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Supply and Demand Analysis of Water Resources based on System Dynamics Model

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Abstract. Humans require clean water for industrial, agricultural, domestic and ecological purposes. Due to climate change and population increase, the lack of clean water resources is becoming more and more serious. A system dynamics model of water resources is proposed for alleviating water shortage, changing the imbalance between supply and demand, promoting sustainable patterns of consumption and production, protecting and managing water resources. First, a water supply and demand model combining principles and methods of system dynamics was constructed by analyzing the factors that influence water resources. The model is divided into five subsystems according to the water's purpose, i.e. a supply amount subsystem, an industrial water subsystem, an agricultural water subsystem, an ecological and domestic water subsystem, and a sewage water subsystem. In the model, the supply and demand index can indicate whether scarcity occurs as well as the degree of scarcity. The province of Shandong, China was picked as object of research. Relevant statistical data were analyzed to predict the supply and demand index in Shandong in 15 years using the model. Water scarcity in Shandong is explained through social and environmental drivers by addressing physical and economic decline. Finally, an intervention plan was formulated to avoid water shortage from occurring in the next 15 years.

Keywords: *linear regression; model; predication; system dynamics; index of supply and demand; water resources.*

1 Introduction

With climate change and population increase, clean water resources are running out. About 1.6 billion people (one quarter of the world's population) experience water scarcity. Humans require clean water resources for industrial, agricultural, and residential purposes. Water use has been growing at twice the rate of the population over the last century. There are two primary causes for water scarcity: physical scarcity and economic scarcity. Physical availability of water is dependent on natural water sources and technological advances such as desalination or rainwater harvesting techniques. The fact that water use is increasing at twice the rate of population growth suggests that there is another cause of scarcity.

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With the rapid development of economic and social progress, the lack of clean water resources has become a constraint and 'bottle neck' against sustainable development of the economy and social progress. The fact that water use per capita increases suggests that there are many different causes of water scarcity. If the aim is to provide clean fresh water to everyone as much as possible, we must not only understand the environmental constraints on water supply but also how social factors influence availability and distribution of clean water. When analyzing issues of water scarcity, many different types of questions must be considered, such as the way humans historically have exacerbated or alleviated water scarcity, the influence of industry, agriculture, domestic life, and so on, because water resources are closely related to these various aspects of human society.

The water that people need comes from surface water, underground water, and other sources. Meanwhile, water demand is mainly composed of domestic water demand, ecological water demand, agricultural water demand, and industrial water demand [1-6]. In order to effectively alleviate the shortage of clean water, adopting various water-saving measures to guide the sound development of demand and improving the relative carrying capacity of water resources are necessary in the supply chain of water [7-8].

Extensive research has been conducted on water resources. For example, on water management in semiarid regions, water quality in rice irrigation, water quality, and vulnerability of the supply chain. In theoretical development, model solving and simulation have also received wide attention. Analysis of water resources by applying system theory is required. System dynamics models have been widely implemented in this area as they can be used to predict water demand through simulation [9-15]. Of course, the demand of water changes along with the development of a region. Therefore, the demand of water has a relation with the economy, the population and the ecological environment, which change over time. Meanwhile, the supply of water fluctuates. Based on the above considerations, a system dynamics model of water resources was developed for implementation in Shandong Province, China for changing the imbalance between supply and demand, promoting sustainable patterns of consumption and production, and protecting and managing water resources.

The rest of this paper is organized as follows. In the following section, a water supply and demand model is proposed by analyzing the factors that influence water resources. In the model, the supply and demand balance index (*SDBI*) can indicate whether scarcity occurs as well as the degree of scarcity. In Section 3, the model predicts the supply and demand index in Shandong in 15 years by analyzing relevant statistical data, adjusting the variables and determining the control variables. Both social and environmental drivers are proposed by addressing physical and economic scarcity. Based on the analysis, some conclusions are given in Section 4.

2 Measuring the Ability of Providing Clean Water by Model

In this part, a water resources system composed of a supply water subsystem, a water demand subsystem and a sewage water subsystem is presented. Through using system dynamics analysis software, the relationships between the variables were obtained. Then, based on an analysis of these relationships, a model was developed that provides a measure of the ability of a region to provide clean water to meet the needs of its population. By considering the dynamic nature of the factors involved, those that affect both supply and demand can be clearly defined in the modeling process. Therefore, the model must not only understand the environmental constraints on water supply but also how social factors influence availability and distribution of clean water. Figure 1 displays the causal feedback loops of supply and demand of water resources based on system dynamics analysis [2,4].

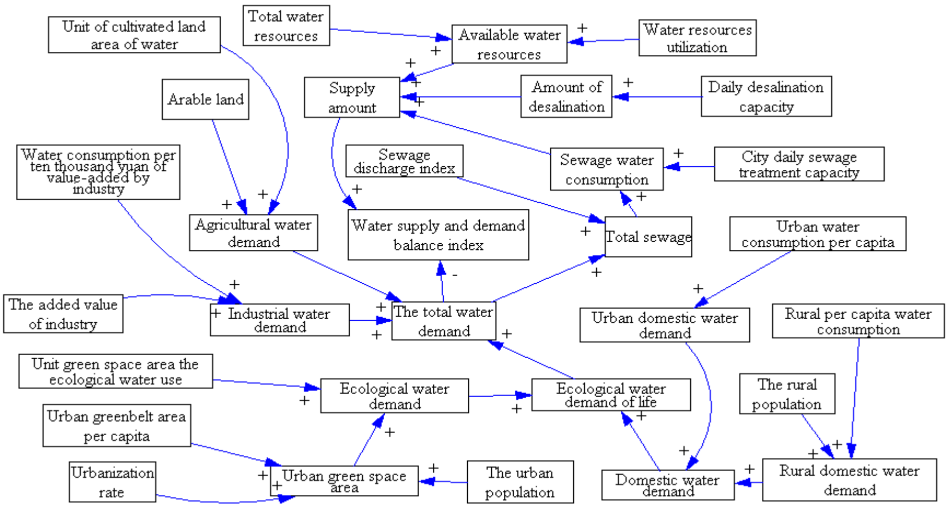

Figure 1 The causal feedback loops in the water demand and supply system.

Through the analysis of the supply and demand of water resources, the imbalance between supply and demand of water resources can be revealed and a solution can be put forward. A water supply and demand balance index can be used to measure the ability of a region to provide clean water to meet the needs of the population. The water supply and demand balance index can then serve as one of the main bases for the development and execution of national water resources policy. Regional water resources planning, urban water supply, industrial and agricultural development planning can also be based on the water supply and demand balance index.

It is evident that the interaction between water supply and demand as expressed in the water supply and demand balance index is a dynamic process. The degree of water scarcity can be indicated as *extreme lack of water*, *acute shortage of water*, *moderate water shortage*, *slight shortage of water*, *no shortage of water* [6], as specified in Table 1.

Table 1 Values of water supply and demand balance index.

Type	Extreme	Acute	Moderate	Slight	No shortage
Value	(0,0.3)	[0.3,0.6]	(0.6,0.9)	[0.9,1)	$\geqslant 1$

The water supply and demand balance index is determined by the total water supply and the total water demand for production and domestic life in a region in Eq. (1) as follows:

$$SDBI = TSW/TWD. \tag{1}$$

where TSW is the total water supply and TWD is the total water demand. If $SDBI > 1$, it means that the total supply of water is more than the total demand and therefore the region has no shortage of water. If $0.9 < SDBI < 1$, it means that the total water supply is smaller than the total demand and therefore the region has a slight shortage of water; this may affect production, which needs a large amount of water. If $0.6 < SDBI < 0.9$ it means that the total water supply is smaller than the total demand and therefore the region has a moderate shortage of water; in this case, production and domestic life may be affected much more. If $SDBI < 0.5$ it means that the total water supply is only half of the total demand and therefore the region has an acute shortage of water; in this case, production has to be stopped at some times because of lack of water and thus the water shortage affects the development of the economy and domestic life in the region.

In the water resources model, it is assumed that the climate and weather do not change very much and no flooding occurs in the area. Hence, the available water resources do not vary tremendously and neither does the amount of rainfall. The total water supply TSW mainly depends on water resources, desalination, rainwater collection and handling of sewage water. Other factors are not considered in the model. Thus, $TSW = AWR + AD + RCQ + HCSW$, where AWR stands for the available water resources. AWR is affected by total available water resources and water resource utilization. AD stands for the amount of desalination. This is related to the daily desalination capacity and technical progress. RCQ stands for the rainwater collection quantity. This is determined by rainfall and technical progress. *HCSW* stands for the handling capacity of sewage water, which is related to technical progress and the quantity of sewage water.

Table 2 Basic information on the main variables in the water resources model.

Symbol	Symbol description	Unit
TSW	water supply	billion cu.m/year
TWD	total water demand	billion cu.m/year
DWI	water demand of industry	billion cu.m/year
DWA	water demand of agriculture	billion cu.m/year
DWL	water demand of life	billion cu.m/year
DWE	water demand of ecology	billion cu.m/year
AWR	available water resources	billion cu.m/year
AD	amount of desalination	billion cu.m/year
RCQ	rainwater collection quantity	billion cu.m/year
HCSW	handling capacity of sewage water	billion cu.m/year
TP	total population	10000 persons
VA	value of agriculture	100 million yuan/year
VI	value of industry	100 million yuan/year
UGSA	urban green space area	ha
ATS	total amount of sewage	10000 tons/year
WPUA	water consumption per unit value of agriculture	cu.m/yuan
WPUI	water consumption per unit value of industry	cu.m/1000 yuan
WPD	domestic water consumption per capita	cu.m
WESA	water consumption of each green space area	cu.m
RP	rural population	10,000 persons
UP	urban population	10,000 persons
CL	cultivated land	ha
WPCL	water consumption per unit cultivated land	cu.m
UR	urbanization rate	%
WPRC	rural water consumption per capita	cu.m/person/year
WPUC	urban water consumption per capita	cu.m/person/year
SDI	sewage discharge index	%
STCD	city daily sewage treatment capacity	10,000 tons
SDBI	supply and demand balance index of water	-

In the water resources model, it is assumed that the total demand of water is composed of the water demand of industry, agriculture, domestic life and ecology (See Table 2 for the details). Other factors are ignored. Thus, $TWD = DWI + DWA + DWL + DWE$, where *DWI* stands for the water demand of industry. This is related to the added value of industry and the water consumption per added value of industry. As the added value of industry increases, the water demand of industry increases as well. Because of technical progress, water consumption per added value of industry may be reduced. *DWA* stands for the water demand of agriculture.

This is related to the amount of arable land and water consumption per arable land. *DWL* stands for the water demand of domestic life. This is decided by the size of the population and water consumption per capita. *DWE* stands for the water demand of ecology. This is related to the amount of urban green space and water consumption per urban green space area. Subsequently, the subsystems can be constructed in detail based on the causal feedback loops of the water supply and demand system. First, the main variables and notations used in the water resources model based on supply and demand are needed.

2.1 Supply Amount Subsystem

In the supply amount subsystem, the supply amount is the most important factor. The supply amount is relevant for available water resources, total water resources, daily desalination capacity, amount of desalination, and water resource utilization. These factors, which are dynamic in nature, affect supply and demand in the modeling process. See Figure 2 for details.

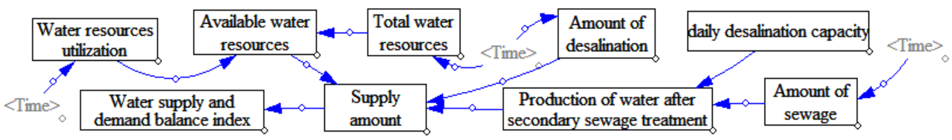

Figure 2 Supply amount subsystem.

2.2 Industrial Water Subsystem

Figure 3 displays the industrial water consumption subsystem. In the industrial water consumption subs ystem, the water consumption per ten thousand yuan of added value by industry, the added value of industry, and the industrial value have an important relation with industrial water demand. Obviously, some industries need a large amount of water, especially industrial chemical plants, electrolytic aluminum plants and so on. As the industrial value increases, much more water is needed and more water changes into sewage. Therefore, the water consumption unit value of industry is a very important index.

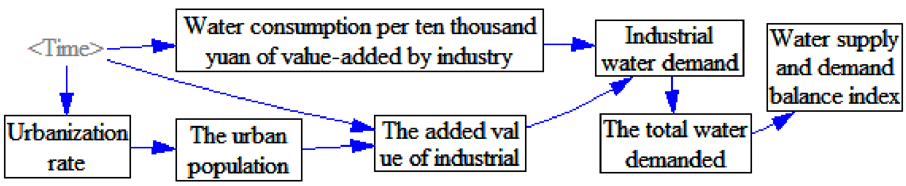

Figure 3 Industrial water consumption subsystem.

As a result of technical progress, water recycling is found in more and more plants. This will become an important way of saving water. The water consumption unit value of industry can come down so that even when the industrial value increases the total water consumption of industry may decrease.

2.3 Agricultural Water Subsystem

In the agricultural water subsystem, water consumption is related to variables such as the water supply and demand balance index, amount of cultivated land area of arable land, agricultural value, the water consumption unit value of agriculture, and so on. The supply and demand balance index of water depends on the total water demand and the total water supply. If the supply and demand balance index of water is smaller than 1, the agricultural water consumption will be reduced. This will affect the agriculture value. Along with technical progress, water-saving irrigation methods can be used more widely so that the water consumption unit value of agriculture can come down year by year. Hence, even if the agriculture value increases, the total water consumption of agriculture may decrease. Simultaneously, the amount of arable land will vary with time. Figure 4 displays the agricultural water consumption subsystem.

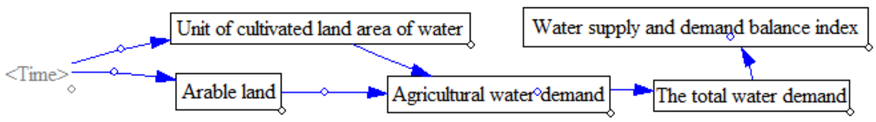

Figure 4 Agricultural water subsystem.

2.4 Ecological and Domestic Water Subsystem

Figure 5 displays the ecological and domestic water consumption subsystem. In the ecological and domestic water subsystem, ecological and domestic water demand, rural green space area, ecological water use, and urban green space area determine the ecological water demand. Urban green belt area per capita and the urbanization rate determine the total urban green space area.

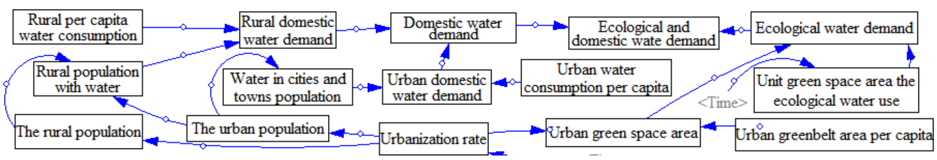

Figure 5 Ecological and domestic water subsystem.

All the above mentioned variables will vary more or less over time. Rural domestic water demand depends on rural per capita water consumption, rural population size, and the urbanization rate. Urban domestic water demand depends on the size of the population living in cities and towns, and urban water consumption per capita.

2.5 Sewage Water Subsystem

In the sewage water subsystem, domestic sewage depends on urban domestic sewage and rural domestic sewage. Domestic sewage and industrial wastewater compose the total sewage. The total amount of water produced by sewage treatment depends on the sewage treatment rate and total sewage. Figure 6 displays the sewage water subsystem.

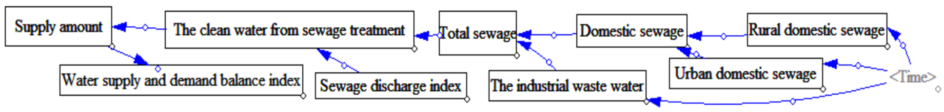

Figure 6 Sewage water subsystem.

3 Simulation of the System Dynamics Model

By analyzing the factors that influence the water supply and demand balance, a system dynamics model of the water supply and demand was constructed. Taking Shandong Province, China as an example, the model analyzes the regional balance between the supply and demand of water. The basic parameters for the model can be determined based on the population number in this area, the birth rate, the available water resources (including surface water, underground water, desalinated water, water from sewage treatment), the total water demand (from industry, agriculture, domestic life and the ecological environment) and sewage water, the GDP, and the urban and rural Engel coefficient. Then, a simulation was carried out of the water resource system of Shandong Province. Through analysis of the result, some policy suggestions for improving the water demand and supply balance are proposed in Section 3.4.

3.1 Basic Information about Shandong Province, China

Shandong Province is an important province on China's east coast. It is located in the lower reaches of the Yellow River, west of the Bohai Sea and the Yellow Sea. The coast of Shandong is about 420 km long and its width is more than 700 km. In 2014, the average annual rainfall was 679.5 mm, the average of total water resources amounted to 30.307 billion m^3, the surface water resources amounted to 19.83 billion m^3, the average groundwater resources amounted to 16.54 billion m^3, the average annual water use from the Yellow River amounted to 7 billion m^3. Between 60 and 70% of annual rainfall is collected in summer. Hence, waterlogs and droughts easily occur in winter, spring and autumn, by which the agricultural production is affected. In 2014, per capita water resources amounted to 299.7 m^3, far less than the internationally recognized amount necessary to support regional economic and social development, i.e. the critical value of 1000 m^3 per capita. Less than 500 m^3 per capita means an area has serious water shortage.

3.2 Data Preprocessing

According to the principle of determining the control variables, the model sets the time boundary from 2014 to 2030. First, the data of some variables need to be analyzed before putting them into the model to predict the water supply and demand index. By looking up the statistical yearbook entry for Shandong Province, data about the population from 2005 to 2014 can be obtained. By analyzing the population data, it can be seen that $R^2 = 0.9937$, i.e. close to 1, which shows that the fit of the linear regression is good. The regress equation for population growth is in Eq. (2) as follows:

$$y_1 = 61.794x + 9183.5, \tag{2}$$

where y_1 indicates total population, x indicates years.

Analyzing the value of industry based on the trends in the data, the value of industry in Shandong for the last 10 years can be shown by the model. It can be seen that $R^2 = 0.9868$, i.e. close to 1, which shows that the fit of the linear regression is good. The regress equation for the value of industry can be gotten in Eq. (3) as follows:

$$y_2 = 12000x + 17728, \tag{3}$$

where y_2 indicates the value of industry.

By looking up the statistical yearbook entry for Shandong Province, data on water consumption per unit value of industry from 2005 to 2014 can be found. Analyzing the data on water consumption per unit value of industry, the model can find the water consumption per unit value of industry in Shandong for the last 10 years. It can be seen that $R^2 = 0.9247$, i.e. close to 1, which shows it is a nonlinear regression. The regress equation for the water consumption per unit value of industry is in Eq. (4) as follows:

$$y_3 = -0.1367 \ln x + 0.5487, \tag{4}$$

where y_3 indicates the water consumption per unit value of industry.

By looking up the statistical yearbook entry for Shandong Province, data on the value of agriculture from 2005 to 2014 can be found. Analyzing the value of agriculture, the model can be used to find the value of agriculture in Shandong for the last 10 years. It can be seen that $R^2 = 0.9965$, i.e. close to 1, which shows that the fit of the linear regression is good. The regress equation is in Eq. (5) as follows:

$$y_4 = 629.6x + 2951, \tag{5}$$

where y_4 indicates the value of agriculture. By looking up the statistical yearbook entry for Shandong Province, data on water consumption per unit value of agriculture from 2005 to 2014 can be found. By analyzing the water consumption per unit value of agriculture data, the model can be used to find the water consumption per unit value of agriculture in Shandong Province for the last 10 years. It can be seen that R^2 = 0.9408, i.e. close to 1, which shows that the fit to the linear regression is good. The regress equation for the water consumption per unit value of agriculture can be gotten in Eq. (6) as follows:

$$y_5 = -0.0032x + 0.0451, \tag{6}$$

where y_5 indicates the water consumption per unit value of agriculture.

By looking up the Statistical yearbook entry for Shandong Province, data on the area of green space from year 2005 to 2014 can be gotten. By analyzing the area of green space data, the model can be used to find the area of green space in Shandong Province for the last 10 years. It can be seen that R^2 = 0.9951 is close to 1, which shows the fit to the linear regression is good. The regress equation for the area of green space is in Eq. (7) as follows:

$$y_6 = 1.1909x + 10.891, \tag{7}$$

where y_6 indicates the area of green space. By looking up Statistical yearbook entry for Shandong Province, data on the amount of total sewage from year 2005 to 2014 can be gotten. By analyzing the amount of total sewage data, the model can be used to find the amount of total sewage space in Shandong Province for the last 10 years. It can be seen that R^2 = 0.9904 is close to 1, which shows the fit to the linear regression is good. The regress equation for total sewage is in Eq. (8) as follows:

$$y_7 = 28030x + 250550, \tag{8}$$

where y_7 indicates the amount of total sewage.

By looking up Statistical yearbook entry for Shandong Province, data on the domestic water consumption per capita from year 2005 to 2014 can be found. By analyzing the domestic water consumption per capita data, the model can be used to find the domestic water consumption per capita in Shandong Province for the last 10 years. It can be seen that R^2 = 0.9205 is close to 1, which shows the fit to the linear regression is good. The regress equation for the domestic water consumption per capita is in Eq. (9) as follows:

$$y_8 = 0.8738x + 26.693, \tag{9}$$

where y_8 indicates the domestic water consumption per capita.

3.3 Prediction of Water Situation by the Model

In the model, the time boundary is 2014 to 2030, a total of 17 years. The main historical data are from 2008 to 2013, so 2014 was taken as the basic simulation year. Before running the simulation, 6 variables were selected to check the consistency of the system dynamics model (see Table 3 for details). In Table 3, it can be seen that the error between the predication data and the real data is lower than 12.8%. This means that the goodness of fit is well. Therefore, the model can basically reflect the operation of the actual system and can be used for prediction. Climate change and population growth explain the fact that water scarcity is increasing [16-17]. The demand and supply balance has changed, but the effect is not obvious. The water resource model can be used to see what the water situation will be in 15 years. A prediction of the supply and demand balance index can be gotten by the model.

Table 3 Consistency check of the system dynamics model.

Year	2014		2015		Error	
Water demand	**Real**	**Prediction**	**Real**	**Prediction**	**2014**	**2015**
demand of agr. water	146.72	146.22	143.29	161.49	-0.34%	12.7%
demand of ind. water	28.64	28.23	29.59	29.57	-1.43%	-0.07%
demand of dom. water	33.39	34.99	32.99	35.07	4.79%	6.30%
demand of ecol. water	5.78	5.04	6.89	06.10	-12.8%	-11.47%
total supply	214.52	240.52	212.76	215.57	12.12%	1.32%
total demand	214.52	214.48	212.77	232.24	-0.02%	9.15%

Obviously, a prediction of the water supply and demand balance index is very useful to safeguard the availability of enough clean fresh water. By the simulation, it can be seen that the water supply and demand balance index is under 1 from 2015, and supply is lower than demand in the following 15 years. The lowest index is 0.54, which is almost half of the balance index. According to the SD model, we can see that water supply and demand balance index decreases year by year, so water shortage will become very serious in Shandong, affecting the area's production and people's domestic lives. Specific prediction data of the water supply and demand balance index can be obtained. Water shortage will reach 851 million cu.m in 2016 and grow to 18,546 million cu.m in 2030. More specifically the water demand of agriculture more than doubles from 2014 to 2030. The water demand of industry increases by 24% from 2014 to 2030. The ecological and domestic water demand increases by more than 50%. However, the water supply has no obvious increase. This makes the water shortage in Shandong more and more serious. To satisfy the water demand of domestic life, the water demand of industry, agriculture and ecology have to be reduced. This will reduce the agriculture value, industrial value and people's happiness. Hence, sustainable development of Shandong is also impeded. It can be seen that the water supply changes from 21,014 million cu.m to 27,154 million cu.m, so there is no obvious increase. At the same time, total water consumption increases from 21,449 million cu.m to 40,169 million cu.m, i.e. it is almost doubled. This makes the water shortage in Shandong even more serious.

3.4 Intervention Plan

Water resources management is a kind of intervention and organization of human resources. Given a limited amount of resources, the goals of water resources management are: maximal provision of water to cover the needs for human life and social-economic development, reasonable utilization and protection of water resources, prevention and control of water disasters, and giving full play to the comprehensive benefits of water resources. The characteristics of Shandong determine the basic requirements of water resources management.

3.4.1 Increasing Water Supply

In order to improve the water balance index, it is firstly necessary to increase the supply of water. It has to be admitted that the earth's water resources are limited so it is necessary to increase rainwater recycling and seawater desalination. Rainwater is a precious natural resource, which plays a very important role in the natural water cycle system. Rainwater utilization can be divided into: direct utilization of rainwater and comprehensive utilization of rainwater. It can increase the water supply. On the other hand, it is conducive to damaging coastal areas due to excessive exploitation of underground water by expansion of underground funnels, serious ground subsidence and other issues. Although rainwater utilization has an overall advantage, there are also some disadvantages. For example, it inevitably impacts the surrounding areas, which increases the economic cost.

3.4.2 Decreasing Water Demand

In order to improve the water supply and demand balance index, it is also necessary to reduce water demand, i.e. the reduction of agricultural, industrial, ecological and domestic water consumption. For the optimal allocation of water resources in Shandong Province, it is very important to improve the local ecological environment and water infrastructure. An example is the Jiaodong Yellow River water diversion project, which is an important part of the east route of the South to North Water Division Project. This cannot only alleviate the uneven distribution of water resources in the region, but also guide sustainable development.

3.5 Water Resources after Intervention in the Future

Once we know what causes the imbalance between supply and demand of water resources, an intervention plan can be designed taking all the drivers of water scarcity into account. Intervention can be used to mitigate water scarcity and project water availability in Shandong according to the model. To obtain more clean water, it is necessary to take all drivers of water scarcity into account and analyze all the various contributing factors, which can be divided into 3 groups: increasing the supply of water, such as rainwater recycling; seawater desalination and the intensity of water transfer; the water demand of industrial production; the amount of water pollution.

According to the model, the water supply increases by 85,227 million cu.m in 17 years through the above intervention. The changes on the demand side are: water consumption is reduced by 86 cu.m over an agriculture value increase of 1000 yuan; by 5 cu.m over an industry value increase of 1000 yuan. The changes on the supply side are: the utilization ratio of water resources increases by 7.4%, the utilization ratio of sewage increases by 107.6% and seawater desalination increases by 83.1%. The new water supply and water consumption can be seen in Table 4.

Table 4 Prediction data of water after intervention.

Year	Total demand of water	Total supply of water	Water supply and demand balance index	Lack of water
2014	214.21	237.18	1.11	-
2015	225.77	236.32	1.05	-
2016	231.22	201.58	0.87	29.65
2017	241.17	261.30	1.08	-
2018	256.95	259.13	1.01	-
2019	273.99	262.28	0.96	11.71
2020	283.33	276.85	0.98	6.49
2021	293.87	289.90	0.99	3.96
2022	281.07	276.71	0.98	4.36
2023	287.14	309.31	1.08	-
2024	287.56	327.27	1.14	-
2025	302.35	300.99	1.00	1.36
2026	330.48	316.41	0.96	14.07
2027	334.04	330.56	0.99	3.46
2028	325.05	330.88	1.02	-
2029	338.26	344.30	1.02	-
2030	368.84	344.80	0.93	24.04

After the intervention, the supply and demand balance index is close to 1, so supply and demand are almost in balance. In the next 15 years, total water supply is 490,576 million m^3, i.e. 85,227 million m^3 more than before. At the same time water demand is 487,529 million m^3, i.e. 43,726 million m^3 less than before. Supply is greater than demand and the surplus is 3,047 million m^3 in 15 years. There should be enough storage capacity, so that excess water from abundant water years can be used in the next year. This will be good for the water resources and it can be useful for normal work, life and social development.

4 Conclusions

A system dynamics model was developed to predict the supply and demand balance trend of water resources in Shandong Province, China. On the supply side, it mainly considers the water supply from seawater desalination, rainwater collection, sewage treatment, and water diversion. On the demand side, it mainly considers the industrial, agricultural, domestic and ecological consumption of water. An intervention plan for solving regional water scarcity was presented in which water consumption is reduced by 86 cu.m over an agriculture value increase of 1000 yuan, water consumption is reduced by 5 cu.m over an industrial value increase of 1000 yuan. This intervention reduces total water demand by 43,726 million m^3 in the next 16 years. The utilization ratio of water resources increases by 7.4%, the utilization ratio of sewage increases by 107.6% and seawater desalination increases by 83.1%. Total water supply increases by 85,227 million m^3 in the next 16 years. Hence, the water demand for the sustainable development of Shandong Province can be satisified.

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