System Dynamics Analysis of Water Resource Carrying Capacity in Shandong Province of China

Huanhuan Qin[1], Amy Sun[2], Baoxiang Zhang[1, 3], Chunmiao Zheng[1, 4]
[1]Center for Water Research, College of Engineering， Peking University
[2]Energy, Resources & Systems Analysis, Sandia National Laboratories
[3]Water Resources Research Institute of Shandong Province
[4]Department of Geological Sciences, University of Alabama
Room301, ZhongGuanCun Founder Building No.298 ChengFu Rd,
HaiDian District, Beijing, China, 100871
Telephone number: +8613811992913
Email Address:qhhcoewrc@gmail.com

Abstract: *Water Resource Carrying Capacity (WRCC) is an important metric for regional water management in China. Shandong Province of China faces a serious water shortage if WRCC is not managed at a sustainable level. This study focuses on applying system dynamics methodology to evaluate different development scenarios and their associated WRCC for Shandong. System characteristics of local water resources and demand in Shandong are captured and modeled using system dynamics within VENSIM software. The dynamic model of Shandong's WRCC consists of 5 subsystems: agricultural development, population growth, industry and tertiary industry, water resources, and water pollution. Historical data are used to calibrate model parameters. Impact on the WRCC is assessed through three growth scenarios: modest industrial growth, aggressive industrial growth, growth combined with wastewater recycles. Based on simulation results, WRCC that most likely can sustain economic growth without overstressing the water supply is one with modest growth combined with wastewater recycle.*

Key words: Shandong Province, water resources carrying capacity, system dynamics model

1 Introduction

Water is an essential resource for human well being and other life-support systems. Adequate water supply is one of major requirements for supporting socioeconomic development [1]. As a result of growing economic development in China, however, the demand for water resource is ever-increasing. Stress builds up on water resource when the use of water exceeds its carrying capacity. Responsible management of water resource is one of the key attributes that impact environment at every spatial scale from local watershed to global water cycle. In this work, a model founded on water balance, or referred to as the water resource carrying capacity(WRCC) for Shandong Province is developed using system dynamics to understand the past, current, and projected future use of water in that region.

Geographically, Shandong Province is located in eastern China, lower reaches of China’s Yellow River, northern Bohai Sea, and eastern Yellow Sea. Figure1 shows the region of Shandong Province, spanning north latitude 34°25′ to 38°23′ and east longitude 114°36′ to 122°43′.The area of Shandong Province is 156.7 thousand km^2, which accounts for 1.6% of China's land area. Due to its temperate climate, the precipitations of Shandong Province occur during monsoon months spanning June, July and August. The average annual temperature range from 11.0℃(Wendeng, a city of Shandong) to 14.2℃(Jinan, the capital of Shandong).Between 1916 and 2003, the average annual precipitation is approximately 637mm [2]. By the end of 2008, there are 17 prefecture-level cities in Shandong Province, with a total population of 94.17 million and a total GDP of 3,107 billion RMB. The average total amount of fresh water resources in Shandong Province is 30.58 billion m^3, accounting for 1.09% of total water resources of China. Per capita fresh water in the Province is 344 m^3, which is less than one-sixth of the average for the whole country and one-twenty-fifth of the average for the whole world [3]. Water shortage has become a bottleneck for sustainable development in Shandong Province.

Figure1. Location of Shandong Province

2 System Dynamics Model for Shandong Province

2.1 Water Resource Carrying Capacity

Water Resources Carrying Capacity (WRCC) is a concept originated in mechanics, referring to the load placed on an object without producing any damage. It was later adopted by ecology to measure the maximum population of a species that a specific area can sustain under certain environmental conditions [4]. To quantify impact due to shortage of resources and environmental pollution, the carrying capacity concept was developed and become widely used to describe the ability of an ecological system to withstand the development and limits of a particular human activity. Water Resources Carrying Capacity (WRCC) is studied by many scholars, later than its equivalent on land, referred to as Land Resources Carrying Capacity. Water Resources Carrying Capacity has been broadly discussed together with other natural resources in sustainable development literature. Rijisberman J used WRCC as a measure of urban water security [5]; Harris focused on the study of WRCC in agricultural production areas [6]. Ruan Ben-qing and Shen-Jin [7] (1998) pointed out that WRCC will ultimately be determined by population. WRCC is defined as the population that can be supported by the resource represented in a direct or indirect way in a certain area. Hence, WRCC analyses require considerations in both time and spatial scales of social, environmental, and natural load balance. WRCC should strive to be compatible with local resources as well as social, cultural, customs, standards of living and as such, it is centric to our study.

2.2 System Dynamic Methodology

System dynamics (SD) was first founded by J.W. Forrester, a professor at the Massachusetts Institute of Technology (MIT), in 1956[8]. Forrester put forward a method in 1958 to analyze complex business issues, such as production management and inventory management. The understanding of close relationships of amongst components is represented by a mathematical modeling framework equipped with feedback control theory. SD is advantageous in dealing with a high degree of non-linear., high-level, and multi-variable problems [9]. Combined improvements of the modeling framework and with the improvement of computer technology, system dynamics methodology has been applied in many fields, such as urban planning, ecological environment planning, land carrying capacity, waste-water reuse and the development of rail freight [10, 11, and 12].

Use of system dynamics has been applied to evaluate systems interactions and behavior for water resource management. Sun Xin-Xin (2007) has conducted a study on the WRCC of Baoji city, a city of Shanxi province northwest of China, using a system dynamics method [13]. The carrying capacity system of Baoji city is divided into five subsystems: population growth, industrial development, agriculture irrigation, water recycle and water supply. A SD model of Baoji city is then constructed through the analysis of the structural and causal relationships and various levels of feedback. Simulations of different strategies are put forward to test the impacts on WRCC and an optimal development scenario is recommended to the policy-maker. Wang Yan-Bo (2006) has conducted a study on the WRCC of Shijiazhuang city, capital of Hebei province [14]. A SD model of Shijiazhuang city is constructed based on the status quo of water environment in Shijiazhuang City. Analysis and comparison of various scenarios are taken to get an integrated development scenario of economy and environment in order to provide a scientific policy-making basis for sustainable developments of Shijiazhuang city's water environment. Niu (1994) has pointed out that it is essential to forecast the long-term future water demand in water resources planning and management and system dynamics method can handle it easily and conveniently [15].

2.3 Model structure and Sub-components

Figure 2 shows a conceptual water balance of Shandong water system. Figure 3 shows the flow chart of Shandong's WRCC system. Appendix details the abbreviations for variables and parameters in the Shandong model. In this work, the system capacity for Shandong consists of surface water supply, groundwater supply, "water supply from the south-to-north-divert project."The categories under consumption include population, industrial development, and agriculture. The WRCC system of Shandong is further divided into 5 sub-systems, including population system, agriculture system, industry and tertiary industry system, water pollution system, and system of water resources. Each sub-system is interrelated and mutually influence by other sub-systems. The assumptions and causal relations of individual subsystems are further described below.

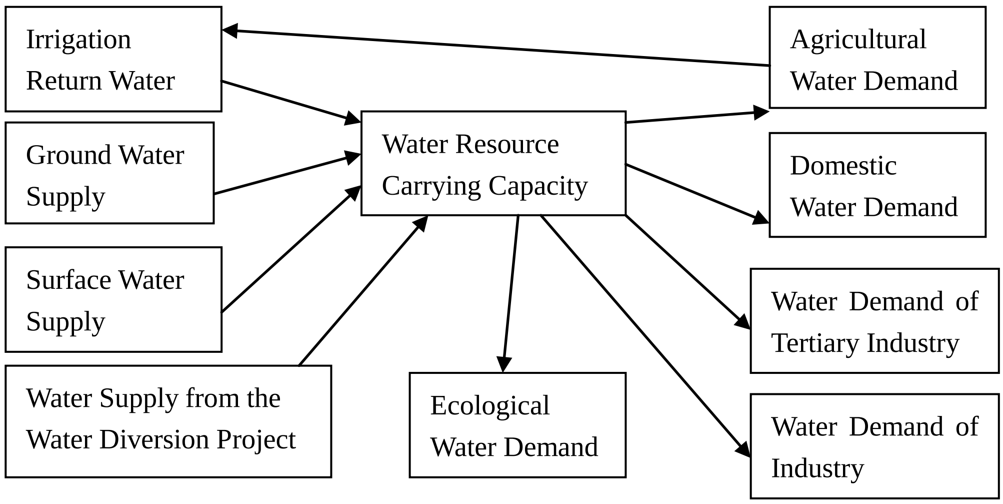

Figure2.Conceptual water balance of System Dynamics model

(1)Sub-system of population

The total population is made up of urban population and rural population. It is impacted by the birth rate and the death rate (in other words, the natural population growth rate), as well as the water deficit index. And the rural population equals the difference between the total population and the urban population. It is assumed that the shortage of water will have a negative impact on the population, which is realistic. The domestic water demand is made up of urban and rural domestic water demand, which depends on the water used duty and population. The main feedback relationships in the sub-system of population include:

Total population $\xrightarrow{+}$ urban domestic water demand $\xrightarrow{+}$ domestic water demand $\xrightarrow{+}$ total water demand $\xrightarrow{+}$ water deficit $\xrightarrow{+}$ water deficit index $\xrightarrow{-}$ total population

The “+” notation means the latter increases or decreases as the former increases or decreases, which is called positive feedback ,while the “-” notation means the latter increases or decreases as the former decreases or increases, which is called negative feedback. The similar takes place thereinafter. Water deficit index is defined as the ratio of water deficit to total water supply, while water deficit is defined as the difference between total water demand and total water supply.

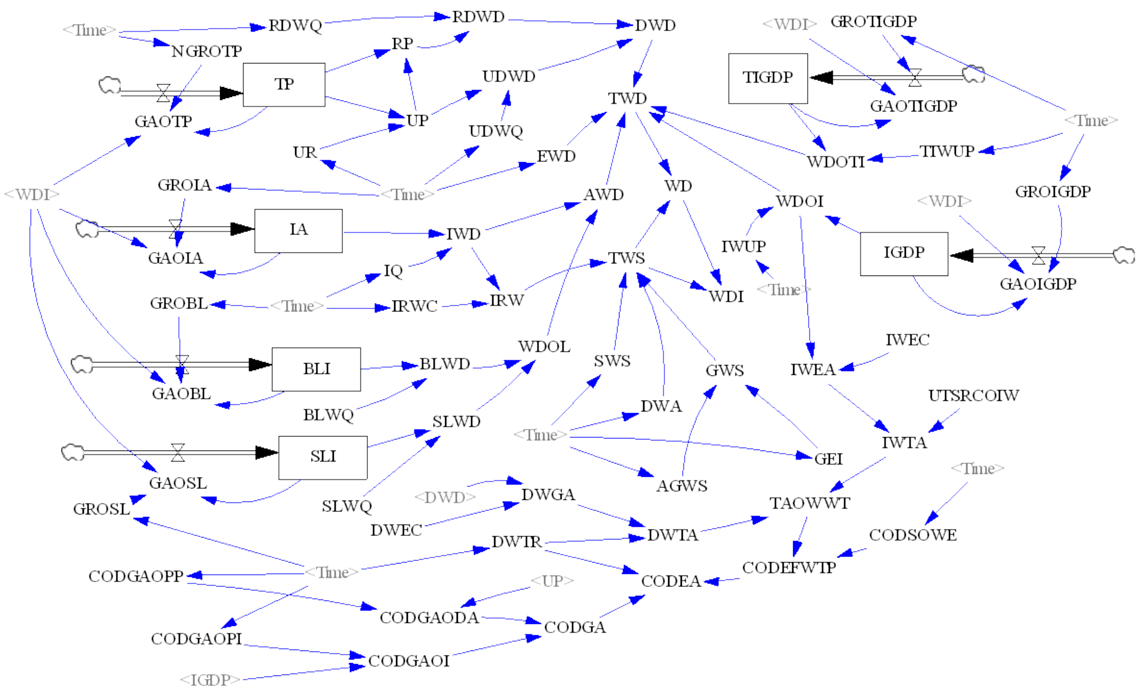

Figure3.Flow Chart of Shandong Province

(Appendix shows the abbreviations for variables and parameters in Shandong model)

(2)Sub-system of industry and tertiary industry

Tertiary industry refers to the service industry, which does not produce material goods. All the industries, except the primary industry (agriculture) and secondary industry, are defined as tertiary industries.

The state variables of industrial and tertiary industry sub-system are industrial GDP and tertiary industrial GDP. These are impacted by their growth rate and water deficit index. The changes of the industrial and tertiary industrial GDP are in relation to the amount of their water consumption and demand. It is supposed that the industrial /tertiary industrial water demand equals the industrial/tertiary industrial GDP multiplies the water used per 10000 RMB. The main feedback relationship in this sub-system includes:

Industrial output $\xrightarrow{+}$ industrial water demand $\xrightarrow{+}$ total water demand $\xrightarrow{+}$ water deficit $\xrightarrow{+}$ water deficit index $\xrightarrow{-}$ industrial GDP

Tertiary industrial output $\xrightarrow{+}$ tertiary industrial water demand $\xrightarrow{+}$ total water demand $\xrightarrow{+}$ water deficit→+water deficit index $\xrightarrow{-}$ tertiary industrial GDP

(3)Sub-system of agriculture

The state variables of the agricultural sub-system are irrigated area, inventory of big livestock, and inventory of small livestock. These variables are determined by their growth rates and water deficit index. The negative effect of water shortage will make the three state variables decrease. The water used by the live stocks equals to the water-use duty multiplies of the quantity of livestock, while the irrigation water is determined by the irrigated area and irrigation quota. Here only livestock and irrigation are considered. The other parts of agriculture, such as forestry and fishery, are not considered here. There are two reasons: first, the data from these uses are difficult to obtain; second, the water used of these parts are small, compared to the livestock and irrigation. Hence the model assumes these factors will not contribute greatly towards the total agriculture water demand. The main feedback relationships in this sub-system include:

Irrigation area $\xrightarrow{+}$ irrigation water $\xrightarrow{+}$ irrigation return water $\xrightarrow{-}$ water deficit index $\xrightarrow{-}$ irrigation area,

Big livestock inventory $\xrightarrow{+}$ big livestock water used $\xrightarrow{+}$ total water demand $\xrightarrow{+}$ water deficit $\xrightarrow{+}$ water deficit index $\xrightarrow{-}$ big livestock inventory, and

Small livestock inventory $\xrightarrow{+}$ small livestock water used $\xrightarrow{+}$ total water demand $\xrightarrow{+}$ water deficit $\xrightarrow{+}$ water deficit index $\xrightarrow{-}$ small livestock inventory.

(4) Sub-system of water pollution

In this sub-system, COD is the main variable.COD emission amount is determined by COD generated amount, COD emission amount from wastewater treatment plants, and the rate of domestic wastewater treated, while the first one derives from two activities: human demand and industrial activity. Total amount of wastewater treatment and COD standard of wastewater emission are taken into account when calculating the value of the second one.

(5)Sub-system of water resources

The surface water and groundwater amount are the most important variables in the sub-system of water resources. The amount of groundwater has a direct relationship with the groundwater exploitation rate. The groundwater is defined as the product of the available groundwater supply and the groundwater exploitation rate. Instead of keeping the surface water and ground water as constant parameters, they are set as table functions, which are different over time. The model also takes into account the most anticipated water management change of Shandong, namely the South-to-North Water Diversion Project. This project includes water gotten from the Yellow River and the Yangtze River. As a part of surface water, the South-to-North Water Diversion Project will play an important role in Shandong Province. It will add the total water supply of Shandong and reduce the degree of water deficit in this region.

2.4 Model variables and equations

The variables in SD are mainly categorized into flow variables, flow rate variables, constants, auxiliary variables and table functions. These are required relational inputs into the VENSIM software. The flow variables express the cumulative quantities, the flow rate variables express the rate of change to cumulative quantities, and the constants do not change over time in an interval time. The table functions are used to express the non-linear relationship between some variables in the model. There are more than 60 variables and parameters .The causal and logical relationships amongst the variables, flow rates and table functions are abstracted into mathematical relations (i.e. state and auxiliary equations), to conduct quantitative analysis. More details of how equations are constructed can be found in reference 8.

2.5 Simulation periods

Once the individual subcomponents of Shandong Province are fully constructed within VENSIM, the analysis is conducted over a length of period. The simulation length is from 2000 to 2020, or a total of twenty years. The simulation time step is one year. The modeling period spans two stages: the first stage is from 2000 to 2007 and is known as the model calibration stage; the second stage is from 2008 to 2020 and is known as the model prediction stage. The model calibration stage is focused on obtaining reasonable parameter values by matching model output to historical data, while the model prediction stage focuses on projecting the future WRCC using the calibrated parameter values with projected water demand.

3 Calibrations to Historical Data

Calibration of the model must be carried out before the analysis. Simulation results are compared with the actual historical data to verify the extent of their agreement, in order to assess the reliability of model parameters and accuracy of the simulation model. The simulation results of total water demand, domestic water demand, agricultural water demand and industrial water demand are compared with the actual data from water resources bulletin. Figure 4 shows the comparison between simulated and historical data between 2000 and 2007. Overall, the water demand is similar between the simulation result and the actual data, though the trends are different between them. The historical data may not show an either monotonic upward or downward trend while the SD simulation method does. The largest relative error is 20%.

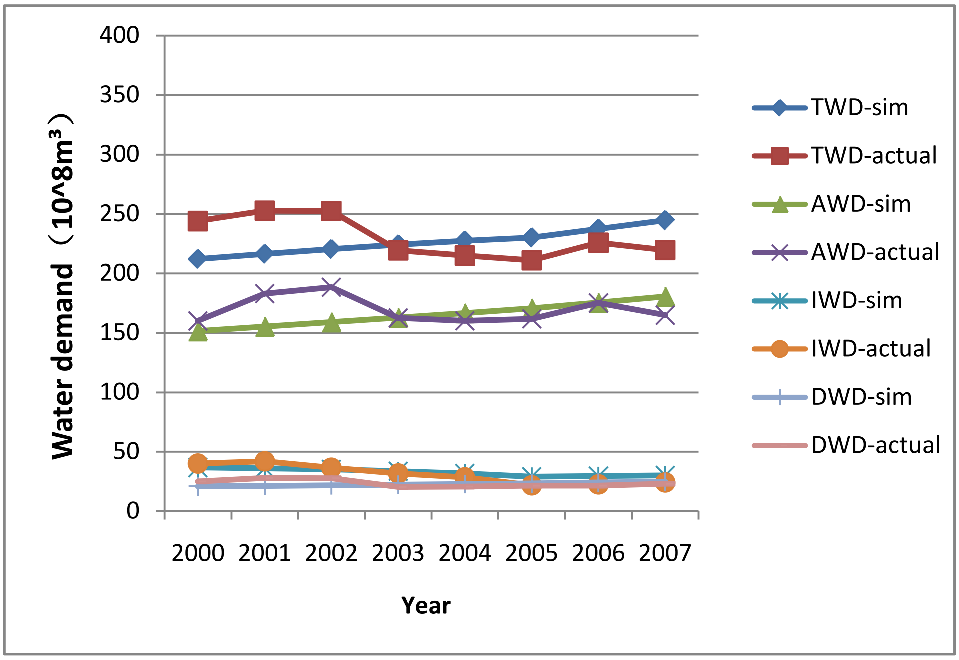

Figure4.TWD,AWD,IWD and DWD in model calibration, compared with historical data, where TWD stands for total water demand,AWD stands for agricultural water demand,IWD stands for industrial water demand and DWD stands for domestic water demand.Sim stands for simulation data and actual stands for historical data.

4 Analysis of WRCC for Shandong Province

4.1 Scenarios

After the model has a set of rate quantities that match well with historical rates, analysis of WRCC is conducted. Agriculture and industrial targets are established through hypothetical development policies and simulated in the model. Specifically the urbanization level, industrial/tertiary industrial GDP growth rate, industrial/tertiary industrial water used per ten thousand RMB, irrigation quota, big/small livestock inventory growth rate are selected to design three different policy scenarios. These are further described below.

(1)Scenario 0

This scenario is also known as the trend-based scenario by assuming that the development policies and system structure do not have a large adjustment in the forecasting period. The constant parameters are the same as in the model calibration stage while the table-function parameters are hypothesized with a moderate trend. The urban population and socio-economic development speed are set to increase only moderately by 2020. According to the actual situation of Shandong Province and the author's experience, the industrial GDP growth rate is set to be 11% in 2010 and 16% in 2020.The tertiary industrial GDP growth rate is 17% in 2010 and 25% in 2020. The urbanization level will be 50% in 2010 and 60% in 2020.

(2)Scenario 1

This scenario is also known as a scenario of economic development by stressing the importance of economic development. Economic development remains the top priority of NCP in the present and future for a long period of time. Therefore, increase the growth rate of industrial GDP to 15% in 2010 and 20% in 2020. The growth rate of the tertiary industrial GDP will be 19% in 2010 and 27% in 2020, while the urbanization level in 2020 will be increased to 65%. Other parameters of this scenario keep the same as scenario 0.

(3) Scenario 2

This scenario is also known as a sustainable development scenario by emphasizing economic development and the protection of water resources at the same time. Domestic sewage treatment rate in 2010 and 2020 will be 80% and 90% (this rate is 55% in 2000), per capita living COD generated amount in 2020 is reduced to 0.0078 tons/ person, the amount of COD generated per 104 RMB of industrial GDP in 2020 is reduced to 0.0008 tons / ten-thousand-RMB. Urbanization rate in 2020 will reach 55%, industrial GDP growth rate from 2010 to 2020 remains at 11%, tertiary industry GDP growth rate in 2020 will fall to 20%, crop irrigation quota in 2020 will drop to $4000m^3/ha$.

4.2 Scenarios comparison

Table 1 presents the results of main years of the three scenarios. Scenario 0 has an emphasis on keeping the status quo, scenario 1 emphasizes on economic development, and scenario 2 has an emphasis on slower economic growth while protecting water resources, which is a sustainable development scenario advocated in China. The total amounts of water demand and water deficit in table 1 are the key points of this study. Throughout the simulation period up to 2020, the total amount of water demand of scenario 1 is the largest, followed by scenario 0 then scenario 2. Accordingly, the water deficit (a positive value indicates shortage of water while a negative value indicates abundance of water) is the least for scenario 2, followed by scenario 0 then scenario 1.

Table1. Water resources carrying capacity of three scenarios for Shandong.

Variables	Year	Scenario 0	Scenario 1	Scenario 2
Total	2010	9 499	9 499	9 499
population	2015	9 710	9 710	9 710
(10^4persons)	2020	9 905	9 905	9 905
Urban	2010	4 749	4 749	4 749
population	2015	5 340	5 583	5 098
(10^4persons)	2020	5 943	6 438	5 448
Irrigation	2010	4.987	4.987	4.987
area	2015	5.034	5.034	5.034
(10^6ha)	2020	5.072	5.072	5.072
Industrial	2010	9 194	9 531	9 194
GDP	2015	16 215	20 033	15 506
(10^8RMB)	2020	31 882	46 713	26 122
Tertiary	2010	11 570	11 974	11 570
Industrial	2015	27 175	30 572	26 055
GDP(10^8RMB)	2020	75 163	91 564	62 410
Total water	2010	265.2	266.6	265.2
demand	2015	307.4	319.2	299.6
(10^8m^3)	2020	363.6	396.4	337.1
Water	2010	-28.02	-26.63	-28.02
deficit	2015	-0.96	10.77	-7.25
(10^8m^3)	2020	54.48	87.33	31.04
Water	2010	-0.0956	-0.0908	-0.0956
deficit	2015	-0.00311	0.0349	-0.0236
index	2020	0.176	0.283	0.101
COD	2010	350 049	354 989	327 292
emission	2015	390 722	437098	347 138
amount (tons)	2020	439 134	550 869	353 173

Additional water allocated from the South-to-North Water Diversion Project plays an important role in solving the water deficit problem of Shandong in the short term. Figure 5 indicates that although the water deficit years of scenario 0 (present situation) can be prolonged to 2016 and to 2015 in scenario 1, these scenarios still lead to water shortage in the long term. This simulation indicates that the water deficit problem cannot be solved totally in all three scenarios. Figure 6 shows the time serials curves of total water demand in the three scenarios. The development tendency of three scenarios is the same: the total water demand of Shandong is increasing over time over the next twelve years. Figure 6 and table 1 present that Shandong needs up to 36.4 billion m^3

water till 2020 in present situation. If economic development is the top priority of NCP, it needs 39.6 billion m^3 water till 2020,while it needs 33.7 billion m^3 water till 2020 if the economic development and protection of water resources are both emphasized, which is less than the first two. The growth rates of total water demand in three scenarios are different: scenario 1 has the maximum growth rate; scenario 2 has the minimal rate, while scenario 0 is in between. More emphasis on the economic development requires more water. The amount of total water demand can be managed sustainably as the economic development and protection of water resources are emphasized at the same time. By slower rate of economic development, such as industrial and tertiary industrial GDP growth rates, and urbanization level, while increasing reuse rate of wastewater, scenarios 2 indicates an increase in total water demand is delayed until 2016. It is the core ideology of sustainable development theory.

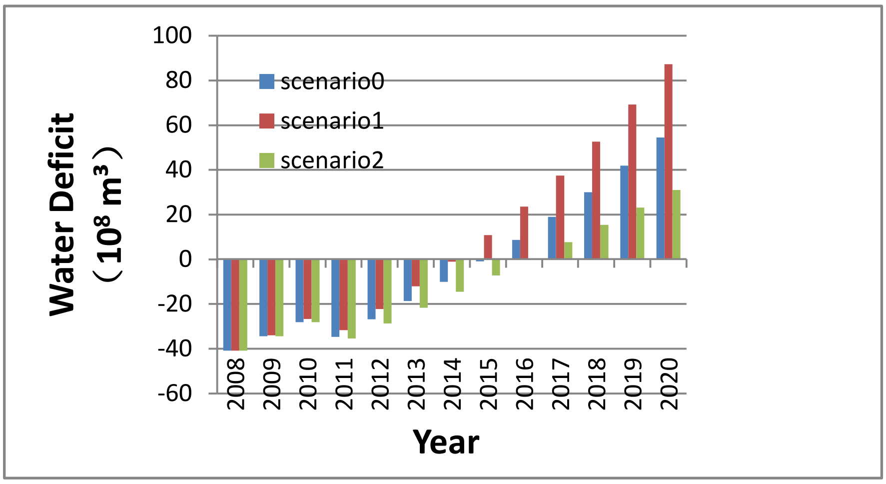

Figure5. Water deficit in three scenarios

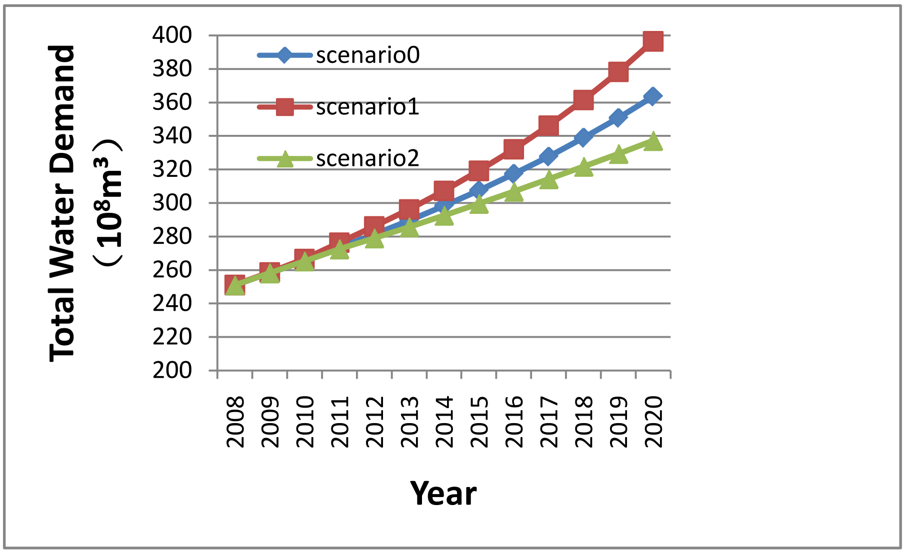

Figure6. Total water demand in three scenarios

Figure 7 shows COD emission amount in three scenarios. COD emission amount is an index of environment in this study. The scenario with the more amount of COD emission, the worse it is considered as to the region's sustainable development. Among all three scenarios, the amount of COD emission in scenario 2 is the least and in scenario 1 it is the most. If the economic development is emphasized over water resources protection (scenario1), COD emission amount will be more than other scenarios (scenarios 0 and 2). Scenario 2 is the best scenario in the sense of environment protection and economic development.

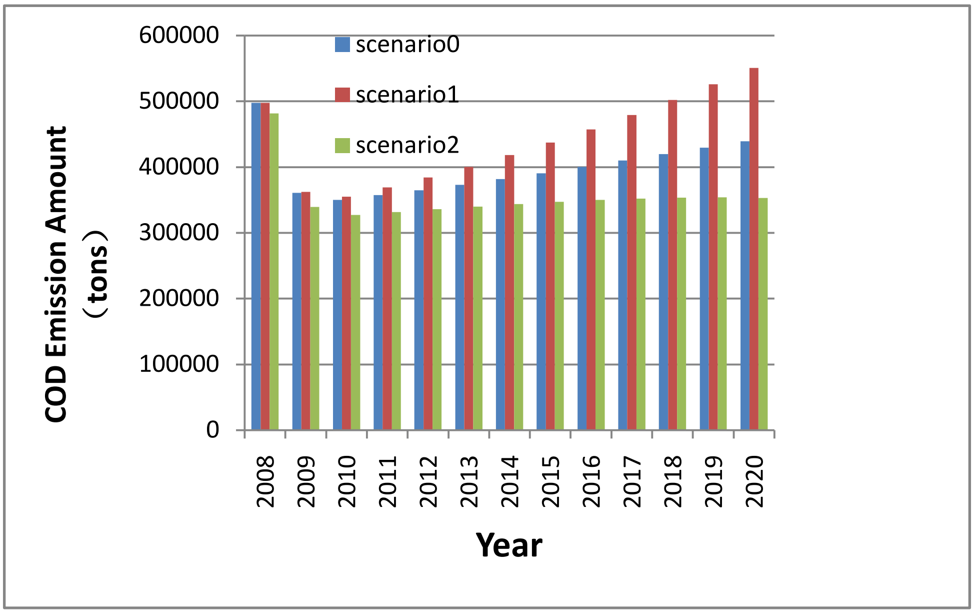

Figure7. COD emisssion amount of three scenarios

4.3 Optimal option

Figure 6 shows that the amount of total water demand of the sustainable development scenario is much less than that of the other scenarios (trend-based scenario and economic development scenario).The WRCC of Shandong will improve a lot if the sustainable development scenario is chosen by the policy maker. The amounts of ground and surface water supply to Shandong do not change much in the prediction period. The only effective way to solve the water deficit problem is to save and reuse water. Scenario 0(trend-based scenario) does not take any action to improve water reuse; scenario1 (economic development scenario) emphasizes economic development so heavily that the amount of total water demand increases rapidly. Only scenario 2 emphasizes combined economic development, water reuse and protection. In this scenario, both economic development and water resources protection are considered equally and the effect of water conservation is obvious. So scenario 2 is the optimal option for the policy maker

5 Conclusions

The following conclusions are summarized by a comparative analysis of the three scenarios, using system dynamics of the water resource carrying capacity of three hypothetical water management scenarios for Shandong Province.

(1)Evaluation of the WRCC through system dynamics modeling provides a dynamic, system-level, and integrated approach towards water planning, compared to a static planning method. In the model, not only the relationships amongst population, water recourses, water environment, industry and agriculture are shown intuitively, but also the inherent relationships among the various sub-systems are clearly reflected throughout the simulations.

(2)This study has shown that one-sided pursuit of either rapid economic or status quo without regard to affordability of water resources will lead to water deficit, even with a short-term relief of water resource from the South-to-North Water Diversion project. According to the condition of Shandong and the simulation results, even scenario 2 cannot solve the water deficit problem but with some delay.

(3)The amount of total water demand of Shandong increases from 25 billion m^3 in 2008 to 36.4 billion m^3 in 2020. It can be reduced to about 31 billion m^3 on average if sustainable development scenario is adopted, while it can be increased to about 37 billion m^3 on average if economic development scenario is adopted.

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Appendix

Abbreviations for variables and parameters in Shandong model (variable types：L——level variable；A——auxiliary variable；R——rate variable；T——table function；C——constant variable)

No.	Abbreviation	Description	Type	Unit
1	TP	Total population	L	persons
2	RP	Rural population	A	persons
3	UP	Urban population	A	persons
4	RDWD	Rural domestic water demand	A	m^3
5	UDWD	Urban domestic water demand	A	m^3
6	DWD	Domestic water demand	A	m^3
7	TWD	Total water demand	A	m^3
8	UR	Urbanization rate	R	1/year
9	IA	Irrigation area	L	m^2
10	GAOTP	Growth amount of total population	A	persons
11	NGROTP	Net growth rate of total population	R	1/year
12	RDWQ	Rural domestic water quota	T	m^3/person

(Continued)

No.	Abbreviation	Description	Type	Unit
13	UDWQ	Urban domestic water quota	T	m^3/person
14	EWD	Ecological water demand	T	m^3
15	GROIA	Growth rate of irrigation area	R	1/year
16	GAOIA	Growth amount of irrigation area	A	m^2
17	IWD	Irrigation water demand	A	m^3
18	IQ	Irrigation quota	T	m^3/m^2
19	IRWC	Irrigation return water coefficient	T	1/year
20	BLI	Big livestock inventory	L	heads
21	GROBL	Growth rate of big livestock	R	1/year
22	GAOBL	Growth amount of big livestock	A	heads
23	GROSL	Growth rate of small livestock	R	1/year
24	GAOSL	Growth amount of small livestock	A	heads
25	SLI	Small livestock inventory	L	heads
26	BLWD	Big livestock water demand	A	m^3
27	BLWQ	Big livestock water quota	C	m^3/head
28	SLWD	Small livestock water demand	A	m^3
29	SLWQ	Small livestock water quota	C	m^3/head
30	WDOL	Water demand of livestock	A	m^3
31	IRW	Irrigation return water	A	m^3
32	AWD	Agricultural water demand	A	m^3
33	WD	Water deficit	A	m^3
34	TWS	Total water supply	A	m^3
35	SWS	Surface water supply	T	m^3
36	DWA	Diversion water amount	T	m^3
37	GWS	Groundwater supply	A	m^3
38	WDI	Water deficit index	A	——
39	IGDP	Industrial GDP	L	RMB
40	GROIGDP	Growth rate of industrial GDP	R	1/year
41	GAOIGDP	Growth amount of industrial GDP	A	RMB
42	TIGDP	Tertiary industrial GDP	L	RMB
43	GROTIGDP	Growth rate of tertiary industrial GDP	R	1/year
44	GAOTIGDP	Growth amount of tertiary industrial GDP	A	RMB
45	WDOTI	Water demand of tertiary industry	A	m^3
46	WDOI	Water demand of industry	A	m^3
47	IWEC	Industrial wastewater emission coefficient	C	1/year
48	IWEA	Industrial wastewater emission amount	A	m^3
49	GEI	Groundwater exploitation index	T	——
50	AGWS	Available groundwater supply	T	m^3
51	IWTA	Industrial water treated amount	A	m^3

(Continued)

No.	Abbreviation	Description	Type	Unit
52	CODSOWE	COD standard of wastewater emission	T	tons/m^3
53	TAOWWT	Total amount of waste water treatment	A	m^3
54	CODEA	COD emission amount	A	tons
55	CODGA	COD generated amount	A	tons
56	CODGAODA	COD generated amount of domestic activity	A	tons
57	CODGAOI	COD generated amount of industrial	A	tons
58	CODGAOPP	COD generated amount of per person	T	tons/person
59	DWEC	Domestic wastewater emission coefficient	C	——
60	DWGA	Domestic wastewater generated amount	A	m^3
61	DWTR	Domestic wastewater treated rate	R	——
62	DWTA	Domestic wastewater treated amount	A	m^3
63	CODEFWTP	COD emissions from wastewater treatment plant	A	tons
64	CODGAOPI	COD generated amount of per 10^4RMB industrial GDP	T	tons/10^4RMB
65	IWUP	Industrial water used per 10^4RMB	T	$m^3/10^4$RMB
66	TIWUP	Tertiary industry water used per 10^4RMB	T	$m^3/10^4$RMB
67	UTSRCOIW	Up-to-standard release coefficient of industrial wastewater	C	——