scales [28]. However, the main disadvantage is that satellite remote sensing is susceptible to weather conditions. Even for high quality satellite, such as sensors on Landsat and SPOT with finer spatial resolution and temporal resolution, the difficulty is still how to meet the monitoring need of crop water stress at a farm scale [28]. While the UAVs remote sensing system could collect crop information and FWCP in a desirable spatial-temporal resolution, the advantages lie in low-cost, being easy to construct, convenient transportation, high flexibility, short operating cycle, and high spatial-temporal resolution. When crop water stress occurs, UAVs can be more suitable to work quickly and meticulously at a farm scale [29]. Although the in situ data are most accurate, their spatial coverage is inadequate and it is often expensive to deploy radars and sensors to improve their spatial-temporal resolutions, especially in developing countries.

Irrigation is mainly carried out before crop sowing and during the whole growth period. To some extent, irrigation tests the FWCP maintenance level routinely (non-water requirement period) and in an emergency (water requirement period). Therefore, the collaborative monitoring schemes for FWCP maintenance through integrating satellite, aerial, and ground remote sensing are designed from the perspective of routine and emergency maintenance after analyzing favorable remote sensing data.

3.1. Favorable Sensing Data for FWCP Maintenance

The accurate and effective observation information related to the FWCP condition is a guarantee of the quality of FWCP maintenance. In this system, information such as crop water shortage diagnosis and irrigation decision making mainly depends on the data from filed probes, field survey, UAVs, and satellite remote sensing. GaoFen satellites (GF series), launched by the China High-resolution Earth Observation System, have the ability to provide high spatial resolution, high temporal resolution, and high spectral resolution. When improving the relevant infrastructure construction and forming a stable operation system, it is a favorable choice to derive information from the GF series for obtaining regional soil moisture data with continuous high spatial resolution [30]. Probes can provide high resolution images continuously, but the drawback is their small coverage. With UAVs remote sensing, soil parameters, crop morphology parameters, and canopy temperature can be derived from visible light, near infrared, and thermal infrared data with high spatial-temporal resolution. With the handheld-intelligent terminal, GPS, and

other ground measure equipment, the main task of the field survey is to collect high-precision information. Through integrating multi-source favorable sensing data, the spatial variability and the mutual relations among the FWCP condition, soil conditions, crop phenotypes, and other parameters would be analyzed accurately. The spatial variability of crop water shortage can be quantified as soon as possible [31–35]. Table 2 lists the multi-source data and the sensed elements in the proposed system.

Table 2. Favorable multi-source data and the sensed monitoring elements of the collaborative sensing system.

Data Source	Data Characteristic			Sensed Elements	Data Acquisition Cost
	Sensor	Band	Spatial Resolution		
GF series	Panchromatic, multispectral, hyperspectral sensors	Panchromatic, red, green, blue, near infrared, red edge	Pan: 1 m or 2 m, multispectral: 4, 8, 16 m	Crop growth, crop planting area, FWCP, surface temperature, soil moisture, etc.	Free under the agreement
UAVs	Multispectral, hyperspectral, thermal infrared	Multispectral, hyperspectral, thermal infrared	Centimeter scale	Crop growth, FWCP, surface temperature, soil moisture, etc.	Low cost, high flexibility, but short operating cycle
Ground sensors	Thermal infrared radiometer, TDR (time-domain reflectometry), pan evaporation, water level meter, Acoustic Doppler Current Profile			Surface temperature, soil temperature, evapotranspiration, precipitation, runoff, etc.	High cost, distribute discretely, low coverage

3.2. Service Analysis

3.2.1. Routine Maintenance Analysis

Routine FWCP maintenance mainly includes managing facilities, safety-inspection and overhaul, etc. Figure 3 expresses the routine maintenance process in the proposed collaborative sensing system. The continuous enrichment of GF series data can meet monitoring FWCP and farmland utilization in time. The ground-based probes are used to measure the FWCP and farmland soil moisture directly. In routine maintenance, the status of FWCP is judged according to the information provided by satellite remote sensing and ground-based probes. If the status is in good condition, it indicates that the FWCP can work well according to the maintenance criteria. In the case of abnormal conditions, the targeted cooperative operation mode of UAVs remote sensing and field survey will be carried out on the basis of the spatial information provided by satellite remote sensing and ground-based probes to maintain accurately. Relevant thresholds should be set according to an irrigated area condition. In addition, information from satellite remote sensing and ground-based probes will be collected and analyzed automatically with reference to the threshold values. On this basis, the ditch rider decides whether or not to carry out further maintenance with UAVs and field survey.

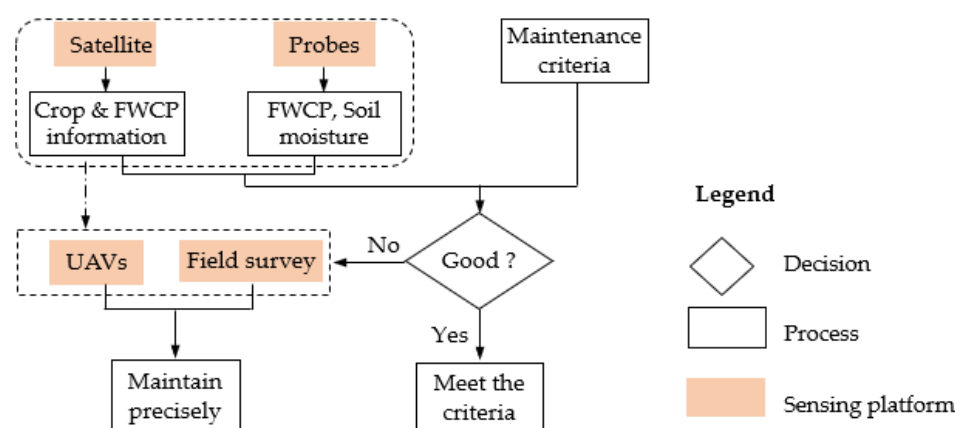


Figure 3. Flowchart for routine maintenance (the dotted arrow indicates that the sensing platforms in the round corner box with a dashed line are combined with those in the dotted rectangular box to maintain precisely due to the poor FWCP condition).

3.2.2. Emergency Maintenance Analysis

Quantifying water balance components can better initiate and evaluate water conservation practices, improve irrigation scheduling, etc. [36]. It is of great importance to allocate water resources optimally and manage supply and demand [37]. In the Middle Rio Grande Conservancy District DSS, scheduling demand based water deliveries is the basis for accurate canal operation. By distributing water among users in a systematic scheduled fashion, an irrigated area can increase WUE, decrease water diversions, and still be satisfied with crop water use requirements, without more irrigation equipment [10]. It is well known that the scheduled water delivery (SWD) is an optimal way to improve water delivery and to support water conservation in irrigation systems. In SWD, water from the main canal is allocated to lateral canals based on their crop water requirements (CWRs), ensuring optimal water use among laterals. Moreover, water delivery can be scheduled within laterals, whereby water use is distributed in turns among farm turnouts along a lateral. Finally, irrigation water will be quantified in two ways, as listed below: (1) Estimate IWR and (2) estimate irrigation water consumption (IWU).

When water shortage exists, crop growth and yield will be suppressed. At the moment, irrigation should be carried out according to the IWR and the FWCP should work well. The maintenance during this period belongs to emergency circumstances in the collaborative sensing system. Figure 4 is the flowchart for emergency maintenance of FWCP, which is obviously different from the routine maintenance. The main factors including meteorological conditions, water and nutrient availability, and the amount of absorbed photosynthetically active radiation determine the crop yield. In order to produce the expected yield, the main factors mentioned should meet crop growth and crops should be protected from pests and diseases. In this process, the need is essential to monitor crop growth continuously. IWR would be estimated with information such as crop planting structure, crop growth, soil moisture, and irrigation quota and the information can be extracted successfully from remote sensing data [8,38,39]. Combined with evapotranspiration, precipitation, crop information, irrigation schedule monitoring, etc., the collaborative sensing system can effectively improve the efficiency of IWU [25,40]. When estimating the IWR, effective precipitation should be subtracted from the CWR. Certainly, the IWR is the amount of water that would be supplied to satisfy the potential transpiration of the crop [26]. Thus, the IWR is a function of precipitation, soil moisture, and soil properties except crop evapotranspiration. The CWR is the amount of water required not only for crop growth but also for the losses due to crop evapotranspiration. Crop evapotranspiration is influenced by weather (air temperature, humidity, radiation, and wind speed) and crop (growth stage, crop height, etc.) conditions. Although it is difficult to be directly observed by remote sensing, crop evapotranspiration can be estimated by evapotranspiration models that need parameters such as land surface temperature, land cover type, vegetation indices, and soil moisture derived from remote sensing data [28,30]. Here, crop evapotranspiration can be expressed as ET_0 (reference crop evapotranspiration) multiplied by crop coefficient (K_c), where K_c is determined by crop characteristics and soil evaporation conditions. K_c can be determined through the relationship between remote sensing spectral characteristics and vegetation features. Finally, the utilization efficiency of irrigation water can be estimated (Equation (1)) [41,42]:

$$\eta = (ET - P)/(I - D) \quad (1)$$

where η is the utilization efficiency of irrigation water, ET is the estimated evapotranspiration during the irrigation, P is for effective precipitation, I is for water withdrawal, and D is drainage water.

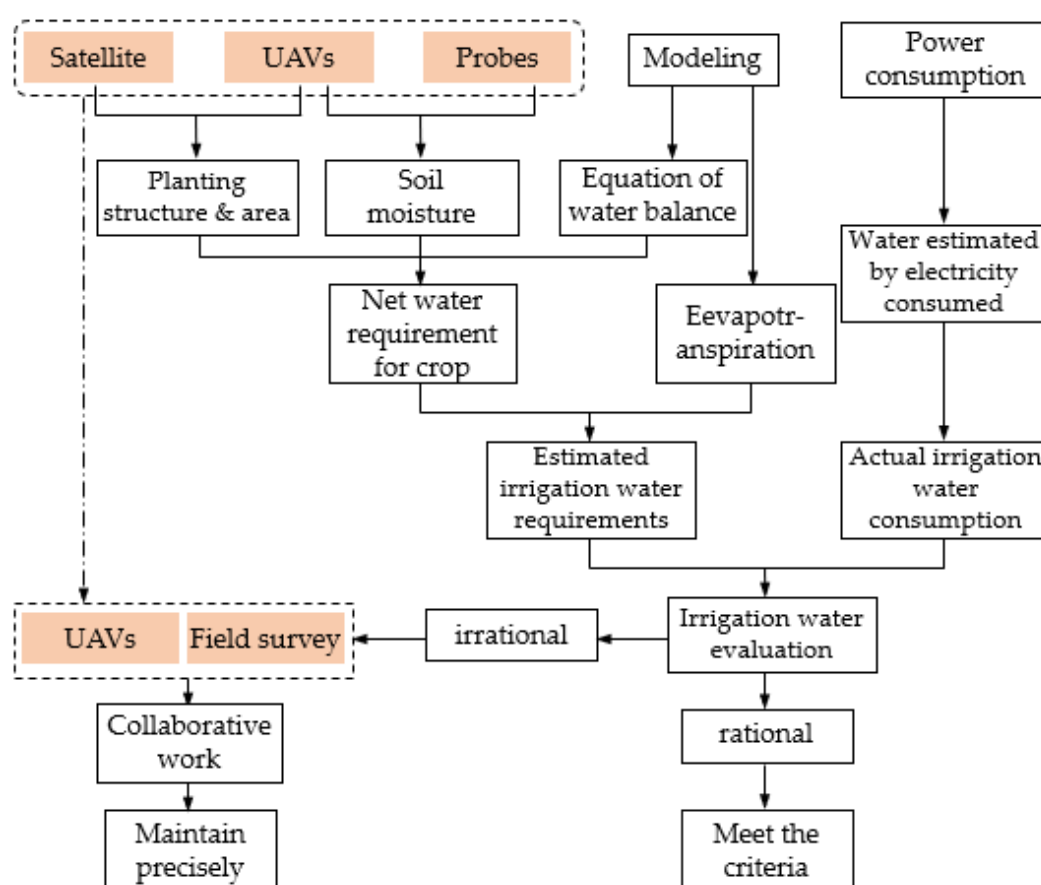


Figure 4. The flowchart of emergency maintenance of FWCP (the dotted arrow indicates that the sensing platforms in the round corner frame with a dashed line are combined with those in the dotted rectangular box to maintain precisely due to the irrational irrigation water consumption. The legend is the same as in Figure 3).

In the collaborative sensing system, the actual IWU is estimated through the hydroelectric conversion equation. Theoretically, the total amount of irrigation water is the product of electricity consumed by a pump station and the hydroelectric conversion coefficient of the pump station [43]. The hydroelectric conversion equation is expressed as Equation (2).

$$Q = E \times \mu \quad (2)$$

In Equation (2), Q is the amount of water withdrawal and the unit is cubic meters, E is the electricity consumption of a pumping station and the unit is kW·h, and μ is the hydroelectric conversion coefficient.

So far, the system should carry out the irrigation evaluation on the basis of the IWR estimated and the irrigation water by a pump station. When the IWU falls in the range of the IWR, it indicates that the conservancy facilities the work well and the FWCP maintenance is qualified. While the precision maintenance should be carried out by combining UAVs and field survey with satellite and ground probes sensing platforms for poor FWCP conditions, such as insufficient irrigation pumping capacity, it loses from irrigation canals.

4. Discussion

Several running collaborative sensing systems exist through the integrating satellite, aerial, and ground observations in China, which are developed for eutrophic lakes and reservoirs [17], precise emergency service [2,15], precise management of orchard production [44], etc. By comparison, there has been no report on the collaborative system for FWCP maintenance, which should consider many factors such as water, crop height, soil moisture, evapotranspiration, etc. In a way, it is necessary to describe the water-soil-air-

plant-human nexus to maintain precisely an irrigation district system, not just some factor alone. Similarly, the watershed, a self-organized complex system containing numerous elements at various scales, was regarded as the best unit to carry out the water-soil-air-plant-human nexus experiment [45]. Yet, when studying the heterogeneity in soil moisture, evapotranspiration, and other related ecohydrological variables, two key issues including scaling and uncertainty are still challenging with multiscale observations through integrating satellite, aerial, and ground observations in a watershed [46]. For an irrigated area, the task of FWCP maintenance is to make the relationship among water, soil, air, plant, and human more benign. Buildings and farmland are often intermingled and crop patterns are diversiform in China. These characteristics could be used to advance the study on the two issues through such a collaborative sensing system.

In the proposed collaborative sensing system, the GF series was considered an optimal satellite remote sensing data in that the GF series covers a variety of types from panchromatic, multispectral to hyperspectral, optical to radar, forming an earth observation system with high spatial, temporal, and spectral resolution capabilities. In addition, there is an increasing tendency to use the GF series for satisfactory vegetation information [47], enabling explicit extraction of cropland areas from heterogeneous and fragmented landscapes [48]. As for UAVs and ground sensors, there are too many options on UAV and sensor types, which can be tailored to the actual situation. In this system, any water loss in the conveying system is not considered and the whole amount of the released water is assumed to be delivered to the field. On fact is that conveyance and operational irrigation water losses from the lateral canal to the plot should be considered. Moreover, the amount of water loss due to seepage often falls within the discharge measurement errors with traditional methods. With new technologies, seepage losses can be determined more accurately and reliably [1,3].

As a matter of fact, two key technologies, mission-driven satellite-ground collaborative mechanism and intelligent real-time processing methods for multi-source data, should be solved when carrying out collaborative remote sensing with on-orbit processing [49]. In addition, most FWCP are characterized by a small scale and mixed with the farmland in China. Ill-posed problems still exist when extracting information and mining intelligently due to the complex and diverse land cover types. Quantifying the rootzone soil moisture is very important to get accurate inference on the IWU. In this regard, satellite soil moisture products should be assimilated in a land surface model to simulate rootzone soil moisture through positive attempts [28]. In addition, it is necessary to strengthen the research on the optimization layout method and intelligent network technology of agricultural water information monitoring network, the space-time fusion and assimilation technology of multi-source information, and the multi-index comprehensive diagnosis model of crop water shortage [33]. During data assimilation, a necessity is to address the issues on the incongruity between spatial-temporal scales of different sensors and corresponding crop models. The desirable way to solve those problems should be “demand driven,” that is, all attempts should be built on the basis of a realistic estimation of water demand. In addition, this will improve the ability of such collaborative sensing system for FWCP maintenance. In all, the main factors related to water, soil, and plant in an irrigated area should be taken into consideration for such collaborative remote sensing applications, which will lead to irrigated agricultural areas as an ideal experimental field to carry out collaborative remote sensing with on-orbit processing, data assimilating, data fusion, etc.

5. Conclusions

Maintaining FWCP under a heterogeneous irrigated area with varying irrigation scheduling is important at both non-irrigation and irrigation times. For this purpose, the possibility of integrating remote sensing data from satellite, UAVs, and ground remote sensing can be explored. In addition, we proposed a framework of the collaborative sensing system for FWCP through integrating satellite, aerial, and ground observations and assured that multi-dimensional spatial-temporal data can meet FWCP maintenance

with accurate and in-time information. The critical aspects of FWCP including crop growth, FWCP, and irrigation are considered. In addition, these measurements will be conducted on main, lateral, and acequia canals to ensure that various canal sizes are supposed to be accounted for.

Through the construction and operation of such collaborative sensing system, the limitation of any single remote sensing platform will be broken and all-around and real-time information on FWCP will be furnished. The collaborative monitoring schemes for the designed FWCP maintenance can engage ditch riders to maintain more effectively, which will enable them to communicate more specifically with farmers in the process of irrigation. Furthermore, the collaborative sensing system needs a uniform standard for multi-source remote sensing data processing and intelligent information extraction such as data fusion, data assimilation, and data mining. In other words, this will promote the application of remote sensing science in the field of agricultural water saving and irrigation. Presently, farmers in China are typically smallholders with limited resources and poor knowledge. Such a collaborative sensing system will be very important to improve WUE and water productivity in each field, which will be helpful in promoting the widespread use of optimized irrigation and management. Moreover, price leveraging is often used to stimulate farmers to invest in optimizing water management. Water fees according to the planted land area rather than the volume of irrigation water ignore the actual amount of irrigation water use, and have discouraged most farmers from investing in FWCP. Objective and detailed irrigation water information provided by such collaborative framework will be charged more reasonably and help farmers save fresh water during irrigation. Overall, it will be helpful to improve the traditional maintenance problems and is also a guarantee for the establishment of long-term scientific management mechanism of FWCP maintenance in developing countries, especially in China.

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