Application feasibility of the novel SWAM Water-Cycle and Allocation Model in the Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract. At present, there are still problems, such as uneven regional distribution and low per capita ownership of water resources in the Pearl River Delta, so solving the problem of water resource allocation is still a hot spot that needs continuous attention in the region today. For a long time, many experts and scholars have proposed models such as WEAP (Water Resources Assessment and Planning) and SWAT (Soil and Water Assessment Tool). Based on the advantages and disadvantages of the current situation of water resource allocation in China, this paper explores and analyzes the applicability of the newly proposed SWAM (SWAM Water-Cycle and Allocation Model) configuration model, compares the previously proposed model, and finally draws conclusions. In this work, the author analyzes the adaptability of SWAM model in the Pearl River Delta region from various aspects and concludes that the SWAM model can effectively alleviate the problems of water resources in the Pearl River Delta region.

1.Introduction

Due to the vast territory of China, there are relatively significant environmental and regional differences between different regions, and the water resources conditions of different regions are very different. However, water resources in China have the characteristics of significant inter-annual variation and uneven distribution, and there are different degrees of water shortage in both northern and southern regions [1]. Nowadays, the total water resource in our country is about 2.8 trillion m^3. In contrast, our country's per capita water resource occupancy is only 2300m^3, which is only about a quarter of the average world level, being one of 13 relatively developing countries in the world [2]. Water resources are vital to everyone, and regional water shortages caused by scarcity and unequal distribution of water resources have caused great distress to people in different regions. In the background of climate change, dynamic adjustment of industrial structure, and the strictest policy of water resource management, the situation of water resources and the structure of water use in China are undergoing profound changes. It is essential to optimize the structure of water use and promote the efficiency of water use to solve the water safety problem in China [3]. The country is now carrying out the rational development, utilization, and protection of water resources, improving people's lives in different regions, especially those lacking water. For urban residents, the rational allocation of water resources in the city is conducive to their stable and happy life.

Water Resources Assessment and Planning (WEAP) model is a water resources allocation model with good flexibility, strong visibility, and high user-friendliness. This model can help users to evaluate water resources through scenarios set based on different input variables and shows strong applicability in basin water resources assessment [4,5]. The WEAP model has recently been widely used at home and abroad because of its unique, efficient, and convenient water resource allocation characteristics. For example, the joint allocation model of multiple water sources based on WEAP constructed by Hou Xiaoling et al. provided technical support for the scientific allocation of water resources in the Xiongan New Area [6]. Gao Liming et al. calculated the allocation scheme with the best comprehensive benefits by constructing the regional optimal allocation model of water resources based on WEAP considering dual control of water quantity and quality [7]. KhazaiPoul et al. used the WEAP model to simulate and obtain the monthly water allocation, which is a crucial variable in the multi-objective irrigation optimization of reservoirs [8]. Kahalil et al. evaluated the relationship between water resources supply and demand in the Mekong River Basin based on the WEAP model [9]. They verified the good fitting performance of the WEAP model to the measured data. Then it can support the effective management of river basin water resources. Above all, the experts and scholars in the actual application and simulation experiment prove the WEAP model can effectively cope with the problems brought by the uneven distribution of water resources, can well meet the demand for reasonable water resources allocation in different areas, and also can according to the actual situation of each region to develop a

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complementary configuration scheme, is an effective tool of modern social reasonable allocation of water resources [10-14].

Although scholars are trying to apply different water resource allocation schemes to meet local demand, we should also see that when the water supply capacity is insufficient, it can hardly meet the water requirements. Most of the existing water resource allocation models for each demand point set clear water distribution priorities, which can help satisfy every aspect of water use[15]. However, this way of resource allocation neglects one point: different water consumption industries have different tolerance to water shortage. For example, the lack of agricultural water impacts the urban economy and society less, while the lack of normal domestic water will cause significant losses to society. Meanwhile, each city of the same urban agglomeration has different development goals and functional positioning, and their economic development levels are also objectively different. It means that the priority order of water distribution in the same water industry should also be different. In order to find out a more reasonable allocation of urban water resources, in addition to the terrain, climate, population, and other factors, we should also consider the above-mentioned possible situations so that the obtained water distribution scheme will be more reasonable and more suitable.

The Guangdong-Hong Kong-Macao Greater Bay Area urban agglomeration is economically developed and densely populated and plays an essential role in national development. Bay area within the city function orientation clear, a clear division of responsibilities, economic and social development level and water level space significant difference, uncertainty and the downstream and upstream water salty tide back, as well as the influence of the water supply security, faced severe challenges [16], needs to be scientific and reasonable water resources allocation in order to improve the capacity of water resources security.

A SWAM Water-Cycle and Allocation Model (SWAM) has been proposed. This allocation model is based on the multi-objective equilibrium optimum of the water cycle simulation model and meets various constraints and system operation rules of the water allocation model [16]. According to the author of this model, this model effectively solves the shortage of multi-objective comparison in previous models to screen the optimal solution. In addition, the model also realizes the integrated simulation of the water cycle simulation and water resources allocation in one picture, which significantly facilitates water resource allocation. Based on the SWAM model, this paper explored the feasibility of applying the SWAM model to the Guangdong-Hong Kong-Macao Greater Bay Area.

2.The research method

2.1 The SWAM model construction principle

The SWAM key modules will include the Water circulation module, Multi-source water supply module, Water demand module, and Multi-objective configuration module. The model framework is shown in Figure 1. The water cycle simulation model starts with the water cycle calculation. The water supply results (the first dotted box) can be used as the basis for the multi-source water supply module. The water source of the multi-source water supply module will be supplied to the 7 different water demand modules in the second dotted box, and the multi-target configuration module will calculate the water allocation scheme. Finally, the recommended scheme is selected among the multiple water allocation schemes, and it is substituted back into the water cycle operation, and so on, until a reasonable and satisfactory result is finally obtained.

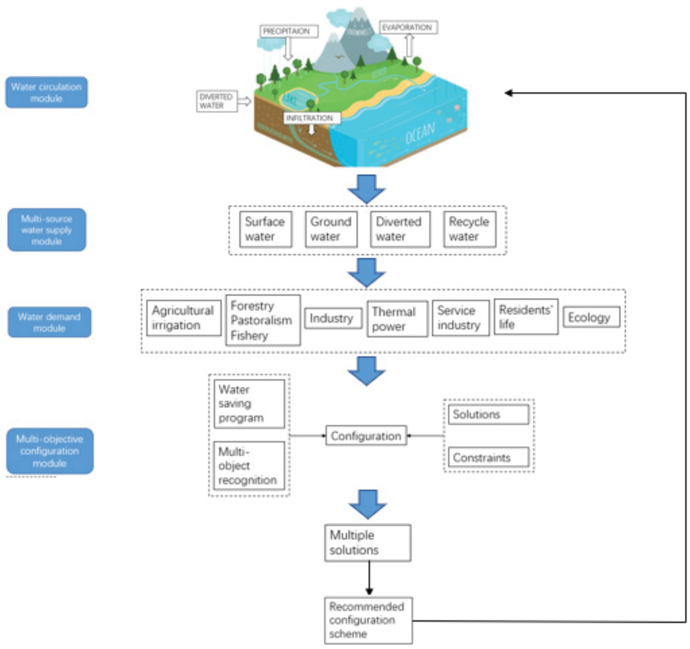

Figure 1. Model framework [17].

2.2 Model plate function description

Each module has different functions in this model, and only by cooperating with each other can the model get the best performance. The water cycle module generalizes all kinds of water conservancy projects as nodes on the watershed calculation river network. It calculates the water balance through specific rules and requirements [17]. In the multi-source water supply module, the actual water extraction in this area can be obtained by calculating the unit's water storage and the water source's available water supply. In the water demand module, water storage is divided into six aspects: agriculture, animal husbandry, industry, service industry, life water demand and ecological environment water demand. Each aspect's water demand is calculated respectively to obtain the water consumption. The multi-objective configuration module obtains a reasonable optimization scheme by calculating the objective function and constraint conditions.

3. Feasibility study of model application

3.1 Overview of study area

The Guangdong-Hong Kong-Macao Greater Bay Area urban agglomeration is one of China's three major coastal urban agglomerations. Located in the central and southern part of Guangdong Province, it comprises 11 cities, including Guangzhou, Shenzhen, Zhuhai, Foshan, Jiangmen, Zhaoqing, Dongguan, Huizhou, Zhongshan, Hong Kong and Macao [18]. The area and population account for about 1% and 5% of the national GDP, contributing 12% of the national GDP. However, per capita GDP is only 20% ~ 50% of that of other Bay areas. Therefore, the economic and social development of Dawan District urban agglomeration is highly dependent on water resources, facing tremendous development pressure, and has high requirements for water supply security. The per capita local water resources in the Greater Bay Area are only 802 m^3, less than 50% of the national average level, among which the per capita water resources in Shenzhen, Hong Kong and Macao are less than 200m^3[19]. At the same time, water supply security in the dry season is faced with significant challenges due to the dual influence of the uncertainty of upstream water inflow and upstream salt tide in the downstream. For example, several dry glasses of water in the Dongjiang River basin threaten the water supply security of Shenzhen, Hong Kong and other cities.

3.2 Analysis

3.2.1 A real-life example of the SWAM application. In Zhao's Simulation Water-Cycle and SWAM Model (SWAM), PartII. Application, the author uses the Nenjiang River basin in the Daxing 'angling Mountains as an example of SWAM model application [20]. A more detailed description of SWAM applicability to the actual watershed. In this article, the author completed the SWAM model for the Nenjiang River basin by following the following steps: partitioning the SWAM computing unit, generalizing the SWAM water resource configuration system, entering the agricultural planting information and management information, entering the SWAM configuration information, entering the SWAM topology relationship, and entering other data. In this process, the author lists which objects are included in each information item to be input so that readers can apply the model more clearly and intuitively. In addition, the author also listed the specific situation of parameter values of each model and part of the selection criteria in the article, which is conducive to the readers in the relevant calculation can get more reasonable and adequate data support, with a high degree of reference.

3.2.2 Analysis of applicability. In this paper, when evaluating the applicability of the SWAM model to the Guangdong-Hong Kong-Macao Greater Bay Area, the model selection method of water resource optimization allocation was published by Wang et al., And its application was applied [21]. In this paper, the author mentioned that the water resource allocation problem is a complex system engineering. A multi-objective model that can cover the whole situation and give overall consideration must be selected to optimize water resource allocation. Moreover, the optimized configuration needs to include five meanings: optimize the area to be determined; optimization must be based on principles of sustainability, fairness, and efficiency; optimization of the ultimate goal of sustainable utilization of water resources, a configuration object for all the available water resources, the non-engineering measures and engineering measures to realize [22], then step by step according to five meanings applicability analysis to conclude.

As for the SWAM model to be built with SWAM, there are no specifications, and it can be applied to all SWAM locations. Secondly, the principal issue is that the optimal allocation should be sustainable, fair and efficient. As mentioned above, this model realizes the modelling of water resource allocation in one picture, which greatly facilitates the analysis and comparison of data by users. In addition, the operation interface of this model is relatively intuitive, friendly, operable and convenient for users to learn and use, perfectly satisfying the principle of efficiency. As for the two principles of sustainability and equity, there is no significant amount of relevant data to conclude, so it is not mentioned as the reference object of this paper.

As for the final optimization goal, this model uses cyclic operation; the optimal water resource allocation scheme is obtained after continuous screening and repeated calculation. Therefore, this model is relatively satisfactory for realizing sustainable development of water resources. In terms of the fourth meaning, the water resources types of this model cover surface water, groundwater, external water transfer and reclaimed water, so it also meets the condition that "the allocation object is all available water resources". The last one, implemented by both non-engineering and engineering measures, is also described in the construction description of the model, so it will not be repeated here.

3.3 Results

Through the above analysis of the fit degree of the model in the above five principles, it is concluded that the model has strong applicability, so it can also be used to optimize the allocation of water resources in the Guangdong-Hong Kong-Macao Greater Bay Area urban agglomeration.

4. Conclusion

The research on optimal water resource allocation plays an essential role in solving the water resources problems in our country and realizing the sustainable utilization of water resources. It has important theoretical and practical significance in promoting the economy's and society's sustainable development [23]. The Outline of the Development Plan for the Hong Kong and Macao Greater Bay Area proposes to build an international first-class Bay Area, pointing out that it is necessary to "strengthen the unified operation of water resources in the Pearl River Basin and strengthen the security of water resources", and scientific and reasonable water resources allocation is an essential support for the security of water supply in the Greater Bay Area [24]. The rational allocation of water resources in the Guangdong-Hong Kong-Macao Greater Bay Area is significant to society and the world. Therefore, it is essential to develop a suitable model for the rational allocation of water resources in the Greater Bay Area as soon as possible. According to the brief analysis presented in this paper, the SWAM model has great potential to be a future water resource allocation program for the Guangdong-Hong Kong-Macao Greater Bay Area and beyond. Due to the limitation of space and technical conditions, this paper only analyses from the appearance and hopes to have the opportunity to further analyse the actual application in the future. Through the above analysis of the fit degree of the model in the above five principles, it is concluded that the model has strong applicability, so it can also be used to optimize the allocation of water resources in the Guangdong-Hong Kong-Macao Greater Bay Area urban agglomeration.

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