Simulation Study on Irrigation Water Consumption of Multi-Source Irrigation Area based on Water Monitoring

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Abstract. The simulation accuracy of irrigation water consumption in multi-source irrigation area is not high. SWAT model water cycle simulation structure and calculation of water balance elements are not suitable for irrigation district water cycle simulation. This paper puts forward a method of building water measurement and monitoring facilities in the main water circulation nodes of irrigation area, combining with the improved SWAT model to establish water circulation model to simulate agricultural water consumption in irrigation area. This method effectively realizes the combination of direct measurement and model calculation of agricultural irrigation water consumption in multi-source irrigation area.

1. Introduction
Statistics of agricultural irrigation water consumption is an important basic work of water resource management. According to the statistical requirements of irrigation water consumption, the measured water volume of water intake source should account for more than 50% of the total irrigation water volume. Because there are many types and quantities of water sources in the South Irrigation Area, the functions of water sources are various, and the water supply quantity of different water sources is greatly affected by hydrological factors, it is very difficult to realize the statistics of irrigation water consumption in the irrigation area by direct water intake measurement[1]. In view of the above problems[2], based on the theory of water cycle, combined with the characteristics of multi-source irrigation projects and water use, this paper puts forward the necessary irrigation water measurement and monitoring combined with the simulation of irrigation water cycle process to extract the irrigation water process, and then determines the statistical method of agricultural water consumption in the irrigation area.

2. Measurement and monitoring of irrigation water consumption in multi-source irrigation area

2.1. Characteristics of multi water source irrigation area
The unique landform and the nearby irrigation habit formed for a long time form the irrigation area irrigated by many irrigation water sources. The following characteristics commonly exist in the South multi water source irrigation area:

(1) Diversity of water sources: The irrigation water source of the irrigation area includes reservoir water and river water; the water source project includes reservoir, mountain pond and other water storage projects with regulation and storage capacity, dam water diversion project (raising water level through weir dam), pumping station water lifting project, etc.

(2) Complexity of configuration: After many years of construction and transformation, the water transmission and distribution project in the irrigation area is more complex, and most of the regional
irrigation is multi-source combined water supply. In actual operation, river water and mountain pond water are generally preferred, followed by reservoir water (from small to large and medium-sized reservoirs). At the same time, the functions of irrigation water sources are also diverse. Agricultural water, industrial water, domestic water and ecological environment water are overlapped.

(3) Randomness of water supply: Because of the randomness of the hydrological year and the complexity of the allocation, there is randomness in the size and proportion of water supply from different sources. For the "long vine and melon" type gravity flow irrigation area, the small-scale water source project (weir, mountain pond, small reservoir, etc.) undertakes most of the irrigation functions in the wet year, and the water supply of the main water source (such as large and medium-sized reservoirs) is small, which accounts for a small proportion of the total water supply of the irrigation area; in the dry year, due to the limited regulation and storage capacity of the small-scale water source project, the main water source project is used in the peak period of irrigation Water, so the proportion of the main water source in the total water supply of the irrigation area will be very large.

2.2. Measurement and monitoring of irrigation water consumption
Because there are many water source projects in the irrigation area and the hydraulic connection is complex, it is neither realistic nor economical to monitor and analyze the water consumption of all water source projects. Based on the measurement and monitoring of the main water sources and important water supply and consumption and drainage nodes, a water cycle simulation model of irrigation area is established to simulate and analyze the overall idea of irrigation water consumption and determine the measurement and monitoring layout of irrigation water consumption. The measurement and monitoring of irrigation water consumption in irrigation area should reflect the principles of important project (node) control and various water source projects coverage.

(1) Water intake: the water intake of the main water source project and the water intake of different types of typical water source projects are measured and monitored.

(2) Channel outlets: the important outlets of the main channels shall be measured and monitored, and the outlets reflecting the complete supply, consumption and discharge relationship of specific areas shall be measured and monitored when conditions permit.

(3) Irrigation water intake: measure and monitor the irrigation water intake which represents the planting structure and management level of the irrigation area.

(4) Regional drainage outlet: the drainage outlet with clear water conservancy relationship, which can basically represent the regional drainage, shall be measured and monitored.

3. Simulation model of irrigation water consumption in irrigation area

3.1. SWAT Model Improvement
SWAT model was developed by Dr. Jeff Arnold of USDA Agricultural Research Center in 1994. It is a Distributed Watershed Hydrological Model Based on GIS. It mainly uses the spatial information provided by remote sensing and GIS to simulate a variety of different hydro physical and chemical processes, such as water quantity, water quality, and pesticide transport and transformation process. Compared with the functions of SWAT model and the general requirements of irrigation water consumption simulation, SWAT model still has some shortcomings in simulating irrigation water cycle structure, water balance elements, multi-source irrigation, etc. The improvement measures are as follows:

(1) Water cycle simulation structure improvement: adjust the water balance simulation sequence of SWAT model, and simulate paddy field as an independent HRU, so that its water cycle simulation level is the same as that of other land use types. At the same time, runoff calculation and seepage calculation of paddy field in impoundment period and non impoundment period are distinguished orderly.
(2) Improvement of water balance factor calculation: in terms of rice field volume calculation, the SWAT model is modified to identify it as a cone, and the rice field surface area is set as its HRU area. At the same time, considering the ridge around the paddy field and introducing the coefficient of the ridge, the part of the ridge need not be irrigated in order to make the irrigation simulation more accurate\cite{5}.

(3) The realization of multi-source irrigation mode: Based on the simulation of mountain pond as irrigation water source, the multi-source combined irrigation mode is introduced, which can simulate the irrigation water amount of different water sources in a given water supply sequence.

3.2. Simulation model construction

(1) River network extraction and subwatershed division: river network extraction and subwatershed division are the basic work of constructing irrigation water consumption simulation model, which not only affects the simulation accuracy of irrigation water consumption, but also determines whether the simulation model can simulate the water consumption of monitoring points. River network extraction uses the distribution map of irrigation area water system to achieve the extraction of irrigation area river network with the help of digital software. On the basis of river network extraction, the subwatershed division is realized by setting the threshold of rainwater collection area and adding control nodes.

(2) Discretization of HRU: SWAT model mainly discretizes HRU according to land use type, soil type and terrain data. On the basis of loading land use data and soil data, the subwatershed is divided into HRU by setting the threshold of land use area, the threshold of soil type area and the threshold of slope.

(3) Basic data input: input basic information such as hydrometeorology, reservoir basic information, mountain pond basic information, field management measures, irrigation water source correspondence, etc. according to SWAT model data format.

3.3. Model calibration

The main task of model calibration is to determine the model parameters, and the main purpose is to make the model simulation results after calibration consistent with the actual water cycle of irrigation area.

(1) Model calibration data: the flow data of the drainage basin where the irrigation area is located and the water intake data of the important nodes are used. The actual monitoring flow or the flow obtained by hydrologic analogy method are used for the flow data of the drainage basin outlet; the water consumption measurement monitoring data are used for the water intake data of the important nodes.

(2) Model calibration parameters: it is necessary to calibrate the relevant parameters of SWAT model, such as yield and runoff simulation, terrain characteristics, land cover characteristics, conventional agricultural irrigation management, and the field loss coefficient, river irrigation water control coefficient and mountain pond irrigation water control coefficient after SWAT model improvement.

(3) Model calibration process: Based on the parameter sensitivity analysis of SWAT model parameters with SWAT? Cup and manual parameter adjustment, the model simulation effect can reach a reasonable range. For SWAT model, the parameters are adjusted manually to make the simulated water quantity and monitoring water quantity in a reasonable range.

(4) Evaluation of calibration effect: the relative error, Nash Sutcliffe efficiency coefficient and linear regression coefficient are calculated respectively by using the measured data and simulation results to evaluate the calibration effect of the model.
4. Study on typical irrigation area

4.1. Irrigation area survey
Wanyao irrigation area is located in Jiangshan City, Quzhou, in the southwest of Zhejiang Province. The total land area of the designed irrigation area is 28300 ha, and the actual irrigation area is 17667 ha. There are various types and quantities of irrigation water sources in the irrigation area. There are 2571 reservoir projects with a total storage capacity of 581 million m³, 2498 mountain ponds with a total storage capacity of 17 million m³ and 22 weirs and dams with an irrigation area of more than 67 ha.

In Wanyao irrigation area, Wanyao Reservoir and Xiakou reservoir are regarded as the control pivotal projects. The four main channels, namely Wanyao main channel, Wanyao south main channel, Xiakou east main channel and Xiakou west main channel, are combined with the surrounding small reservoir, Shantang, weir dam and other water source projects as well as the distribution channel to form an irrigation system of growing rattan and melon.

4.2. Water consumption monitoring of irrigation area
According to the distribution of water source project and canal system project in Wanyao irrigation area and the relationship between water supply and consumption, according to the principle of full monitoring of key water source project, typical monitoring of other water source projects and key monitoring of important water outlets and receptacles, 3 places are set at the downstream of Wanyao reservoir and Xiakou reservoir, 6 places are set at the downstream of other typical water sources, 16 places are set at the downstream of important water outlets and receptacles, totaling 25 places Measurement and monitoring facilities.

4.3. Simulation model of irrigation water consumption
(1) Construction of water cycle model
Based on the improved SWAT model, according to the landform conditions, river system distribution, canal system engineering distribution and water intake monitoring facilities layout of the irrigation area, using the DEM, land use, soil distribution and other data of the irrigation area, the processes of river network extraction, sub basin division, HRU dispersion, data input and so on are respectively carried out, and the water cycle simulation model of the Wanyao irrigation area is established. In the water cycle model of Wanyao irrigation area, two river basins, Jiangshan port and Daqiao Town, are set up to form 148 sub basins, 10 land use categories and 33 generalized water sources. The construction process of water circulation model in Wanyao irrigation area is shown in the figure below.
Figure 1. Water cycle model construction process of Wanyao irrigation area

(2) Parameter calibration and model verification

Based on the monthly discharge data of Jiangshan port and Daqiao town from 1990 to 2006, the susfi_2 in Swatcup was used to analyze the parameter sensitivity of the SWAT Model in Wanyao irrigation area, and the top 10 model parameters of lat_utime and gw_udelay were obtained. On this basis, with manual parameter adjustment, the sensitivity parameters of the model are calibrated, and the calibration results of the model parameters are shown in the table below.

Table 1. Parameters of water circulation model in Wanyao irrigation area

| Parameter name | Woodland | Rice   | Dry Land | Orchard | Town   |
|----------------|----------|--------|----------|---------|--------|
| LAT_TIME       | 0.035    |        |          |         |        |
| GW_DELAY       | 0.65     | 0.67   | 0.97     | 0.8     | 0.52   |
| USLE_P         | 82.39    | 73.57  | 92.61    | 79.87   | 72.73  |
| ESCO           | 0.84     | 0.36   | 0.79     | 0.71    | 0.61   |
| SURLAG         |          |        | 13.42    |         |        |
| CN2            |          |        | 0.11     |         |        |
| MSK_CO2        |          |        | 0.43     |         |        |
| MSK_X          | 0.98     | 0.98   | 0.71     | 0.44    | 0.84   |
| MSK_CO1        |          |        | 0.85     |         |        |
| SOL_AWC        |          |        | 1.15     |         |        |

The evaluation grade of relative error of periodic simulation results of water cycle model rate in Wanyao irrigation area is excellent, the evaluation grade of linear regression coefficient is good, and the evaluation grade of Nash coefficient is excellent. See the figure below for the comparison between the simulated flow and the measured flow of water circulation model in Wanyao irrigation area.
4.4. Simulation analysis of irrigation water consumption

According to the simulation results of water cycle model from 1990 to 2017, according to the statistics, under the multi-year average situation, the multi-year average agricultural irrigation water consumption in Wanyao irrigation area is 182 million m³, and the statistical results of agricultural irrigation water consumption in the irrigation area are shown in the table below.

![Figure 2. Export verification results of Jiangshan station in Wanyao irrigation area](image2)

![Figure 3. Export verification results of Daqiao station in Wanyao irrigation area](image3)

From the above table, it can be seen that the water supply of local water source projects such as river, mountain pond and small reservoir shows a change rule of more in wet season and less in dry season; the water supply of key water source projects such as Wanyao Reservoir and Xiakou reservoir shows a change rule of less in wet season and more in dry season.

5. Figures

(1) The irrigation area in South China has many characteristics, such as many water sources, complex structure of water intake system, various functions of water resources in the irrigation area, and relatively lagging measurement and monitoring facilities. The method of typical measurement
combined with water cycle simulation can effectively solve the problem of low simulation accuracy of irrigation water consumption.

(2) The water cycle simulation structure and calculation of water balance elements of SWAT model are improved, and the water cycle simulation of Wanyao irrigation area is applied. The actual simulation results show that the improved SWAT model can better adapt to the characteristics of multi-source irrigation area in South China and simulate its water cycle law and process.

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