An In-Depth Assessment of Water Resource Responses to Regional Development Policies Using Hydrological Variation Analysis and System Dynamics Modeling

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Abstract: To maintain sustainability and availability of regional water resources, appropriate integrated water resource management (IWRM) should be based on an assessment of water resource background and responses to regional development and utilization policies. The study proposed an assessment method combining hydrological variation analysis with a system dynamics (SD) model to support IWRM in the Baiyangdian Region, Northern China. Integrated variation analysis and attributive analysis were used to identify variation time and causes of runoff. Then, based on the current water resource situation, an accessibility analysis examined the possibility of achieving a water resources supply and demand balance of social economic development and the ecological environment within individual internal management. Finally, an SD model simulated water resource response to development policies to predict future policy impacts. Results showed that 65.18% of the impact on runoff was from human activities. Sustainability goals were impossible through internal management, but with eco-migration policies and $1 \times 10^8$ m$^3$ inter-basin transferred water, it could quickly be achieved, and water ecosystem function could also be recovered. Establishment of the Xiong’an New Area necessitated introduction of integrated cross-basin management to protect the Baiyangdian Region from degradation of its ecological function. Our study proposed a new method for comparison of internal and cross-basin IWRM.

Keywords: sustainable development and utilization; water resource management; hydrological variation analysis; system dynamics model; Baiyangdian Region

1. Introduction

Water, energy, and food (WEF), the fundamental resources for human living and society development, are interwoven in complicated ways and interact with each other in a complicated relationship, therefore, sustainability of the WEF-nexus is the key to realizing regional sustainable development [1,2]. However, rapid socio-economic development and human population growth leads to water scarcity, which has a strong negative influence on food production, human health and wellbeing, political stability, economic prosperity, and environmental protection [3–5]. Water scarcity generally refers to the physical and volumetric difference between limited quality water supply...
and the increasing water demands for human living and production [6–10]; it was indicated as a problem in the late 1980s and has become the highest risk and challenge to the United Nations Sustainable Development Goals [6,11,12]. Given the complexity and severity of the water scarcity crisis, it is essential to understand the impact of socio-economic activities and water resource responses. The Global Water Partnership (GWP) has introduced a multi-criterion planning and decision-making process of integrated water resource management (IWRM) to coordinate the relationship of water, related resources, and linked management sectors, in order to maximize economic and social welfare with the sustainable development of ecosystems and environment [13–15]. Accordingly, the IWRM should be practiced based on the interrelationship between ecological and socio-economic systems to ensure the availability and sustainability of water resources [13,16,17]. Water resource response assessment is, therefore, of great significance to regional IWRM as it allows coordinated development of water resources and the social economy.

In traditional “command and control” approaches to IWRM, researchers emphasized adequate access to water resources for human needs, regardless of the basic water demand needed to maintain ecosystem services [18]. Recently, some scholars have started to focus on the ecological and environmental factors involved when water resources are being managed [19–21]. However, the complex social–ecological system contains complicated cross-scale dynamic interactions and multiple feedback mechanisms. This means that IWRM must be designed with careful consideration of both socio-economic development and ecological and environmental protection [22,23].

System dynamics (SD), developed by Forrester in the 1960s, is a widely used method that is able to visualize the feedback loops and simulate the behavior of dynamic systems [24]. Because water resource systems are composed of separate but interrelated subsystems, it is crucial to use systems theory to analyze the interaction and feedback mechanisms between socio-economic subsystems and ecological subsystems, and so enable prediction of the influences caused by outside disturbance. The SD model has, therefore, been widely used in IWRM [24–27]. However, the current system dynamics methods used for IWRM are mostly focused on the policy effects in different development scenarios, and pay insufficient attention to the inherent characteristics and development trends of regional water resources. The impacts of climate change and human activities vary from place to place, so it is necessary to predict water resource responses based on water resource variation trends and policy impact assessment to achieve pertinence and sustainability in IWRM [28,29]. Hydrological variation analysis based on statistics has been widely used to estimate the effects of climate change and human activities on regional hydrological process; as its model structure is simple, there are fewer data requirements and there is less parameter uncertainty [30–33]. Internal feedback relationships among water resource subsystems, and water resource effects under various regional water resource utilization scenarios, can be revealed on the basis of the current situation and variations in water resources through a combination of SD and hydrological variation analysis. This combination is expected to improve decision making in regional water resource development and planning as a result.

The aim of the study was to propose a new method that combined hydrological variation analysis and SD model, taking the Baiyangdian Region (including Baiyangdian Lake and its surrounding area) as a case study. Baiyangdian Lake, the largest freshwater lake in the North China Plain, has great social, economic, and ecological values, such as material production, water conservation, flood control, drought resistance, local microclimate regulation, and biodiversity protection. As with most shallow lakes, its water quantity and quality are vulnerable to human activities and climate change. After the establishment of the Xiong’ an New Area, a future metropolitan area in China’s national strategic planning, the Baiyangdian Region will face more severe environmental protection challenges. Therefore, it is crucial to assess water resource status and its response to future policies to support IWRM in the Xiong’ an New Area. First, integrated variation analysis identified the variation time and trend of inflow volume, and attributive analysis estimated the impacts of natural and human factors on inflow. These gave a comprehensive assessment of the water environment and identified ecological problems in the Baiyangdian Region. An SD model was then built to simulate the water resource
responses to the eco-migration policy and construction of the Xiong’an New Area, and to predict the
effects and problems of these policies, so providing advice for the management and restoration of
ecological function in the Baiyangdian Region. The highlight of this study was to analyze both the
relationship between water supply and demand, and water resource responses to different utilization
policies, based on an objective understanding of the water resource background and system dynamics
theory. This allowed us to offer realistic IWRM suggestions in the Baiyangdian Region and provide a
new perspective for global research of sustainable utilization strategy of regional water resources.

2. Materials

The Baiyangdian Basin, which covers approximately 31,200 km², is located in the center of the
North China Plain and belongs to the Daqing River System of the Haihe River Basin. Baiyangdian
Lake, the largest freshwater lake in the North China Plain, is situated in the low-lying exit of the
basin (38°43’–39°02’ N, 115°38’–116°07’ E), and covers approximately 366 km² (Figure 1). There is
considerable interannual change in the precipitation in the Baiyangdian Region (including Baiyangdian
Lake and villages around the lake), which in years of high flow is three times more than in years of
low flow. The lake is shallow and covers a wide area, so its volume is too small to allow it to store
water. Water mobility is weak owing to the hydrodynamic conditions. As a result, it is difficult for
Baiyangdian Lake to adjust and recover itself.

Precipitation and upstream runoff are the main surface water sources for the Baiyangdian Region.
However, both of them have declined recently because of climate change and human activities (such as
land use/cover change, water extraction, pollutant discharge, and so on), leading to a water crisis in
the region. Although inter-basin water transfer has alleviated this to some extent, it has also increased
the cost of water extraction. Internal IWRM is, therefore, the most economical solution to the problem.
If water resources are to be sustainable, however, it is crucial to fully consider the current regional
hydrologic situation and likely future changes before practicing internal management. According
to Ecology and Environment Protection and Improvement Plan for Baiyangdian Basin (2018–2035) [34],
80% of local residents will be relocated until the end of 2020. The eco-migration policy will not
only be related to regional social and economic development, but will also have an unpredictable
influence on the ecological environment. On 1 April 2017 the Chinese government decided to set up
Xiong’an New Area in Heibei Province, which is expected to be the national model for high-quality and
sustainable development. Because the Baiyangdian Region is an important component of the Xiong’an
New Area, the development and utilization of its water resources are not only related to ecological
safety, but are also key to achieving harmony and sustainability between economic development
and environment protection in Xiong’an. As a consequence, it is necessary to assess water resource
responses to regional development and utilization policies to provide a reference for Baiyangdian
IWRM in this changing situation.

The meteorological data used in the study were obtained from meteorological stations around the
lake and the China Meteorological Data Service Center [35]. Water quality data were obtained from
Baoding Municipal State of the Environment [36]. Water level data, hydrologic data, and socio-economic
data were taken from government reports and statistics yearbooks [37–41]. Land use data were
downloaded from the Resource and Environment Data Cloud Platform [42], and interpreted from
remote sensing images.
An SD model was then built to simulate the water resource responses to the eco-migration policy and construction of the Xiong’an New Area, and to predict the effects and problems of these policies, so providing advice for the management and restoration of ecological function in the Baiyangdian Region. The highlight of this study was to analyze both the relationship between water supply and demand, and water resource responses to different utilization policies, based on an objective understanding of the water resource background and system dynamics theory. This allowed us to offer realistic IWRM suggestions in the Baiyangdian Region and provide a new perspective for global research of sustainable utilization strategy of regional water resources.

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Figure 1. Location of the Baiyangdian Region, North China.

3. Methods

3.1. Assessment Process Combing Hydrological Variation Analysis and System Dynamics Modeling

An in-depth assessment process of water resource responses to regional development policies was as follows. First, we used integrated variation analysis to investigate the time series variability of precipitation and runoff depth in the Baiyangdian Region, and to identify their variation times and trends. Attributive analysis based on the Budyko theory was then used to determine the main factor influencing the variability. Assessment of the current situation regarding water resources then allowed us to determine whether the sustainable development goals could be achieved by internal management or integrated cross-basin management. To do this, it was necessary to assess the effects of implementing management policies. In the study, an SD model with a water quantity module and a water quality module was built, to simulate the water responses to the eco-migration policy and the establishment and development of the Xiong’an New Area. Comprehensive consideration of policy impacts and regional water conservation potential allowed us to determine the volume of inter-basin transferred water (Figure 2).
3.2. Hydrological Variation Analysis Based on the Budyko Theory

According to water balance and energy balance theory, Budyko [43] pointed out that precipitation and evapotranspiration were the main factors affecting regional hydrologic processes in a long time series. Regional mean runoff can be predicted by the curvilinear relationship between the evaporative index and the dryness index [18]. The Budyko theory can be further developed into Fu’s formula, based on the physical meaning of hydrologic processes (Equation (1)) [44]:

$$\frac{E}{P} = 1 + \frac{E_0}{P} \left[ 1 + \left( \frac{E_0}{P} \right)^{\omega} \right]^{1/\omega}$$

where $\omega$ is the character parameter, $P$ is precipitation, $E_0$ is potential evapotranspiration, and $E$ is actual evapotranspiration.

Human activities will change the underlying surface of the catchment, so affecting the hydrologic cycle, which will lead to a change in $\omega$. Assuming that the impact of human activities and that of climate change are independent of each other, the runoff variation can be divided into two parts (Equation (2)):

$$\Delta Q_T = \Delta Q_C + \Delta Q_H$$

Figure 2. Assessment process combing hydrological variation analysis and system dynamics modeling.
where \( \Delta Q_T \) is the total runoff variation and equals the difference between the average runoff before the variation time and after the variation time, \( \Delta Q_C \) is the runoff variation caused by climate change, and \( \Delta Q_H \) is the runoff variation caused by human activities. Assuming that the runoff was only affected by climate change before variation time, \( \Delta Q_C \) can be calculated as in Equations (3)–(5):

\[
\Delta Q_C = s_1 \Delta P + s_2 \Delta E_0
\]

\[
s_1 = \left[ 1 + \left( \frac{E_0}{P} \right) \right]^{1/\omega} - \left[ 1 + \left( \frac{E_0}{P} \right) \right]^{1-\omega} \left( \frac{E_0}{P} \right)^\omega
\]

\[
s_2 = \left[ 1 + \left( \frac{E_0}{P} \right) \right]^{1-\omega} \left( \frac{E_0}{P} \right)^\omega - 1
\]

where \( s_1 \) and \( s_2 \) are sensitivity coefficients.

Therefore, taking the situation before variation time as the reference, the impacts on runoff caused by human activities and climate change can be calculated by Equations (6) and (7):

\[
P_C = \frac{\Delta Q_C}{\Delta Q_T}
\]

\[
P_H = \frac{\Delta Q_H}{\Delta Q_T}
\]

where \( P_C \) is the impact of climate change and \( P_H \) is the impact of human activities.

3.3. SD Model for Water Resource Response to Eco-Migration Policy

3.3.1. System Boundaries

The border of Baiyangdian Lake and that of Anxin County were taken as system boundaries. The data in 2005 were taken as initial values, and the time scale was from 2006 to 2014, with a time step of 1 year. The water storage capacity of Baiyangdian Lake was approximately represented by its annual average water level because the water level was stable. The SD model was composed of a water quantity module and a water quality module, and was implemented in STELLA 9.0 software.

3.3.2. Water Quantity Module

Water balance theory was used to build the water quantity module, as in Equation (8):

\[
V(t) = V(t-\Delta t) + [I(t) + P(t) + Ef(t) - E(t) - O(t) - S(t) - L(t)] \times \Delta t
\]

where \( V \) is water storage volume, \( I \) is upstream inflow volume, \( P \) is precipitation, \( Ef \) is reused wastewater volume, \( O \) is outflow volume, \( S \) is water supply, \( L \) is water leakage volume, and \( \Delta t \) is time step set as 1 year.

The system was divided into two parts: lake interior and lake exterior.

(1) Water demand of lake interior (\( D_{IL} \))

Water demand from the lake interior included agricultural water demand (\( D_{AL} \)), domestic water demand (\( D_{DL} \)), water demand for reed growth (\( D_{RIL} \)), and ecological water demand (\( D_{EL} \)).

\( D_{AL} \) can be expressed as in Equations (9) and (10):

\[
D_{AL}(t) = A_{per} \times P_L(t) \times D_{pa}
\]

\[
R_{AL}(t) = D_{AL}(t) \times r_a
\]

where \( A_{per} \) is per capita farmland area and \( P_L \) is population. Only 50% of the population of the part-water village was included (the total population ranges from 80,000 to 100,000). \( D_{pa} \) is water
demand per unit area of farmland, $R_{AL}$ is the volume of agricultural wastewater, $r_a$ is the agricultural wastewater discharge rate, and $t$ is time.

$D_{DL}$ can be expressed as in Equations (11) and (12):

$$D_{DL}(t) = P_L(t) \times D_{pd}$$
$$R_{DL}(t) = D_{DL}(t) \times r_{di}$$

where $D_{pd}$ is per capita domestic water demand, $R_{DL}$ is the volume of domestic wastewater discharged directly into the lake, and $r_{di}$ is the domestic wastewater discharge rate into the lake interior.

With respect to $D_{RL}$, 20% of water surface evaporation was considered to be water demand for reed growth, as this was used as the standard in the study [45]. The area of water surface was identified from land use data.

Ecological water demand is the water required for an ecological water level, but this is usually ignored in most studies. To enable an overall understanding of the water requirements of a social–ecological system, we considered the ecological water demand to be a standard in assessing the current situation and the effect of water supply. A water level of 7.3 m was considered to represent ecological water demand [46].

In conclusion, the total water demand of the lake interior ($D_L$) was calculated as in Equation (13):

$$D_L = D_{DL} + D_{AL} - R_{AL} - R_{DL}$$

(2) Water demand of lake exterior ($D_O$)

Water demand of lake exterior included domestic water demand ($D_{DO}$), industrial water demand ($D_{IO}$), and agricultural water demand ($D_{AO}$).

$D_{DO}$ can be expressed as in Equations (14)–(17):

$$NP(t) = NP(t - \Delta t) + NP(t - \Delta t) \times K_D(t) \times \Delta t - PL(t)$$
$$D_{DO}(t) = NP(t) \times D_{po}$$
$$R_{DO}(t) = D_{DO}(t) \times r_{do}$$
$$E_{DO}(t) = D_{DO}(t) \times r_{de}$$

where $NP$ is the total population of local people, $K_D$ is the change rate of people, $K_D = \text{birth rate} - \text{death rate} + \text{immigration rate} - \text{emigration rate}$, $D_{po}$ is per capita water demand, $R_{DO}$ is the volume of reused domestic wastewater, $r_{do}$ is the reuse rate of domestic wastewater, $E_{DO}$ is the volume of domestic wastewater discharged into the lake, and $r_{de}$ is the domestic wastewater discharge rate in the lake exterior.

$D_{IO}$ can be expressed as in Equations (18)–(21):

$$V_I(t) = V_I(t - \Delta t) + V_I(t - \Delta t) \times K_I(t) \times \Delta t$$
$$D_{IO}(t) = V_I(t) \times D_V$$
$$R_{IO}(t) = D_{IO}(t) \times r_{IR}$$
$$E_{IO}(t) = D_{IO}(t) \times r_{IE}$$

where $V_I$ is total industrial production value, $K_I$ is the growth rate of total industrial production value, $D_V$ is the water demand per 10,000 yuan industrial production value, $R_{IO}$ is the volume of reused industrial wastewater, $r_{IR}$ is the reuse rate of industrial wastewater, $E_{IO}$ is the volume of industrial wastewater discharged into the lake, and $r_{IE}$ is the industrial wastewater discharge rate.
where \(\text{D}_{\text{An}}\) is the water consumption of different types of agricultural land (farmland, forest land, and grassland, which were identified from land use data), \(S_n\) is the area of different types of agricultural land, \(\text{R}_{\text{AO}}\) is the volume of reused agricultural water, \(r_{\text{RAO}}\) is the reuse rate of agricultural wastewater, \(\text{E}_{\text{AO}}\) is the volume of agricultural wastewater, and \(r_a\) is the agricultural wastewater discharge rate.

In conclusion, the total water demand of the lake exterior (\(\text{D}_O\)) was calculated as in Equation (25):

\[
\text{D}_O = \text{D}_{\text{IO}} + \text{D}_{\text{AO}} + \text{D}_{\text{DO}} - \text{R}_{\text{IO}} - \text{R}_{\text{AO}} - \text{R}_{\text{DO}}
\] (25)

### 3.3.3. Water Quality Module

As it is shallow, the water quality of Baiyangdian Lake is greatly influenced by its quantity. Therefore, in the study, the impacts on pollutant concentrations of inflow water, outflow water, and human wastewater were carefully considered. These allowed us to build the water quality module, which we coupled with the water quantity module (Section 3.3.2). According to the water quality characteristics \([47,48]\) and pollution loads caused by human activities, chemical oxygen demand (COD\(_{\text{Mn}}\)), total nitrogen (TN), and total phosphorus (TP) were chosen as the main indicators of water quality, considering that TN and TP could indicate inorganic pollution level and COD\(_{\text{Mn}}\) could indicate organic pollution level. These three pollutants are also the goals of local Pollution Total Amount Control (a Chinese pollution treatment policy). The pollutant concentrations in Baiyangdian Lake vary a little in time and space, because of its stable water storage volume, poor hydrodynamic conditions, shallow water level, and absence of temperature stratification. A zero-dimensional lake water quality model can, therefore, be used to simulate change in the water quality of Baiyangdian Lake, ignoring the complicated chemical reactions. Only the pollutant load caused by human activities and pollutant reduction by water release, sedimentation, and reed adsorption were considered. We described the change in Baiyangdian water quality as in Equations (26) and (27):

\[
V(t)C(t) = V(t)C(t - \Delta t) + Q_L + [I(t)C_I(t) + E(t)C_E(t) + F_d(t)C_d(t) - O(t)C(t) - kC(t)V(t)]\Delta t - Q_R
\] (26)

\[
E(t) = E_{\text{Io}}(t) + E_{\text{Do}}(t) + E_{\text{Ao}}(t)
\] (27)

where \(V\) is lake water volume, \(C\) is pollutant (TN, TP, COD\(_{\text{Mn}}\)) concentrations, \(Q_L\) is the pollutant load of interior inflow, \(I\) is upstream inflow volume, \(C_I\) is pollutant concentrations in upstream inflow, \(E\) is exterior inflow volume, \(C_E\) is pollutant concentrations of exterior inflow, \(F_d\) is volume of inter-basin transferred water, \(C_d\) is pollutant concentrations of inter-basin transferred water, \(O\) is outflow volume, \(Q_R\) is the pollutant load absorbed by reeds, and \(k\) is the pollutant removal rate.

### 3.3.4. STELLA Model

On the basis of the analyses shown in Sections 3.3.2 and 3.3.3, we built a STELLA model to simulate the water response (Figure 3).
land, \( RAO \) is the volume of reused agricultural water, \( r_{RAO} \) is the reuse rate of agricultural wastewater, \( EAO \) is the volume of agricultural wastewater, and \( r_a \) is the agricultural wastewater discharge rate.

In conclusion, the total water demand of the lake exterior \( DO \) was calculated as in Equation (25):

\[
DO = DI + DA + DO - RI - RA - RD \tag{25}
\]

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\[
V(t)C(t) = V(t - \Delta t)C(t - \Delta t) + \frac{Q_i}{V_i}C_i(t) + \frac{E}{E_d}C_d(t) - O(t)C(t) - kC(t)V(t) \tag{26}
\]

\[
E(t) = E_i(t) + E_d(t) + E_A(t) \tag{27}
\]

where \( V \) is lake water volume, \( C \) is pollutant (TN, TP, COD\(_{Mn}\)) concentrations, \( Q_i \) is the pollutant load of interior inflow, \( I \) is upstream inflow volume, \( C_i \) is pollutant concentrations in upstream inflow, \( E \) is exterior inflow volume, \( C_d \) is pollutant concentrations of inter-basin transferred water, \( O \) is outflow volume, \( Q_R \) is the pollutant load absorbed by reeds, and \( k \) is the pollutant removal rate.

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Figure 3. STELLA model of water resource response to eco-migration policy: (a) water supply of Baiyangdian Lake; (b) water demand and wastewater discharge of lake interior; (c) water demand of lake exterior; (d) wastewater discharge of lake exterior; (e) pollutant load in Baiyangdian Lake.

3.3.5. Calibration and Verification

We took 2005 as the initial year (i.e., the data in 2005 as initial values) and used the STELLA model to simulate the water quality and quantity of Baiyangdian Lake from 2006 to 2014. We calibrated the values of parameters based on the measured data in 2005 (Table 1), with differences between simulated values and measured values being limited to 15%. The results of the calibrated model are shown in Figure 4 and the error analysis results are shown in Tables 2 and 3.

Table 1. Calibrated values of parameters.

| Parameters                                      | Values       | Parameters                                      | Values       |
|------------------------------------------------|--------------|------------------------------------------------|--------------|
| Annual net population growth rate in interior  | 8.0%         | Annual net population growth rate in interior  | 8.5%         |
| Leakage parameter                              | 0.100        | Annual irrigation water demand per square meter of rice | 0.847 m³/a |
| Annual irrigation water demand per square meter of corn | 0.545 m³/a  | Annual irrigation water demand per square meter of wheat | 0.604 m³/a |
| Annual irrigation water demand per square meter of cotton | 0.450 m³/a  | Discharge rate of agricultural wastewater       | 4.0%         |
| Water demand of per 10,000 yuan industrial GDP | 121.69 m³    | Discharge rate of industrial wastewater         | 44.3%        |
| Reuse rate of industrial wastewater            | 4.0%         | Annual per capita domestic water demand in exterior | 438 m³/a    |
| Discharge rate of domestic wastewater in exterior | 17.6%       | Reuse rate of domestic wastewater in interior  | 4.0%         |
| Annual per capita domestic water demand in interior | 110 m³/a   | Entry rate of domestic wastewater in interior    | 90.0%        |
| Per capita farmland area in interior           | 6723.964 m²  | Number of ducks per capita in interior           | 3,500        |
| Number of fish per capita in interior          | 5.800        | Annual COD₃₅₀ concentration of per unit domestic wastewater | 1.640 × 10⁸ g/a |
| Annual COD₃₅₀ concentration in inflow of per unit duck | 217.783 g/a | Annual TN concentration in inflow of per unit duck | 43.800 g/a  |
| Annual TP concentration in inflow of per unit duck | 0.081 g/a  | Annual average removal rate of TN               | 85.0%        |
| Annual average removal rate of TP              | 90.0%        | Annual average removal rate of COD₃₅₀           | 50.0%        |
Figure 4. Simulation results of (a) water level and (b) pollutant concentrations.

Table 2. Simulation results and verification of water quantity.

| Year | Simulated Water Quantity ($\times 10^8$ m$^3$) | Predicted Water Level (m) | Measured Water Level (m) | Error (%) |
|------|---------------------------------------------|---------------------------|--------------------------|-----------|
| 2005 | 1.16                                        | 7.34                      | 7.24                     | 1.37      |
| 2006 | 0.57                                        | 6.69                      | 6.80                     | −1.61     |
| 2007 | 0.66                                        | 6.81                      | 6.74                     | 1.03      |
| 2008 | 0.64                                        | 6.79                      | 7.06                     | −3.79     |
| 2009 | 0.69                                        | 6.84                      | 7.14                     | −4.27     |
| 2010 | 1.23                                        | 7.37                      | 7.06                     | 4.40      |
| 2011 | 1.82                                        | 7.74                      | 7.06                     | 9.65      |
| 2012 | 1.95                                        | 7.82                      | 7.58                     | 3.10      |
| 2013 | 2.49                                        | 8.10                      | 8.44                     | −4.07     |
| 2014 | 1.87                                        | 7.77                      | 8.39                     | −7.38     |
Table 3. Simulation results of water quality.

| Year | COD$_{Mn}$ (mg/L) | TN (mg/L) | TP (mg/L) | Water Level (m) |
|------|-------------------|-----------|-----------|-----------------|
| 2005 | 11.05             | 3.67      | 0.67      | 7.34            |
| 2006 | 25.24             | 3.46      | 0.20      | 6.69            |
| 2007 | 22.91             | 2.58      | 0.10      | 6.81            |
| 2008 | 22.45             | 2.33      | 0.08      | 6.79            |
| 2009 | 20.89             | 2.20      | 0.08      | 6.84            |
| 2010 | 11.26             | 2.58      | 0.04      | 7.37            |
| 2011 | 8.83              | 1.00      | 0.04      | 7.74            |
| 2012 | 9.71              | 1.11      | 0.04      | 7.82            |
| 2013 | 9.01              | 1.03      | 0.04      | 8.10            |
| 2014 | 9.04              | 0.75      | 0.02      | 7.77            |

According to Table 2, the error rate between predicted water level and measured data varied from −7.38% to 9.69%. Comparing the simulated pollutant concentrations (Table 3) and the measured data [49] in 2010, the error rate of COD$_{Mn}$ concentrations was 14.1%, that of TP was 16.4%, and that of TN was 25%. These were all acceptable in the study, and so the simulated results of the STELLA model were credible.

4. Results and Discussion
4.1. Accessibility to Sustainable Development Goal of Internal Management

Precipitation and potential evapotranspiration data were collected from meteorological stations around the lake. To calculate and compare these, the inflow volume was transformed to runoff depth, which was equal to annual inflow volume divided by catchment area. The spatial distribution of precipitation and potential evapotranspiration were obtained by inverse interpolation in ArcGIS 10.2 software. Time series variation analyses of precipitation and runoff depth from 1961 to 2000 showed that the Hurst coefficient of precipitation was 0.5308, which failed the significance test in $\alpha = 0.05$; that of runoff depth was 0.7049, which passed the significance test. According to integrated variation analysis of runoff depth, its variation time was 1979 and the variation trend was that of decline.

According to average precipitation, potential evapotranspiration, and runoff, we were able to calculate the actual evapotranspiration, character parameter, and sensitivity coefficients (Table 4). According to the Ecological Environment Assessment Report of Baiyangdian Lake [50], at least $1.26 \times 10^8$ m$^3$ runoff supply is needed to maintain a minimum ecological water level (7.3 m) in Baiyangdian Lake. We further calculated the natural runoff of Baiyangdian Lake (Table 4).

Table 4. Changes in natural parameters in the Baiyangdian Region.

| Year          | $E$ (mm) | $P$ (mm) | $Q$ (mm) | $Q_r$ (mm) | $\omega$ | $s_1$  | $s_2$ |
|---------------|----------|----------|----------|------------|----------|--------|-------|
| Before variation time | 488.68   | 551.46   | 46.57    | 73.39      | 2.64     | 0.29   | −0.087 |
| After variation time  | 453.15   | 502.39   | 9.74     | 56.95      | 2.65     | 0.26   | −0.072 |

Equations (6) and (7) indicated that the impact on runoff of climate change was 34.19% and that of human activities was 65.18%, which were consistent with Hu et al. [51] and Yuan et al. [52]. Absolute values of sensitivity coefficients ($s_1$ and $s_2$) both declined after variation time (Table 4), which indicated that the impact of climate change has been relieved, while that of human activities has been aggravated. Human activity was the main cause of runoff variation.

Comparing measured runoff with natural runoff revealed that the reduction in runoff from water extraction was 20.39 mm, accounting for 84% of human activities. Therefore, if only internal management is used to achieve the sustainable development goal, it is necessary to reduce regional
water consumption by 20% under the current conditions. However, population growth is inevitable with the establishment and development of the Xiongan New Area, and will lead to an increase in water demand. Adequate access to agricultural water demand is closely tied to food security, so it is unwise to reduce agricultural water to achieve the conservation goal. The proportion of industrial water is small and has fallen every year, so the potential of saving industrial water has also declined. It is impossible to achieve a sustainable development goal only through internal management, and integrated cross-basin management needs to be introduced to the Baiyangdian Region.

Mohammad et al. [53] used the standardized precipitation index, the standardized water-level index, and the percent departure from normal rainfall to monitor meteorological and hydrological drought in the Yarmouk Basin, northern Jordan from 1993 to 2014. The results showed that the Yarmouk Basin suffered frequent and irregular extreme meteorological and hydrological drought because of the rainfall pattern changes and precipitation decrease caused by climate change, and the increasing groundwater extraction caused by growing population and water demands. The hydrological drought was more severe than the meteorological drought. These results were consistent with our study. However, Mohammad’s study only evaluated regional water drought and its effects on water resources qualitatively. In our study, we not only identified the variation times and trends of precipitation and runoff, but also quantified the impact of climate change and human activities so that we could have a full and essential understanding of the regional water resource background and provide a basis for water resource response assessment.

4.2. Simulation of Water Resource Response to Integrated Management Policies

4.2.1. Current Eco-Migration Policy

We assumed that most emigration was from the full-water village (refers to the village fully surrounded by water), and other migration was from the part-water village (refers to the village partly surrounded by water). The final goal of the eco-migration policy is to move 80% of villagers from the full-water village until the end of 2020. We assumed that 50% of villagers would move from the full-water village every year. Of these, 50% would settle in Anxin County, and the other villagers would move to other places. In addition, $1 \times 10^8$ m$^3$ water would be transferred annually to the Baiyangdian Region to maintain its ecological health. Results of the water resource responses to the eco-migration policy, simulated by the calibrated model, are shown in Table 5. In this situation, groundwater extraction was approximately $3 \times 10^8$ m$^3$, which is less than the maximum groundwater extraction volume ($19.77 \times 10^8$ m$^3$) in Baoding City, Hebei Province.

| Year | Population of the Full-Water Village | Population of Eco-Migration | Water Level (m) | COD$_{Mn}$ (mg/L) | TN (mg/L) | TP (mg/L) | Transferred Water Volume ($\times 10^8$ m$^3$) |
|------|-------------------------------------|-----------------------------|----------------|-------------------|-----------|-----------|---------------------------------|
| 2015 | 108,822                             | 0                           | 6.48           | 34.1              | 2.68      | 0.10      | 1.00                            |
| 2016 | 109,746                             | 0                           | 7.40           | 8.89              | 0.75      | 0.03      | 1.00                            |
| 2017 | 110,678                             | 23,519                      | 7.43           | 7.85              | 0.74      | 0.03      | 1.00                            |
| 2018 | 64,579                              | 13,723                      | 7.42           | 7.62              | 0.76      | 0.03      | 1.00                            |
| 2019 | 37,681                              | 8,007                       | 7.64           | 6.01              | 0.60      | 0.03      | 1.00                            |
| 2020 | 21,987                              | 4,672                       | 7.75           | 5.46              | 0.55      | 0.02      | 1.00                            |

The population of the full-water village in 2020 would be reduced to 20% of current numbers, and this met the expectations of the policy goal (Table 5). Because transferred water addressed the shortage of local water, it would be possible to maintain the ecological water level (7.3 m) and reduce pollutant concentrations. Predictions of water quality in 2020 are shown in Table 6. Reference to the Environmental quality standards for surface water (GB3838-2002) [54] suggested that the water quality in 2020 could reach class III, which would be compatible with the ecological function of Baiyangdian Lake. Therefore, the eco-migration policy would be of considerable value in quickly improving the ecological and environmental quality, and even in recovering the water ecosystem function.
### Table 6. Water quality of Baiyangdian Lake in 2020.

| Pollutants | Standards (mg/L) | Assessment | Pollutant Concentration in 2020 (mg/L) | Water Quality Class |
|------------|------------------|------------|--------------------------------------|---------------------|
|            | Class I | Class II | Class III | Class IV | Class V |                      |                      |
| TP         | 0.01    | 0.025    | 0.05     | 0.10     | 0.20    | 0.02                  | I                    |
| TN         | 0.20    | 0.50     | 1.00     | 1.50     | 2.00    | 0.55                  | III                  |
| COD$_{Mn}$ | 15      | 15       | 20       | 30       | 40      | 5.46                  | I                    |

#### 4.2.2. The Establishment and Development of the Xiong’an New Area

We further analyzed the impact of the Xiong’an New Area on the assumption of the eco-migration policy (Section 4.2.1). We assumed that immigration would begin in 2028. The volume of transferred water would remain at $1 \times 10^8$ m$^3$. The constraint conditions of the model were an ecological water level for Baiyangdian Lake of 7.3 m and maximum groundwater extraction volume of $19.77 \times 10^8$ m$^3$. The water resource responses are shown in Table 7.

### Table 7. Impact of establishment and development of the Xiong’an New Area.

| Year | Water Level (m) | Water Demands ($\times 10^8$ m$^3$) | COD$_{Mn}$ (mg/L) | TN (mg/L) | TP (mg/L) | Class of Water Quality |
|------|-----------------|-------------------------------------|-------------------|-----------|-----------|------------------------|
| 2029 | 7.3             | 13.625                              | 58.81             | 9.38      | 0.50      | Inferior V             |
| 2030 | 7.3             | 13.985                              | 50.03             | 6.25      | 0.30      | Inferior V             |
| 2031 | 7.3             | 14.355                              | 42.27             | 4.74      | 0.20      | Inferior V             |
| 2032 | 7.3             | 14.725                              | 36.31             | 3.83      | 0.20      | Inferior V             |
| 2033 | 7.3             | 13.625                              | 58.81             | 9.38      | 0.50      | Inferior V             |

Our simulation suggested that population growth would lead to a sharp increase in water demand and pollutant discharge, exceeding the self-purification capacity and causing severe water deterioration (Table 7). In other words, after establishment and development of the Xiong’an New Area, the water quantity and quality would be damaged, and there would even be a risk of ecosystem function degeneration in the Baiyangdian Region. Therefore, to prevent deterioration of the ecological environment and maintain sustainability, it is a prerequisite to manage water conservation, control the total amount of pollutants, and increase cross-basin transferred water before and during the construction of the Xiong’an New Area.

Odeh et al. [55] compared land use maps with groundwater level spatial distribution maps to analyze the effects of urbanization and agricultural activities on groundwater levels and salinity in Irbid governorate, Jordan from 1984 to 2014, and the results showed that population growth, urban expansion, and agricultural development increased water demands and groundwater extraction, resulting in a groundwater level decrease and salinity of pumped groundwater increase. Hu et al. [56] used participatory rural appraisal methods, ecological footprint, and stochastic impacts by regression on population, affluence, and technology models to assess the environmental impact of eco-migration policies in Huanjiang County, China, and the results showed that population growth and resource over-exploitation caused by eco-migration policies were the main reasons for the negative environmental stress on immigration areas. These results were consistent with our study. However, Odeh’s method and Hu’s methods could only assess the policy impacts based on the current situation, without taking into account the interrelationship between ecosystem and the socio-economic system. As noted in the 2030 Agenda for Sustainable Development [57], one of the main sustainable development goals is to build sustainable cities and communities by guaranteeing adequate water supply. Therefore, effective IWRM should be based on interaction and feedback relationship analysis of water demand subsystems in different scenarios to choose the most sustainable management plan. The policy assessment method based on the SD model built into our study was able to predict water resource responses in different
scenarios, with comprehensive consideration of interactive mechanisms between subsystems, and so it was able to provide multi-perspective assessments of policies.

5. Conclusions

Using the Baiyangdian Region—with its severe water shortage and poor habitat quality problems—as a study case, we proposed a multi-angle method combined with hydrological variation analysis and an SD model to assess water resource responses to development and utilization policies. The results showed that human activity, especially water extraction, was the main cause of variations in regional runoff. With high-intensity human activities, it is impossible to achieve sustainable development goals through internal IWRM. Nevertheless, with the help of cross-basin transferred water and eco-migration policies, the ecological water environment could be considerably improved. However, after the establishment and development of the Xiong’an New Area, there will be a new water crisis in the Baiyangdian Region. The study provides a new perspective for regional IWRM study and comparison.

Multi-angle problem identification and IWRM were not only useful in solving water problems in the Baiyangdian Region, but may also be meaningful for the coordinated development of Beijing–Tianjin–Hebei Integration. However, owing to the objective limitations of the current data, there were some deficiencies in the study: ignorance of changes and potential risks during the year and no consideration of reactions between pollutants (owing to the lack of clear explanations of reaction mechanisms). Future work should focus on a detailed study of the mechanisms involved in physical, chemical, and biological reactions over a short time scale to improve and popularize our research results.

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References

1. Wang, Q.; Li, S.; He, G.; Li, R.; Wang, X. Evaluating sustainability of water-energy-food (WEF) nexus using an improved matter-element extension model: A case study of China. J. Clean. Prod. 2018, 202, 1097–1106. [CrossRef]
2. Huang, D.; Li, G.; Sun, C.; Liu, Q. Exploring interactions in the local water-energy-food nexus (WEF-Nexus) using a simultaneous equations model. Sci. Total Environ. 2020, 703, 135034. [CrossRef] [PubMed]
3. Jin, N.; Ren, W.; Tao, B.; He, L.; Ren, Q.F.; Li, S.Q.; Yu, Q. Effects of water stress on water use efficiency of irrigated and rainfed wheat in the Loess Plateau, China. Sci. Total Environ. 2018, 642, 1–11. [CrossRef]
4. Hart, O.E.; Halden, R.U. On the need to integrate uncertainty into US water resource planning. Sci. Total Environ. 2019, 691, 1262–1270. [CrossRef]
5. Jiang, L.; Japaer, G.; Boa, A.; Yuan, Y.; Zheng, G.; Guo, H.; Yu, T.; De Maeyer, P. The effects of water stress on croplands in the Aral Sea basin. J. Clean. Prod. 2020, 254, 120114. [CrossRef]
6. Liu, J.; Yang, H.; Gosling, S.N.; Kummel, M.; Florke, M.; Pfister, S.; Hansakani, N.; Wada, Y.; Zhang, X.; Zheng, C.; et al. Water scarcity assessments in the past, present and future. Earths Future 2017, 5, 545–559. [CrossRef]
7. Xie, P.; Zhuo, L.; Yang, X.; Huang, H.; Gao, X.; Wu, P. Spatial-temporal variations in blue and green water resources, water footprints and water scarcities in a large river basin: A case for the Yellow River basin. *J. Hydrol.* 2020, 590, 125222. [CrossRef]

8. Mehta, L. Whose scarcity? Whose property? The case of water in western India. *Land Use Policy* 2007, 24, 654–663. [CrossRef]

9. Hussein, H. Lifting the veil: Unpacking the discourse of water scarcity in Jordan. *Environ. Sci. Policy* 2018, 89, 385–392. [CrossRef]

10. Edwards, G. Shifting constructions of scarcity and the neoliberalization of Australian water governance. *Environ. Pl. A* 2013, 45, 1873–1890. [CrossRef]

11. Yao, Y.; Sun, J.; Tian, Y.; Zheng, C.; Liu, J. Alleviating water scarcity and poverty in drylands through telecouplings: Vegetable trade and tourism in northwest China. *Sci. Total Environ.* 2020, 741, 140387. [CrossRef] [PubMed]

12. Hussein, H.; Menga, F.; Greco, F. Monitoring Transboundary Water Cooperation in SDG 6.5.2: How a Critical Hydropolitics Approach Can Spot Inequitable Outcomes. *Sustainability* 2018, 10, 3640. [CrossRef]

13. Finger, M.; Tamiotti, L.; Allouche, J. *The Multi—Governance of Water: Four Case Studies*; State University of New York Press: New York, NY, USA, 2006.

14. Wang, K.; Davies, E.G.R.; Liu, J. Integrated water resources management and modeling: A case study of Bow river basin, Canada. *J. Clean. Prod.* 2019, 240, 118242. [CrossRef]

15. Chang, I.S.; Zhao, M.; Chen, Y.; Guo, X.; Zhu, Y.; Wu, J.; Yuan, T. Evaluation on the integrated water resources management in China’s major cities—Based on City Blueprint® Approach. *J. Clean. Prod.* 2020, 262, 121410. [CrossRef]

16. Nikolic, V.V.; Simonovic, S.P.; Milicevic, D.B. Analytical Support for Integrated Water Resources Management: A New Method for Addressing Spatial and Temporal Variability. *Water Resour. Manag.* 2012, 27, 401–417. [CrossRef]

17. Liu, D.; Guo, S.; Shao, Q.; Liu, P.; Xiong, L.; Wang, L.; Hong, X.; Xu, Y.; Wang, Z. Assessing the effects of adaptation measures on optimal water resources allocation under varied water availability conditions. *J. Hydrol.* 2018, 556, 759–774. [CrossRef]

18. Holling, C.S.; Meffe, G.K. Command and Control and the Pathology of Natural Resource Management. *Conserv. Biol.* 1996, 10, 328–337. [CrossRef]

19. Anwar Sadat, M.; Guan, Y.; Zhang, D.; Shao, G.; Cheng, X.; Yang, Y. The associations between river health and water resources management lead to the assessment of river state. *Ecol. Indic.* 2020, 109, 105814. [CrossRef]

20. Guo, X.; Feng, Q.; Si, J.; Xi, H.; Zhao, Y.; Deo, R.C. Partitioning groundwater recharge sources in a desert oasis environment: Implications for water resources management in endorheic basins. *J. Hydrol.* 2019, 579, 124212. [CrossRef]

21. Kanakoudis, V.; Tsitsifili, S.; Papadopoulou, A.; Cencur Curk, B.; Karleusa, B. Water resources vulnerability assessment in the Adriatic Sea region: The case of Corfu Island. *Environ. Sci. Pollut. Res.* 2017, 24, 20173–20186. [CrossRef]

22. de Wet, C.; Odume, O.N. Developing a systemic-relational approach to environmental ethics in water resource management. *Environ. Sci. Policy* 2019, 93, 139–145. [CrossRef]

23. McGinnis, M.D.; Ostrem, E. Social-ecological system framework: Initial changes and continuing challenges. *Ecol. Soc.* 2014, 19, 30. [CrossRef]

24. Mirchi, A.; Madani, K.; Watkins, D.; Ahmad, S. Synthesis of System Dynamics Tools for Holistic Conceptualization of Water Resources Problems. *Water Resour. Manag.* 2012, 26, 2421–2442. [CrossRef]

25. Kotir, J.H.; Smith, C.; Brown, G.; Marshall, N.; Johnstone, R. A system dynamics simulation model for sustainable water resources management and agricultural development in the Volta River Basin, Ghana. *Sci. Total Environ.* 2016, 573, 444–457. [CrossRef] [PubMed]

26. Stave, K.A. A system dynamics model to facilitate public understanding of water management options in Las Vegas, Nevada. *J. Environ. Manag.* 2003, 67, 303–313. [CrossRef]

27. Zhou, Y.; Guo, S.; Xu, C.Y.; Liu, D.; Chen, L.; Ye, Y. Integrated optimal allocation model for complex adaptive system of water resources management (I): Methodologies. *J. Hydrol.* 2015, 531, 964–976. [CrossRef]

28. Wang, W.; Shao, Q.; Yang, T.; Peng, S.; Xing, W.; Sun, F.; Luo, Y. Quantitative assessment of the impact of climate variability and human activities on runoff changes: A case study in four catchments of the Haihe River basin, China. *Hydrol. Process.* 2013, 27, 1158–1174. [CrossRef]
29. Zhao, G.; Tian, P.; Mu, X.; Jiao, J.; Wang, F.; Gao, P. Quantifying the impact of climate variability and human activities on streamflow in the middle reaches of the Yellow River basin, China. *J. Hydrol.* **2014**, *519*, 387–398. [CrossRef]

30. Li, Z.; Li, Q.; Wang, J.; Feng, Y.; Shao, Q. Impacts of projected climate change on runoff in upper reach of Heihe River basin using climate elasticity method and GCMs. *Sci. Total Environ.* **2020**, *716*, 137072. [CrossRef] [PubMed]

31. Mu, X.; Wang, H.; Zhao, Y.; Liu, H.; He, G.; Li, J. Streamflow into Beijing and Its Response to Climate Change and Human Activities over the Period 1956–2016. *Water* **2020**, *12*, 622. [CrossRef]

32. Xu, X.; Yang, D.; Yang, H.; Lei, H. Attribution analysis based on the Budyko hypothesis for detecting the dominant cause of runoff decline in Haihe basin. *J. Hydrol.* **2014**, *510*, 530–540. [CrossRef]

33. Zhang, K.; Ruben, G.B.; Li, X.; Li, Z.; Yu, Z.; Xia, J.; Dong, Z. A comprehensive assessment framework for quantifying climatic and anthropogenic contributions to streamflow changes: A case study in a typical semi-arid North China basin. *Environ. Model. Softw.* **2020**, *128*, 104704. [CrossRef]

34. Hebei Provincial Government. *Ecology and Environment Protection and Improvement Plan for Baiyangdian Basin (2018–2035)*; Hebei Provincial Government: Shijiazhuang, China, 2019. (In Chinese)

35. China Meteorological Data Service Center. Available online: http://data.cma.cn/ (accessed on 27 November 2016). (In Chinese).

36. Environmental Protection Bureau of Baoding. *Economic Statistical Yearbook of Baoding*; China Statistics Press: Beijing, China, 2006. (In Chinese)

37. Hebei Province Department of Water Resources. *Hebei Provincial Water Resources Bulletin*; Hebei Province Department of Water Resources: Shijiazhuang, China, 2006. (In Chinese)

38. Hebei General Hydrometric Station. *Hydrometric Data Yearbook of People’s Republic of China*, 4th ed.; Haihe River Basin; Hebei General Hydrometric Station: Shijiazhuang, China, 2006; Volume 3. (In Chinese)

39. Hebei Provincial Government. *Hebei Provincial Economic Yearbook*; China Statistics Press: Beijing, China, 2006. (In Chinese)

40. Baoding Municipal Statistical Bureau. *Economic Statistical Yearbook of Baoding*; China Statistics Press: Beijing, China, 2006. (In Chinese)

41. Hebei Provincial Bureau of Statistics. *National Economic and Social Development Statistics Bulletin of Hebei Province*; Hebei Provincial Bureau of Statistics: Shijiazhuang, China, 2006. (In Chinese)

42. Resource and Environment Data Cloud Platform. Available online: http://www.resdc.cn/ (accessed on 27 November 2016). (In Chinese).

43. Budyko, M.I. *Climate and Life*; Academic Press: New York, NY, USA, 1974.

44. Fu, B. On the calculation of the evaporation from land surface. *Chin. J. Atmos. Sci.* **1981**, *5*, 23–31. (In Chinese)

45. Deng, R.Q. *Analysis and Assessment of Water Resources-Ecology-Socioeconomic System of Baiyangdian Wetland*; Hebei Agricultural University: Baoding, China, 2011.

46. Zhao, X.; Cui, B.; Yang, Z. A study of the lowest ecological water level of Baiyangdian Lake. *Acta Ecol. Sin.* **2005**, *25*, 1033–1040. (In Chinese)

47. Han, Q.; Tong, R.; Sun, W.; Zhao, Y.; Yu, J.; Wang, G.; Shrestha, S.; Jin, Y. Anthropogenic influences on the water quality of the Baiyangdian Lake in North China over the last decade. *Sci. Total Environ.* **2020**, *701*, 134929. [CrossRef]

48. Yang, Y.; Yin, X.; Yang, Z. Environmental flow management strategies based on the integration of water quantity and quality, a case study of the Baiyangdian Wetland, China. *Ecol. Eng.* **2016**, *96*, 150–161. [CrossRef]

49. Yang, L.; Chen, S. Assessment of water environment quality of Baiyang Lake. *South—North Water Transf. Water Sci. Technol.* **2015**, *13*, 457–462. (In Chinese)

50. Hebei Provincial Environmental Scientific Research. *Ecological Environment Assessment Report of Baiyangdian Lake*; Hebei Provincial Environmental Scientific Research: Shijiazhuang, China, 2006. (In Chinese)

51. Hu, S.; Liu, C.; Zheng, H.; Wang, Z.; Yu, J. Assessing the impacts of climate variability and human activities on streamflow in the water source area of Baiyang Lake. *J. Geogr. Sci.* **2012**, *22*, 895–905. [CrossRef]

52. Yuan, Y.; Yan, D.; Wang, H.; Wang, Q. Attributive analysis on evolution of inflow to Baiyangdian Wetland. *Water Resour. Hydropower Eng.* **2013**, *44*, 1–4, 23. (In Chinese)

53. Mohammad, A.H.; Jung, H.C.; Odeh, T.; Bhuiyan, C.; Hussein, H. Understanding the impact of droughts in the Yarmouk Basin, Jordan: Monitoring droughts through meteorological and hydrological drought indices. *Arab. J. Geosci.* **2018**, *11*, 103. [CrossRef]
54. Ministry of Ecology and Environment of the People’s Republic of China. *Environmental Quality Standards for Surface Water (GB3838-2002)*; China Environmental Press: Beijing, China, 2002. (In Chinese)

55. Odeh, T.; Mohammad, A.H.; Hussein, H.; Ismail, M.; Almomani, T. Over-pumping of groundwater in Irbid governorate, northern Jordan: A conceptual model to analyze the effects of urbanization and agricultural activities on groundwater levels and salinity. *Environ. Earth Sci.* 2019, 78, 40. [CrossRef]

56. Hu, Y.; Zhou, W.; Yuan, T. Environmental impact assessment of ecological migration in China: A survey of immigrant resettlement regions. *J. Zhejiang Univ. Sci. A* 2018, 19, 240–254. [CrossRef]

57. United Nations. *Transforming our World: The 2030 Agenda for Sustainable Development (A/RES/70/1)* United Nations: New York, NY, USA, 2015.

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