Research on Extension Strategy Generation of Sustainable Utilization of Regional Water Resources

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Abstract

Sustainable utilization of water resources has been a global issue of common concern. Under the prerequisites to meet the development need of the region's population, resources, environment and economy, we should solve simultaneously both water crisis and ecological environment construction, which may be more important for the arid and semi-arid regions. Although a lot of results in other aspects of sustainable utilization of water resources have been achieved, it has not been discussed how to generate the strategies to deal with the contradictory problem between water crisis and ecological environment construction. In this paper, Extension Analysis and Extension Transformation were utilized to generate a variety of innovative schemes for sustainable utilization of water resources. By using an appropriate evaluation methodology, we chosen one or more excellent schemes and changed them into the specific programs that can be implemented in practice. The strategy generation process can be achieved by computer software, which makes the decision-making be intelligent. The extension generation method provides a formalized and quantitative way for effectively solving water crisis and ecological environment construction, and clarifies the relevant departments ideas. It is also fit for basin water resources.

Keywords Sustainable utilization of water resources; Water crisis; Ecological environment; Utilization strategy; Extensible methods

1 Introduction

As society and economy developed, the demand of water increased. However, the available water provided by the natural world is limit. At present, the water resources problem in the world especially the arid and semi-arid regions is becoming more and more serious, and it mainly shows that water scarcity is increasing and water conflicts are of comprehensive intensification. Initially, the water management only focused on some aspects of water utilization and protection such as supply, irrigation, hydropower and others. The traditional management ways of water supply and decentralized sectors ignored the integrity of natural environment and the diversity of water use. Therefore, we could not coordinate the various water relations and did not achieve the sustainable utilization of water resources. In order to avoid this deficiency, some scholars have proposed integrated management of water resources which unified water, land and related resources into a jointly development[1-6]. Other scholars believed that the fundamental way to ease the water crisis and the eco-environment destruction is to implement sustainable management of water resources[7,8]. They considered the development and utilization of water resources together with the complex system of social economy - water resources - ecological environment, and inquired the concrete pathway of water sustainable development, which means that we should support the coordinated development among population, resources, environment and economy, and meet the water needs of intrageneration and intergeneration of human being under the promise of maintaining the social continuity and the ecosystem integrity. Sustainability is the most rational utilization pattern to integrate the development, utilization, protection, control and management of water resources, and the essence of sustainable utilization is to coordinate water utilization with environmental protection, economic growth and social development. Many results of sustainable utilization of water resources have been achieved, such as Efficiency evaluation of water use[9-11], Water allocation problem[12-14], Ecological environment impacts[5, 6, 15], Analysis for present situation and countermeasures[16], and Rules establishment and construction which included effective system of water property, open water market, reasonable emerged mechanism of water price and complete management system of water resources[9-10], and so on.

Although scholars have made abundant achievements in many aspects of the sustainable utilization of water resources, we are still hard to coordinate the development among population quality, natural resources, living environment and national economy, and can not accurately grasp the quantitative relationship between the water crisis and the construction of ecosystem. To study the strategy generation methods of sustainable utilization of water resources is helpful for solving the relationship between the water crisis and the eco-environment construction in practice, and improving the decision-making capacity of water resources management. It has more practical significance to support the sustainable development of nature, economy and society.

The following sections of this paper are below. We introduced some basic knowledge of Extenics in Section 2, and proposed extension strategy generation step of sustainable utilization of regional water resources in Section 3. The extension planning process of sustainable utilization is introduced in Section 4, and we give a modified case in Section 5. At the end of this paper, a conclusion is given.

2 Preliminaries of Extenics

Extenics is an original interdisciplinary which was put forward by a Chinese scholar in 1983. It discusses the rules and methods of extension and innovation of objective things by using the formalized models, which are utilized to solve the contradictory problems. Contradictory means that people's goals can not be reached in current conditions[17]. At present, the contents of Extenics include basic-element theory, extension set theory and extension logic. For the sake of simplicity and convenience, we only introduce the knowledge of basic-element theory that will be utilized in this paper.

Basic-element theory includes Extensible Analysis Theory (EAT), Conjugate Analysis Theory (CAT) and Extension Transformation Theory (ETT). EAT includes Divergence Analysis Theory, Correlative Analysis Theory, Implication Analysis Theory and Opening-up Analysis Theory. CAT includes Nonmaterial and Material Conjugate Analysis, Soft and Hard Conjugate Analysis, Latent and Apparent Conjugate Analysis as well as Negative and Positive Conjugate Analysis. ETT includes Basic Extension Transformations, Conductive Transformation and Conjugate Transformation, Calculation of Extension Transformations and Nature of Extension Transformations. All of knowledge above will be introduced below and can be seen in [17].

Firstly, we introduce the basic concept of basic-element, which includes matter-element, affair-element and relation-element. Basic-element is a logical cell of Extenics.

Definition 2.1: An ordered triple M = (O_m, c_m, v_m), which is as the fundamental element for matter description composed of matter O_m, the characteristic c_m of $O_m$and the value v_m of O_m about c_m, is called as one-dimensional matter-element. Furthermore, the following array composed of matter O_m, n-names of characteristics of c_{m1}, c_{m2},$\cdots$, c_{mn} and the corresponding value v_{mi} of O_m about c_{mi} $(i = 1, 2, \cdots, n)$

$$M = \begin{bmatrix} O_m & c_{m1} & v_{m1} \\ & c_{m2} & v_{m2} \\ & \vdots & \vdots \\ & c_{mn} & v_{mn} \end{bmatrix} = (O_m, C_m, V_m) \quad or \quad M = \begin{bmatrix} O_m & c_{m1} & \cdots & c_{mn} \\ & v_{m1} & \cdots & v_{mn} \end{bmatrix},$$

is n-dimensional matter-element, where $C_m = [c_{m1}, c_{m2}, \cdots, c_{mn}]^T$ and $V_m = [v_{m1}, v_{m2}, \cdots, v_{mn}]^T$.

Definition 2.2: The ordered triple A = (O_a, c_a, v_a,) as the fundamental element for affair description composed of the action O_a, the characteristic c_m of O_a and the value v_a of O_a about c_a, is called one-dimensional affair-element. Furthermore, the following array composed of action O_a, n characteristics of c_{a1},

$c_{a2},\cdots$, c_{an} and the obtained value v_{ai} of O_a about c_{mi} (i=1,2,$\cdots$,n)

$$A=\begin{bmatrix} O_a & c_{a1} & v_{a1} \\ & c_{a2} & v_{a2} \\ & \vdots & \vdots \\ & c_{an} & v_{an} \end{bmatrix}=(O_a,C_a,V_a) \quad or \quad A=\begin{bmatrix} O_a & c_{a1} & \cdots & c_{an} \\ & v_{a1} & \cdots & v_{an} \end{bmatrix},$$

is n-dimensional affair-element, where $C_a=[c_{a1},c_{a2},\cdots,c_{an}]^T$ and $V_a=[v_{a1},v_{a2},\cdots,v_{an}]^T$.

Definition 2.3: The n-dimensional array composed of relative or relation symbol (refer to as relation name) O_r, n characteristics c_{ri} of O_r and the corresponding value v_{ri} of O_r about c_{ri} (i=1,2,$\cdots$,n) which is as the following:

$$R=\begin{bmatrix} O_r & c_{r1} & v_{r1} \\ & c_{r2} & v_{r2} \\ & \vdots & \vdots \\ & c_{rn} & v_{rn} \end{bmatrix}=(O_r,C_r,V_r) \quad or \quad R=\begin{bmatrix} O_r & c_{r1} & \cdots & c_{rn} \\ & v_{r1} & \cdots & v_{rn} \end{bmatrix},$$

where $C_r=[c_{r1},c_{r2},\cdots,c_{rn}]^T$ and $V_r=[v_{r1},v_{r2},\cdots,v_{rn}]^T$, and R describes the relation between v_{r1} and v_{r2}, is n-dimensional relation-element.

Because the relation-element R often contains the same characteristics such as antecedent c_{r1}, consequent c_{r2}, degree c_{r3}, maintaining mode c_{r4}, contact channel c_{r5}, contact method c_{r6}, location c_{r7}, and so on, we simply denote it as $R\left(O_r,V_{r1},V_{r2},\cdots\right)$.

Definition 2.4: Matter-element, Affair-element and Relation-element are collectively referred to as Basic-element which is expressed as

$$B=\begin{bmatrix} O & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix}=(O,C,V) \quad or \quad B=\begin{bmatrix} O & c_1 & \cdots & c_n \\ & v_1 & \cdots & v_n \end{bmatrix},$$

where O (Object) indicates a certain object (matter, action or relation), and c_i is a characteristic of object O, and v_i is the corresponding value of O about c_i (i=1, 2, $\cdots$, n), and $C=[c_1,c_2,\cdots,c_n]^T$ and $V=[v_1,v_2,\cdots,v_n]^T$.

Secondly, we introduce the principles of extensible analysis which include divergent, correlative, implication and opening-up ones below:

Principle 2.1 (Principle of divergent analysis): From one basic-element, multiple basic- elements with the same object (or characteristic) can be extended, and the set of basic-elements with the same object (or characteristic) must be non-empty.

Inference 2.1: From one basic-element, multiple basic-elements with the same object and value (or with the same characteristic and value, or with the same object and characteristic) can be extended.

Definition 2.5: Given two sets of basic-elements $\{B_1\}$ and $\{B_2\}$, for any $\mathrm{B}_1 \in \{B_1\}$, if there is at least one $\mathrm{B}_2 \in \{B_2\}$ to let B_1 corresponds to B_2 , then $\{B_1\}$ and $\{B_2\}$ are correlative and we denote them as $\{B_1\} \sim \{B_2\}$. In particular, as to the sets of basic-elements $\{B_1\}$ and $\{B_2\}$ with c_0 as their evaluated characteristic, for any $\mathrm{B}_1 \in \{B_1\}$, if there is at least one $\mathrm{B}_2 \in \{B_2\}$ to let $c_0(B_2) = f(c_0(B_1))$, then $\{B_1\}$ and $\{B_2\}$ are correlative about the evaluated characteristics c_0 and it is denoted as $\{B_1\} \sim c_0 \{B_2\}$.

Principle 2.2 (Principle of correlative analysis): For a given matter-element $M = (O_m, c_m, v_m)$, there is at least one matter-element with the same characteristic $M_c = (O'_m, c_m, c_m(O'_m))$ or matter-element with the same matter $M_O = (O_m, c'_m, c'_m(O_m))$ or matter-element with different matters $M' = (O'_m, c'_m, c'_m(O'_m))$, to let $M \sim M_c$, or $M \sim M_O$ or $M \sim M'$.

Definition 2.6: Suppose B_1 and B_2 are two basic-elements, and B_1 is realized inevitably with the realization of B_2, then we call that the basic-element B_1 implies the basic-element B_2, and it is denoted as $B_1 \Rightarrow B_2$. Especially, if $B_1 \Rightarrow B_2$ under the condition l, then $B_1 \Rightarrow (l)B_2$.

Definition 2.7: Let B, B_1 and B_2 be basic-elements, and

(1) if both B_1 and B_2 are realized inevitably with the realization of B, then the basic-elements B_1 and B_2 imply the basic-element B, and it is denoted as $B_1 \wedge B_2 \Rightarrow B$.

(2) if either B_1 or B_2 is realized inevitably with the realization of B, then the basic-element B_1 or B_2 implies the basic-element B, and it is denoted as $B_1 \vee B_2 \Rightarrow B$.

(3) if B is realized inevitably with the realization of both B_1 and B_2, then the basic-element B implies the basic-elements B_1 and B_2, and it is denoted as $B \Rightarrow B_1 \wedge B_2$.

(4) if B is realized inevitably with the realization of either B_1 or B_2, then the basic-element B implies the basic-element B_1 or B_2, and it is denoted as $B \Rightarrow B_1 \vee B_2$.

Principle 2.3 (Principle of implication analysis): If B1⇒B2 and B2⇒B3, then B1⇒B3.

Definition 2.8: The possibilities of composing, decomposing and expanding/contracting that Matter, Affair and Relation own are called as composability, decomposability and expandability/contractability, correspondingly, and they are identified as Openness of basic-element.

According to Composability of basic-element, one matter can combine with other matter to generate new matter. By decomposability, one matter can be decomposed into several new matters with certain characteristics that may be different from ones of original matter. Similarly, one matter can be expanded or contracted to provide possibility for solving contradictory problems.

Principle 2.4 (Principle of opening-up analysis): For any basic-element, the opening-up analysis includes the analysis of composability, decomposability and expandability/contractability:

(1) Composability analysis: Given a basic-element $B_1 = (O_1, c_1, v_1)$, there is at least one basic- element $B_2 = (O_2, c_2, v_2)$ to allow B_1 and B_2 to be composed into B, and B_2 is called as the composable basic-element of B_1, where $B = B_1 \bigoplus B_2$ and

1) when $O_1 = O_2$ and $c_1 \neq c_2, B = (O_1, c_1 \bigoplus c_2, v_1 \bigoplus v_2) = \begin{pmatrix} O_1 & c_1 & v_1 \\ & c_2 & v_2 \end{pmatrix}$;

2) when $O_1 \neq O_2$ and $c_1 = c_2, B = (O_1 \bigoplus O_2, c_1, v_1 \bigoplus c_1(O_2))$;

3) when $O_1 \neq O_2$ and $c_1 \neq c_2, B = \begin{pmatrix} O_1 \bigoplus O_2 & c_1 & v_1 \bigoplus c_1(O_2) \\ & c_2 & c_2(O_1) \bigoplus v_2 \end{pmatrix}$;

(2) Decomposability analysis: Any basic-element B=(O,c,v) can be decomposed into several basic-elements $B_1, B_2, \cdots, B_m$ with the same characteristics under certain condition l, where $B_i = (O_i, c, c(O_i))(i = 1, 2, \cdots, m)$, and we denote B//(l) $\{B_1, B_2, \cdots, B_m\}$.

(3) Expandability/Contractability analysis: For a real positive number α , any basic-element B=(O,c,v) can be expanded $(\alpha > l)$ or contracted $(l > \alpha > 0)$ as $\alpha B = (O, C, \alpha v)$ under certain condition.

Thirdly, we introduce the principle of conjugate analysis below:

Extenics help us to completely understand the matter from its physical, systematic, dynamic and antithetic properties. In terms of physical property of matter, all matters are composed of a physical part and a non-physical part, then the physical part is called material part and the non- physical part is non-material part by Extenics, respectively. When considering a matters structure from its systematic property, the matters components as a whole are called the hard part of matter and the relations between the matter and its components as well as between the matter and other matters are the soft part of the matter. Furthermore, from the dynamic property, any matter is changing continuously. Stagnation is ever-relative while motion is permanent. The parts that have not been appeared are called as the latent parts of the matter and the appeared parts are the apparent parts of the matter. The latent part may become apparent under certain conditions. From the antithetic property, all matters have two parts that are antithetic. In Extenics, the part producing the positive value in the measure of matter about certain characteristic is the positive part of matter and the other taking negative value is the negative part of matter. So matter's conjugate analysis includes nonmaterial-material, soft-hard, negative-positive and latent-apparent ones. We should analyze a matter according to the following property.

Principle 2.5 (Principle of Conjugate analysis): All matters have four pairs of conjugate parts, i.e., the nonmaterial-material, the soft-hard, the negative-positive and the latent-apparent ones. Each conjugate part of any matter has numerous characteristics and it can be denoted by an n-dimensional basic-element. At the same time, in each pair of conjugate part of any matter, one certain conjugate part has at least one characteristic that is relevant to certain characteristic of its corresponding conjugate.

Fourthly, we introduce the extension transformation below:

The tool for solving the contradictory problem is extension transformation. By using certain transformations, an unfeasible problem can be transformed a feasible one. We only introduce the general concept and the basic types of transformation.

Definition 2.9: Supposing that the object Γ_0 is a matter-element, affair-element, relation- element, criteria or any element in the universe of discourse, and the transformation from Γ_0 to the object Γ or multiple objects $\Gamma_1, \Gamma_2, \cdots, \Gamma_n$ in the same class is called as extension transformation of Γ and it is denoted as $T\Gamma_0 = \Gamma$ or $T\Gamma_0 = \{\Gamma_1, \Gamma_2, \cdots, \Gamma_n\}$.

Definition 2.10: The object Γ have five types of basic transformations below:

(1) Substitution transformation, i.e., $T\Gamma = \Gamma_0$;

(2) Increasing/decreasing transformation, i.e., the increasing transformation $T\Gamma = \Gamma \bigoplus \Gamma_0$ and the decreasing transformation $T\Gamma = \Gamma - \Gamma_0$;

(3) Expansion/contraction transformation: $T\Gamma = \alpha\Gamma$, where it is expansion when $\alpha > 1$ and contraction when $1 > \alpha > 0$;

(4) Decomposition transformation: $T\Gamma = \{\Gamma_1, \Gamma_2, \cdots, \Gamma_n\}$, where $\Gamma_0 = \Gamma_1 \bigoplus \Gamma_2 \bigoplus \cdots \bigoplus \Gamma_n$;

(5) Duplication transformation: $T\Gamma = \{\Gamma, \Gamma_1\}$.

Principle 2.6 (Principle of Extension transformation): For any object Γ , there must exist a certain transformation T to let $T\Gamma = \Gamma_0$, where $\Gamma \neq \Gamma_0$. On the other hand, if there is a certain transformation T to let $T\Gamma = \Gamma_0$, there should be another transformation T_1 to let $T_1\Gamma = \Gamma_0$. Furthermore, it can be utilization several transformations to successfully solve a contradictory problem.

3 Extension Strategy Generation Step of Sustainable Utilization of Regional Water Resources

During the process of sustainable utilization of water resources, we need to simultaneously solve two goals of water crisis and ecological environment construction in the planning area, and should meet the needs of population promotion, resource exploitation, environmental protection and economic development in the planning period. In order to effectively solve this problem, we propose the extension strategy generation of sustainable utilization of water resources according to the literature [17] below:

1) Define the contradictory problem. Combining with the regional goals and development needs, we draw up the basic-elements of goals (water crisis solution and ecological environment construction) and the basic-elements of conditions (population promotion, resource development, environmental protection and economic development) of sustainable utilization of water resources in the planning period. Under the basic-elements of conditions, the two goals can not be achieved at the same time, and they constitute a contradictory problem.

2) Assume that the targets are not changed and do extension analysis for the four basic- elements of conditions. Suppose that the premise of targets without change is that the tasks of targets are feasible, then we should obtain the appropriate basic-elements of goals by using correct investigation methods. At that moment, we get the extension analysis matter-elements through expanding the condition basic-elements by using Correlative analysis, Divergent analysis, Conjugate analysis and Opening-up analysis.

3) Generate a variety of utilization strategies of water resources by extension transformation to the extension analysis matter-elements. The purpose of doing extension transformation is to resolve the contradictory problem and make two objectives be achieved simultaneously. Extension transformation to the extension analysis matter-elements is mainly for the values of characteristics of matter-elements, and the transformations include substitution, increasing, decreasing, expansion, contraction and decomposition, as well as the integration of these basic transformations.

4) Evaluate and select the utilization strategies of water resources. We may get a group of extension transformation matter-elements after doing a complete extension transformation, and then form an integral strategy. However, it is not true that every strategy can effectively solve the problem between water crisis and ecological environment construction, or that the solution effect is the same as others. Therefore, we should evaluate and select the strategies by using the following steps:

(1) At first, we should determine some indexes $A_1, A_2, \cdots, A_l$ to measure the strategies which make up a measurement condition set. The measurement condition set is utilized to judge whether the strategies are feasible or not. The measurement criterions of sustainable utilization of water resources in general are technical feasibility and economic viability, and the technical feasibility is usually viewed as the prerequisite which must be satisfied.

(2) Secondly, evaluate and select the strategies. First step, we abandon the strategies which do not meet the prerequisites, i.e., if the strategies whose technol-

ogy is not feasible, then they are removed, and we utilize the rest of measurement criterions to justify other strategies. Next step, by using the correct methods of investigation and analysis to get the values of remaining strategies for other criterions, we select an appropriate function such as the comprehensive evaluation method to compute the superior degrees of these strategies, and choose the strategies whose degree is the maximum as the optimal ones.

5) Draw up the specific programs of action according to the optimal strategies. The purpose to form the action programs is to make the decision-makers and executors understand the optimal strategies, so that they can correctly implement them and accomplish the goals.

4 Extension Planning Process of Sustainable Utilization of Regional Water Resources

1) Define the contradiction problem of water utilization

The process of water utilization involves the natural, economic and social systems, and induces many contradictory problems between the ecological environment and the economic development goal as well as the social development mode. In the arid and semi-arid regions, we should solve the contradiction between water crisis and ecological environment construction under the premise of regional development of population, resources, environment and economy. In Extenics, the formalized model and the extension analysis methods are utilized to study how to resolve conflict issues, which are also suitable for selecting feasible and effective utilization strategies of water resources and provide a formalized approach for relevant departments.

The extension analysis process of water utilization should be made efforts to solve the central issues of water crisis and ecological environment construction on the basis of development of population, resources, environment and economics in this regional which includes administrative region and watershed. In the arid and semi-arid regions, water crisis and ecological environment construction can not be achieved at the same time, so this is a contradictory problem. Sustainable utilization of water resources means the synthesis between ecological environment construction and water utilization. Therefore, the goal of contradictory problem that should be resolved within the region is ecological environment construction and water crisis, and the problems conditions are development needs of population, resources, environment and economics. Then the regional government may formulate the general objective basic-elements G_1 and G_2 below:

$$G_1 = \begin{pmatrix} construct & a_1 & a_2 & a_3 & a & t \\ & b_1 & b_2 & b_3 & A & T \end{pmatrix} \quad and \quad G_2 = \begin{pmatrix} W & a & c_2 & c_3 & t \\ & A & w_2 & w_3 & T \end{pmatrix},$$

where for the basic-element G_1, construct is a verb, and the characteristics are a_1=dominating object, a_2 = acting object, a_3 = receiving object, a = location and t = time, and the values of these characteristics are b_1 = ecological environment, b_2 = {administration, beneficiaries, contractors, collaborators, etc.}, b_3 = {vegetation, land, species}, A = a certain region which may be an administrative region or watershed, and T = a planning period, such as three-year plan, etc.. Apparently, G_1 is an affair-element. For another basic-element G_2, W=water resources, and the characteristics are c_2 = ownership quantity and c_3 = demand quantity, and the unit of the values w_2 and w_3 is hundred million cubic meters. Here, the equation $w_3 > w_2$ holds, which indicates that the water demand within the region A is larger than the water owner, and the water crisis exists in this region. The quantity w_2 is an average statistical value of water resources for recent years, and the quantity w_3 is a forecasting value of water demand of the region A in the planning period. Also apparently, G_2 is a matter-element.

In addition, the premise to resolve the contradictory problem between ecological environment construction and water crisis is to meet the development needs of regional population, resources, environment and economics, thus we establish the following condition basic-elements:

$$l_1 = \begin{pmatrix} upgrade & a_1 & a_2 & a_3 & a & t \\ & r_{11} & r_{12} & r_{13} & A & T \end{pmatrix}, \quad l_2 = \begin{pmatrix} exploit & a_1 & a_2 & a_3 & a & t \\ & r_{21} & r_{22} & r_{23} & A & T \end{pmatrix},$$

$$l_3 = \begin{pmatrix} improve & a_1 & a_2 & a_3 & a & t \\ & r_{31} & r_{32} & r_{33} & A & T \end{pmatrix} and \quad l_4 = \begin{pmatrix} develop & a_1 & a_2 & a_3 & a & t \\ & r_{41} & r_{42} & r_{43} & A & T \end{pmatrix},$$

where the values of characteristic a_1 are r_{11}=population, which includes rural and urban ones, r_{21}= natural resources, r_{31}=living environment and r_{41}=economics, and the values of characteristic a_2 are corresponding administrations, and the values of characteristic a_3 are r_{13}=population qualities, which include population quantity, educational background, etc., r_{23}= {land, minerals, wild beast}, r_{33}={green belt, waste treatment, transportation belt}, and r_{43}=economics. Waste treatment mainly refers to exhaust, waste water and garbage, and transportation belt includes the road clean, green, construction and maintenance, etc..

Because we can not simultaneously achieve the goals G_1 and G_2, it is a contradictory problem, and thus we establish the extension model $P = (G_1 \wedge G_2) \uparrow (l_1 \wedge l_2 \wedge l_3 \wedge l_4)$. The purpose to do extension analysis is to transfer the contradictory problem into the co-existence issue by doing the correlative analysis, the divergent analysis, the conjugate analysis and the opening-up analysis on the goal basic-elements and the condition basic-elements.

In general, there are five approaches to resolve contradictory problem with multi-objectives and multi-conditions: Firstly, all targets are not changed, but make some (or all) conditions be transformed; Secondly, all conditions are unchanged but some (or all) targets are transformed; Thirdly, part of the targets are changed and some (or all) conditions are altered; Fourthly, part of conditions are changed and some (or all) targets are transferred; Fifthly, all of goals and conditions are changed. In this paper, we only discuss the most simple issue, i.e., all targets are unchanged and some (or all) conditions are transferred. By transferring the conditions, we solve contradictory problem between water crisis and ecological environment construction. For the other issues, we will analyze them in other papers.

Firstly, we define the specific target basic-elements and simplify the condition basic-elements on the basis of the original problem P. According to the reality and overall targets of the region A, we decompose the goal affair-element G_1 on the basis of the investigation and analysis results, then obtain the specific target matter-elements of sustainable utilization of water resources below:

$$G_1' = \begin{pmatrix} g_1 & a_{11} & b_{11} \\ & a_{12} & b_{12} \\ & a_{13} & b_{13} \\ & a_{14} & b_{14} \\ & a_{15} & b_{15} \end{pmatrix}, \quad G_1'' = \begin{pmatrix} g_2 & a_{21} & b_{21} \\ & a_{22} & b_{22} \\ & a_{23} & b_{23} \\ & a_{24} & b_{24} \\ & a_{25} & b_{25} \end{pmatrix} and \quad G_1''' = \begin{pmatrix} g_3 & a_{31} & b_{31} \\ & a_{32} & b_{32} \\ & a_{33} & b_{33} \\ & a_{34} & b_{34} \\ & a_{35} & b_{35} \end{pmatrix},$$

where for the matter-element G_1', the object g_1 is vegetation, and the characteristics of g_1 are a_{11}= administrative, a_{12}= original acreage, a_{13}= planning acreage, a_{14}= original amount of water demand and a_{15} = Incremental of water demand; for the matter-element G_1'', the object g_2 is land, and the characteristics of g_2 are a_{21}= administrative, a_{22}= Remediation acreage, a_{23}= Incremental of vegetation, a_{24}= Incremental of building and a_{25} = Incremental of water demand, as well as the equation $b_{22}= b_{23}+ b_{24}$; for the matter-element G_1''', the object g_3 is species, and the characteristics of g_3 are a_{31}= administrative, a_{32}= Original amount, a_{33}= Incremental of species, a_{34}= Original amount of water demand and a_{35} = Incremental of water demand. Then, the target affair-element G_1 is transformed into three specific target matter-elements. Furthermore, the land g_2 mainly refers to the unutilized land in the region A.

Meanwhile, in the case of non-confusion, we can simplify the condition basic-elements by omitting the characteristics Location and Time. Therefore, we transform the condition basic- elements l_1, l_2, l_3 and l_4 into the simple forms below:

$$l_1' = \begin{pmatrix} R_1 & a_1 & r_{11} \\ & a_2 & r_{12} \\ & a_3 & r_{13} \end{pmatrix}, \quad l_2' = \begin{pmatrix} R_2 & a_1 & r_{21} \\ & a_2 & r_{22} \\ & a_3 & r_{23} \end{pmatrix},$$

$$l_3' = \begin{pmatrix} R_1 & a_1 & r_{31} \\ & a_2 & r_{32} \\ & a_3 & r_{33} \end{pmatrix} and \quad l_4' = \begin{pmatrix} R_1 & a_1 & r_{41} \\ & a_2 & r_{42} \\ & a_3 & r_{43} \end{pmatrix},$$

where R_1=upgrade, R_2=exploit, R_3=improve and R_4=develop.

Through the transformations above, the original problem $P = (G_1 \wedge G_2) \uparrow (l_1 \wedge l_2 \wedge l_3 \wedge l_4)$ is converted to $P' = (G_1' \wedge G_1'' \wedge G_1''' \wedge G_2) \uparrow (l_1' \wedge l_2' \wedge l_3' \wedge l_4')$. Because the problem P is the specific form of the original one P, it can be resolved when P is achieved. Thus we only do extension analysis for the condition basic-elements of the problem P.

2) Extension analysis process of condition basic-elements

The correlative analysis on condition basic-elements: The correlation of basic-element discusses the correlations among the same or different objects (matters, actions or relationships) as well as among their characteristics or values. It can make people more clearly understand the interactions between each of condition basic-elements and the sustainable utilization of water resources by using the formalized way. On the basis of the correlation between water resources and the development of population, resources, environment and economics, we get the correlative matter- elements W_1, W_2, W_3 and W_4 of condition basic-elements below:

$$W_1 = \begin{pmatrix} W & k_1 & w_{11} \\ & k_2 & w_{12} \\ & k_3 & w_{13} \end{pmatrix}, \quad W_2 = \begin{pmatrix} W & k_1 & w_{21} \\ & k_2 & w_{22} \\ & k_3 & w_{23} \end{pmatrix},$$

$$W_3 = \begin{pmatrix} W & k_1 & w_{31} \\ & k_2 & w_{32} \\ & k_3 & w_{33} \end{pmatrix} and \quad W_4 = \begin{pmatrix} W & k_1 & w_{41} \\ & k_2 & w_{42} \\ & k_3 & w_{43} \end{pmatrix},$$

where the matter W=water, and the characteristics k_1, k_2 and k_3 represent User, Use volume and Use mode, respectively, and the values of k_1 are w_{11} = population, w_{21} = natural resources, w_{31} = living environment and w_{41} = economy, and the values w_{12}, w_{22}, w_{32} and w_{42} of k_2 are the average statistical value of regional water utilization in recent years which are consumed by population, natural resources, environment and economics, respectively, and the values of characteristic k_3 are w_{13}={drink, wash, rinse, etc.}, w_{23}={produce, drink, etc.}, w_{33}={irrigate, rinse, etc.} and w_{43}= {irrigate, produce, wash, drink, rinse, etc.}. The new matter-elements W_1, W_2, W_3 and W_4, which come from the results after doing the correlative analysis on the condition affair-elements, are called the correlative matter-elements of condition basic-elements.

Divergent analysis on the correlative matter-elements: The divergence of matter-element includes: Different characteristic with same matter, Different value with same characteristic, Different matter with same value, Same characteristic with same matter, Same value with same characteristic, Same value with same matter, Similar value with same characteristic, etc. By using the divergent analysis, we can understand the multiple aspects of correlative matter-elements which involve in the process of water utilization. Doing the divergent analysis on the values of characteristic k_1 of correlative matter-elements according to Same characteristic with same matter, we grasp all water users in region A and get following matter-elements ($\mapsto$ means divergence):

$$W_1 \mapsto W_1^1 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{11}^1 & w_{12}^1 & w_{13}^1 \end{pmatrix}, \quad W_1^2 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{11}^2 & w_{12}^2 & w_{13}^2 \end{pmatrix};$$

$$W_2 \mapsto W_2^1 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{21}^1 & w_{22}^1 & w_{23}^1 \end{pmatrix}, \quad W_2^2 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{21}^2 & w_{22}^2 & w_{23}^2 \end{pmatrix},$$

$$W_2^3 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{21}^3 & w_{22}^3 & w_{23}^3 \end{pmatrix};$$

$$W_3 \mapsto W_3^1 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{31}^1 & w_{32}^1 & w_{33}^1 \end{pmatrix}, \quad W_3^2 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{31}^2 & w_{32}^2 & w_{33}^2 \end{pmatrix},$$

$$W_3^3 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{31}^3 & w_{32}^3 & w_{33}^3 \end{pmatrix};$$

$$W_4 \mapsto W_4^1 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{41}^1 & w_{42}^1 & w_{43}^1 \end{pmatrix}, \quad W_4^2 = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{41}^2 & w_{42}^2 & w_{43}^2 \end{pmatrix}, \cdots,$$

$$W_4^m = \begin{pmatrix} W & k_1 & k_2 & k_3 \\ & w_{41}^m & w_{42}^m & w_{43}^m \end{pmatrix},$$

where w_{11}^1 = rural residents, w_{11}^2 = urban residents ; w_{21}^1 = land, w_{21}^2 = minerals, w_{21}^3 = Biology; w_{31}^1 = green belt, w_{31}^2 = waste treatment, w_{31}^3 = transportation belt; and the matters w_{41}^1 , w_{41}^2 , $\cdots$, w_{41}^m are m industrial departments in region A such as agriculture, tourism, catering, etc.; and the values w_{12}^1 , w_{12}^2 , w_{22}^1 , w_{22}^2 , w_{22}^3 , w_{32}^1 , w_{32}^2 , w_{32}^3 , w_{42}^1 , $\cdots$, w_{42}^m of characteristic k_2 are the average statistical values of water utilization which consumed by corresponding users of region A in recent years, and the values of characteristic k_3 are $W_{13}^1 \subseteq W_{13} = \{drink, wash, rinse\}$, $W_{23}^1, W_{23}^2, W_{23}^3 \subseteq W_{23} = \{produce, drink\}$, $W_{33}^1, W_{33}^2, W_{33}^3 \subseteq W_{23} = \{irrigate, rinse\}$, as well as $W_{43}^1, \cdots, W_{43}^m \subseteq W_{43} = \{irrigate, produce, wash, drink, rinse\}$. The basic elements which come from the correlative matter-elements by using the divergent analysis are called divergent matter-elements.

Conjugate analysis on divergent matter-elements: The properties of system, material, dynamic and opposition that things own are collectively known as conjugation. We can understand things in a more comprehensive perspective and reveal the development and variation nature of things in a more profound way by using the conjugate analysis. Extension theory describes the structure of things from four pairs of conjugate and opposite concepts which are material and non-material, hard and soft, apparent and latent, as well as positive and negative. In generally, we utilized to consider the problems from the material, hard, apparent and positive aspects of things. However, the nonmaterial, soft, latent and negative angles of things can make us obtain unexpected results. Because the divergent matter-elements come from the water users which are population, resources, environment and economics through divergence analysis, we will do conjugate analysis by combining the User k_1 with water resources W. From the nonmaterial part of things, we firstly determine the requirements of User k_1 and get a new characteristic named Water quality k_4 whose values for all divergent matter-elements are $v_{i4} \in \{I \sim V \text{ grade}\}$, where the standard of water quality refers to the book named **China's Environmental Quality Standard of Surface Water** (GB3838-2002), and the subscript i denotes the serial number of the divergent matter-elements from W_1^1 to W_4^m . Secondly, we justify the economic status and consumption of User k_1 in the region A, and then get a new characteristic of water named Importance k_5, and the values v_{i5} of k_5 satisfy v_{i5} $\in$ {Necessary, Priority, Current situation, Decrease, No}, where No means that the certain user does not consume water and we may remove the corresponding matter- element. Form the soft aspect of things, we view the relationship among the orders of water users, and get two characteristics of water resources named as Former user k_6 and Later user k_7 whose values v_{i6} and v_{i7} are the elements from the set composed by the users in matter-elements above. From latent aspect of things, we analyze the potential utilization values of the consumption and discharge of water and get a characteristic denoted as Recyclability k_8 whose value $vi8 \in$ { yes, no}. Furthermore, according to recyclability, we should determine the characteristic named Recovered amount k_9, and denote its value as v_{i9}. From the negative aspect of things, we mainly view that whether waste water has negative impact for environment or not, and get a characteristic named Emission k_{10} with value $v_{i10} \in$ { direct emission, treatable emission, non-emission}, where non- emission means that the water has been completely consumed by the corresponding user. Then we investigate the technology to treat the wastewater and get another characteristic named Treatable technology k_{11} with the value $v_{i11} \in$ { high, normal, low, no }, where no means that the value v_{i10} is direct emission or non emission. Then we obtain the conjugate matter-elements by using conjugate analysis on divergent matter-elements.

The opening-up analysis on Conjugate matter-elements: The possibility of matter-elements combination or decomposition is called the opening-up property of matter-element which includes addition, multiplication and decomposition of matters, characteristics and values. The opening-up property of matter-element provides another approach to solve the contradictory problems. At first, we discuss the decomposition of water resources, and obtain the characteristic named as Source k_{12} of desirable water in region A whose value $v_{i12} \in$ {surface water, groundwater, external water, recycled water, all water}, where recycled water is reutilized water while wastewater is retrieved, and all water contains surface water, groundwater, external water and recycled water. Secondly, from the additive or multiplicative property of characteristics, we examine User k_1, Water quality k_4 and Former user k_6, and get the characteristic named Freshness k_{13} with the value $v_{i13} \in$ {fresh water, circled water}, where fresh water includes surface water, groundwater and external water. Finally, according to the additive property of values, we study on Utilization volume k_2, Recyclability k_8, Source k_{12} and Freshness k_{13} and obtain the characteristic Increment k_{14} with the value v_{i14}. From the values v_{i12} of Utilization volume k_2 and v_{i14} of Increment k_{14}, we get another characteristic named Recycle volume k_{15} with the value v_{i15}. At last, by using the values v_{i2}, v_{i14} and v_{i15}, we get a characteristic named Total volume k_{16} with the value v_{i16}. The new matter- elements from the conjugate matter-elements by using Opening-up analysis are called Opening-up matter-elements.

Condition matter-elements are now transferred into a group of new matter-elements with the object named water and 16 characteristics through extension analysis which includes correlative analysis, divergent analysis, conjugate analysis and opening-up analysis, and they are called as the extension-analysis matter-elements of condition basic-elements. From the analysis showed above, the final results, i.e., the opening-up matter-elements, are the extension-analysis matter-elements.

3) The generation and optimal selection of sustainable utilization strategy of regional water resources and the program implementation of optimal strategy

By using Extension Analysis, the condition-basic-elements are transferred into extension- analysis matter-elements of sustainable utilization of water resources. For the sake of convenience, we re-order the characteristics of extension-analysis matter-elements as User k_1, Use mode k_2, Water quality k_3, Importance k_4, Former user k_5, Later user k_6, Recyclability k_7, Emission k_8, Treatable technology k_9, Source k_{10}, Freshness k_{11}, Use volume k_{12}, Recovered amount k_{13}, Increment k_{14}, Recycle volume k_{15} and Total volume k_{16}, where the characteristics with non- quantities are in the front and the others with quantities are at the back, and the quantitative characteristics satisfies the following relationship:

(1) The value v_{i12} of Use volume $k_{12} \leq$ The absolute value v_{i13} of Recovered amount k_{13}, and let $v_{i13} \leq 0$ which represents an increase of water resources;

(2) Use volume k_{12}, Increment $k_{14} \in$ {Surface water, Groundwater, External water} = {Initial water}, and their values $v_{i12} + v_{i14} =$ The volume of Initial water, where $v_{i12} \geq 0 \quad and \quad v_{i14} \geq 0$, and they means the consumption;

(3) The value v_{i15} of Recycle volume $k_{15} \geq 0$, which means that the amount

of recycle water was consumed by User i, and $v_{i15} \leq |v_{i13}|$;

(4) The value v_{i16} of Total volume k_{16} satisfies $v_{i16} = v_{i12} + v_{i14} + v_{i15}$, which represent the total amount of water resources consumed by User i.

In general, Extension Transformation of extension-analysis matter-elements, which includes substitution, decomposition, addition, decrease, etc., is only in connection with those quantitative characteristics of water resources, then we obtain a set of new condition matter-elements with new values and we call them as extension-transformation matter-element below:

$$T(W_1^1) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{1,1}^1 & \cdots & w_{1,15}^1 & w_{1,16}^1 \end{pmatrix}, \quad T(W_1^2) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{1,1}^2 & \cdots & w_{1,15}^2 & w_{1,16}^2 \end{pmatrix};$$

$$T(W_2^1) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{2,1}^1 & \cdots & w_{2,15}^1 & w_{2,16}^1 \end{pmatrix}, \quad T(W_2^2) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{2,1}^2 & \cdots & w_{2,15}^2 & w_{2,16}^2 \end{pmatrix},$$

$$T(W_2^3) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{2,1}^3 & \cdots & w_{2,15}^3 & w_{2,16}^3 \end{pmatrix}; \quad T(W_3^1) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{3,1}^1 & \cdots & w_{3,15}^1 & w_{3,16}^1 \end{pmatrix},$$

$$T(W_3^2) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{3,1}^2 & \cdots & w_{3,15}^2 & w_{3,16}^2 \end{pmatrix}, \quad T(W_3^3) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{3,1}^3 & \cdots & w_{3,15}^3 & w_{3,16}^3 \end{pmatrix};$$

$$T(W_4^1) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{4,1}^1 & \cdots & w_{4,15}^1 & w_{4,16}^1 \end{pmatrix}, \quad T(W_4^2) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{4,1}^2 & \cdots & w_{4,15}^2 & w_{4,16}^2 \end{pmatrix},$$

$$\cdots, \quad T(W_4^m) = \begin{pmatrix} W & k_1 & \cdots & k_{15} & k_{16} \\ & w_{4,1}^m & \cdots & w_{4,15}^m & w_{4,16}^m \end{pmatrix}.$$

By carrying out a transformation T, we get a set of extension-transformation matter-elements, which corresponds to a set of sustainable utilization strategy of water resources. Different transformation T corresponds to a different set of extension-transformation matter-elements and then the strategy is different. Repeatedly doing transformation, we obtain a variety of sustainable utilization strategies. To doing extension transformation to extension-analysis matter-elements is known as the sustainable utilization strategy generation of water resources.

Different strategies have different implementation effects in the process of sustainable utilization of water resources. The purpose of extension transformation is to find the best solutions as possible as can, so we need to select the optimal one in a variety of strategies. Firstly, we should determine the evaluation characteristics, such as technological possibility and economic feasibility. Secondly, we select an appropriate evaluation method to calculate the optimal degree of these matter-elements. Finally, choosing the maximum in the optimal degrees and then viewing the corresponding set of matter-elements as the optimal strategy, we formulate the specific action plans according to the optimal strategy. The action plan can achieve the sustainable utilization of water resources during the planning period T in the region A under the required conditions to meet the development of population, resources, environment and economics, and effectively resolve the contradictory problem between water crisis and ecological environment constructions, and then the overall goals can be achieved. The formalized generation process of sustainable utilization strategies of water resources can be shown in Fig. 1.

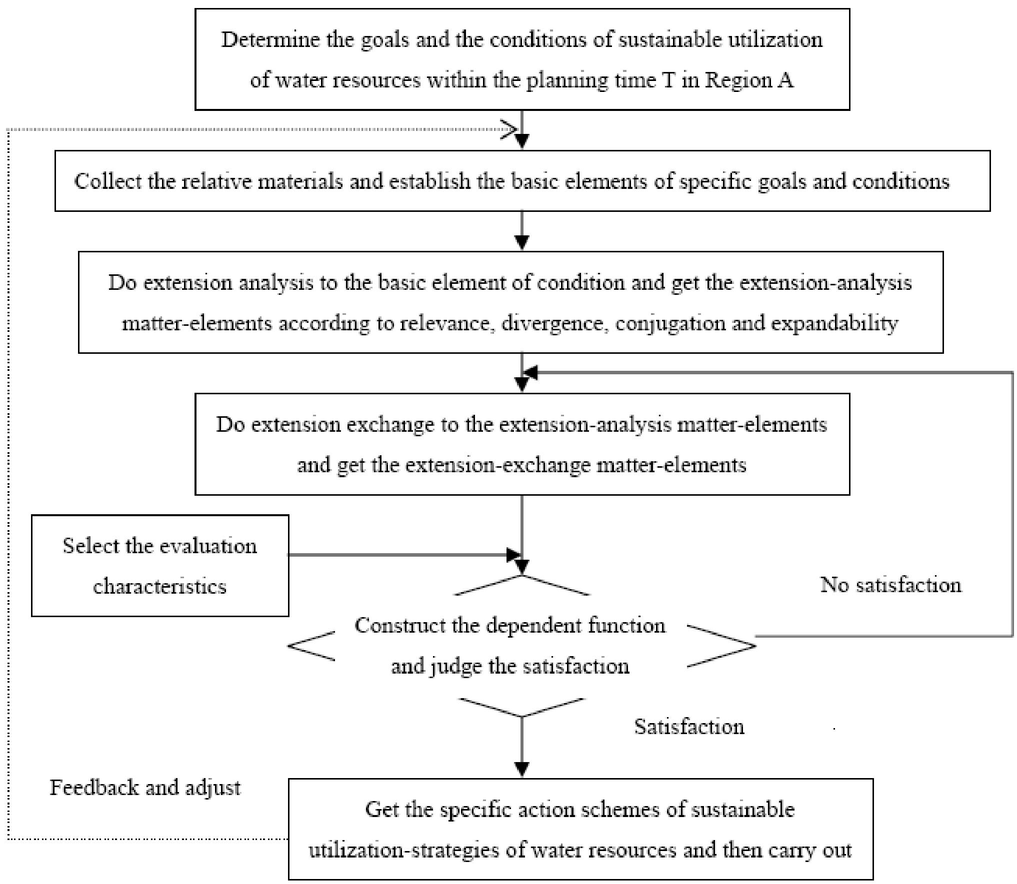

Fig. 1 The flow chart of extension strategy

5 Modified Case Study

In order to illustrate the generation and optimal selection of sustainable utilization strategies of water resources and the program implementation process, we will utilize a specific case to describe it in this section.

1) The overview of socio-economics and water resources in the studied region

One region A located in the middle of Heihe River Basin and the central place of Hexi Corridor is the political, economic and cultural center of Zhangye City, Gansu Province, PR China. The total acreage is about 4000 square kilometers, where the propositions of mountainous, desert area and plain are 14.4%, 34.5% and 51.1%, respectively. The coverage rate of vegetation is only about 3%. The total population in the region is approximately 520,000, where the agricultural population is about 350,000 whose proposition is 65%. In recent years, GDP is about 6.8 hundred million RMB with about 15,000 RMB per person. The water which is utilized to maintain the basic life of population and the production in this region comes from the rivers flowing through the region and the groundwater. The region is a typical agriculture oasis and large irrigated agriculture area. The total volume of available water in the region is about 1.3 hundred million m^3, and the average volumes per person and per acre are about $1330m^3$ and $570m^3$, respectively. So it is a relatively serious water shortage region. From the structure of water utilization, the ratio of agriculture, industry, people living and ecology is 83.7:2.7:6.4:7.2 in 2005, where the proportion of agricultural water is still relatively large. The region A is an important commodity grain base and one of the five bases named West vegetable to East in Northwest of China, and thus the agricultural production plays an important role in the area. Region A has superior condition with 30 kinds of mineral resources, where the reserve of coal has been proven for 1.05 hundred million tons, and the content of both tungsten and molybdenum ranks at the first order in North of China. According to the survey, region A has about 10 species of wild animals, where the total number is only 2,000 surplus and some of them are on the verge of extinction. The averages of annual rainfall and annual evaporation are 120mm and 2000-2350mm, respectively, so it is a typical temperate continental arid climate. There are many problems of water resources, such as serious water shortage, obvious contradiction between supply and demand, irrational utilization structure, low efficiency and effectiveness, thus the water resources is the most important constraints of sustainable development of society and economy in the region.

2) Define contradictory problem and set goal basic-elements and condition matter-elements

The local government of regional A viewed the eco-economic development as the main task. So the government transforms the economic development mode and highlights three goals which are ecological construction, modern agriculture and passage economy. Then sustainable utilization of local water resources may be achieved. Under the requirements to enhance the population quality, exploit the natural mineral resources, improve the living environment and promote economic development, local government makes its efforts to solve the two central goals of water crisis and ecological environment construction. Then the government develops a "Five-Year Plan" according to local condition and obtains following total goal basic-elements G_1 and G_2:

$$G_1 = \begin{pmatrix} Construct & a_1 & a_2 & a_3 & a & t \\ & b_1 & b_2 & b_3 & A & T \end{pmatrix} and \quad G_2 = \begin{pmatrix} W & a & C_2 & C_3 & t \\ & A & 13 & 20 & T \end{pmatrix},$$

where the unit of c_2 and c_3 is hundred million m^3, T=five years, and the meaning of others is the same with corresponding formers. Because the value of c_3 is larger than one of c_2, the water crisis exists.

Then we develop the specific goal basic-elements and simplify the condition basic-elements according to G_1 and G_2 respectively.

On the basis of the actual situation and total goals of region A, we decompose G_1 and get following specific matter- elements:

$$G_1' = \begin{bmatrix} g_1 & a_{11} & b_{11} \\ & a_{12} & 120 \\ & a_{13} & 360 \\ & a_{14} & 0.9 \\ & a_{15} & 2.3 \end{bmatrix}, \quad G_1'' = \begin{bmatrix} g_2 & a_{21} & b_{21} \\ & a_{22} & 300 \\ & a_{23} & 240 \\ & a_{24} & 60 \\ & a_{25} & 3.1 \end{bmatrix} and \quad G_1''' = \begin{bmatrix} g_3 & a_{31} & b_{31} \\ & a_{32} & 2000 \\ & a_{33} & 2300 \\ & a_{34} & 0 \\ & a_{35} & 0 \end{bmatrix},$$

where the characteristics $a_{11}, \cdots, a_{15}, a_{21}, \cdots, a_{25}, a_{31}, \cdots, a_{35}$ are the same as the formers, and the value of a_{13} =the value of a_{12}+ the value of a_{23}. Because the species g_3 usually live in vegetation g_2 such as forest and grassland, its water requirement has been included in the vegetation water demand, so its characteristics a_{34} and a_{35} are 0. At the same time, a part of treated land g_2 will be planted vegetation as woodland and grassland, and another part will be as construction land such as residential housing and factory building. So the value of a_{25} contains the value of a_{25}. Therefore, the total water increment of three specific targets is 3.1 hundred million m^3. If it is together with the original demand 0.90 hundred million m^3, the total water demand of target basic-elements is 4.0 hundred million m^3.

Simplify the condition basic-elements l_1, l_2, l_3 and l_4 as follows:

$$l_1' = \begin{pmatrix} R_1 & a_1 & r_{11} \\ & a_2 & r_{12} \\ & a_3 & r_{13} \end{pmatrix}, \quad l_2' = \begin{pmatrix} R_2 & a_1 & r_{21} \\ & a_2 & r_{22} \\ & a_3 & r_{23} \end{pmatrix},$$

$$l_3' = \begin{pmatrix} R_3 & a_1 & r_{31} \\ & a_2 & r_{32} \\ & a_3 & r_{33} \end{pmatrix} and \quad l_4' = \begin{pmatrix} R_4 & a_1 & r_{41} \\ & a_2 & r_{42} \\ & a_3 & r_{43} \end{pmatrix}.$$

Then we get the problem $p' = (G_1' \wedge G_1'' \wedge G_1''' \wedge G_2) \uparrow (l_1' \wedge l_2' \wedge l_3' \wedge l_4'))$. If the problem has been solved, then the total goal basic-elements G_1 and G_2 can be achieved.

3) Extension analysis and extension transformation

According to the process of extension analysis introduced above, we obtain the extension- analysis matter-elements of condition basic-elements. Firstly, we determine that the values of User k_1 are w_{11}^1 = rural residents, w_{11}^2 = urban residents; w_{21}^1 = land, w_{21}^2 = minerals, w_{21}^3 = Biology; w_{31}^1= green belt, w_{31}^2 = waste treatment, w_{31}^3 = transport belt. We also assume that there are four economic sectors in region A which are w_{41}^1 = agriculture, w_{41}^2 =livestock, w_{41}^3 =building industry and w_{41}^4 = catering industry, respectively; The values of other characteristics, such as Use mode k_2, Water quality k_3, Importance k_4, Former user k_5, Later user k_6, Recyclability k_7, Emission k_8, Treatable technology k_9, Source k_{10} and Freshness k_{11}, are referred to the process of extension analysis in Section 3. These characteristics only have important role for analyzing water utilization and need not do extension transformation. Therefore, we list them separately as the innovation characteristics of extension analysis in Table 1.

The other characteristics of extension-analysis matter-elements involve the quantitative of water resources, such as Use volume k_{12}, Recovered amount k_{13}, Increment k_{14}, Recycle volume k_{15} and Total volume k_{16}. Doing extension transformation such as substitution, decomposition, increase, decrease, etc., to the quantitative of the five characteristics of extension-analysis matter- elements, we get extension-transformation matter-elements with new value. Suppose that some types of extension transformation, which are named as T_1, T_2, T_3 and T_4, respectively, have been done to the values of five quantitative characteristics of extension-analysis matter-elements, we get four sets of extension-transformation matter-elements, i.e., four types of innovation strategies of sustainable utilization of water resources, which can be seen in Table 2 and Table 3.

For the transformation T_1 in Table 2, the value of Use volume k_{12} is the original statistics of water resources in region A, and the value of Increment k_{14} is water increases to meet the development needs of population, resource, environment and economics according to the current consumption structure of water, and the increases is from the fresh water. The value of Recovered amount k_{13} is the recycled quantities from Use volume k_{12} and Increment k_{14} which have been consumed by corresponding users according to the current consumption structure. Recycle volume k_{15} is the re-utilized amount of Recovered amount k_{13}. From Table 2, we know that the water which is only consumed by Minerals, Livestock and Catering industry has been retrieved, and part of the retrieved water has been utilized by Waste treatment, Agriculture and Livestock. In Table 2 and Table 3, the transformations T_2, T_3 and T_4 come from T_1 in turns, and then produce three additional utilization strategies of water resources. Transformations T_2 and T_3 only adopt the water-saving measures, namely that the corresponding users utilize the retrieved water at first for Use volume k_{12} and Increment k_{14} as pos-

Table 1 Analysis Table of Extension Innovation

Basic elememt	User k_1	Use mode k_2	Water quality k_3	Importance k_4	Former user k_5	Later user k_6
w_1^1	rural residents	drink, wash, rinse	grade I-III	Necessary, Priority	rural residents	green belt, waste treatment, transportation belt, agriculture, Animal
w_1^2	urban residents	drink, wash, rinse	grade I-III	Necessary, Priority	urban residents	green belt, waste treatment, transportation belt, agriculture, Animal
w_2^1	land	None	grade I-V	Necessary	agriculture	None
w_2^2	minerals	produce	grade I-IV	Priority	None	green belt, waste treatment, transportation belt
w_2^3	Biology	drink	grade I-III	Priority	None	None
w_3^1	green belt	Irrigate	grade I-V	Priority	residents	None
w_3^2	waste treatment	rinse	grade I-V	Necessary	residents, transportation belt, minerals	None
w_3^3	transportation belt	irrigate, rinse	grade I-V	Priority	residents	waste treatment
w_4^1	agriculture	irrigate	grade I-V	Necessary, Decrease	residents, Animal	land
w_4^2	Animal	drink, rinse	grade I-III	Necessary, Decrease	residents, catering	agriculture
w_4^3	Building	produce	grade I-V	Current situation, Decrease Decrease	None	waste treatment
w_4^4	catering	drink, wash, rinse	grade I-III	Necessary, Decrease	None	Animal

Tabel 1 Analysis Table of Extension Innovation (continued)

Basic elememt	Recyclability k_7	Emission k_8	Treatable technology k_9	Source k_{10}	Freshness k_{11}
w_1^1	yes	direct emission	no	surface water, groundwater, external water	fresh water, recycled water
w_1^2	yes	direct emission	no	surface water, groundwater, external water	fresh water, recycled water
w_2^1	no	non-emission	no	all water	fresh water, recycled water
w_2^2	yes	treatable emission	high	surface water, groundwater, external water	fresh water
w_2^3	no	non-emission	no	surface water	fresh water
w_3^1	no	non-emission	no	all water	fresh water, recycled water
w_3^2	yes	treatable emission	high	all water	fresh water, recycled water
w_3^3	yes	direct emission	no	all water	fresh water, recycled water
w_4^1	no	direct emission	no	all water	fresh water, recycled water
w_4^2	yes	direct emission	no	surface water, groundwater, external water	fresh water
w_4^3	yes	treatable emission	normal	surface water, groundwater, external water	fresh water
w_4^4	yes	direct emission	no	surface water, groundwater, external water	fresh water

Table 2 The first innovation T_1 and the second one T_2 of extension-exchange matter-element (unit: hundred million m^3)

T_1	k_{12}	k_{13}	k_{14}	k_{15}	k_{16}
$T_1(w_1^1)$	0.53		1.2		1.73
$T_1(w_1^2)$	0.27		0.6		0.87
$T_1(w_2^1)$	0		0.06		0.06
$T_1(w_2^2)$	0.25	-0.3	0.7		0.95
$T_1(w_2^3)$	0.01		0.02		0.03
$T_1(w_3^1)$	0.03		0.05		0.08
$T_1(w_3^2)$	0		0.6	0.32	0.92
$T_1(w_3^3)$	0.01		0.03		0.04
$T_1(w_4^1)$	10.85		-1.53	0.1	9.42
$T_1(w_4^2)$	0.58	-0.15	-0.08	0.2	0.7
$T_1(w_4^3)$	0.9		-0.1		0.8
$T_1(w_4^4)$	0.5	-0.2	-0.1		0.4
Total	13.93	-0.65	1.45	0.62	16

T_2	k_{12}	k_{13}	k_{14}	k_{15}	k_{16}
$T_2(w_1^1)$	0.53	-1.4	0.8	0.4	1.73
$T_2(w_1^2)$	0.27	-0.65	0.23	0.37	0.87
$T_2(w_2^1)$	0		0	0.06	0.06
$T_2(w_2^2)$	0.25	-0.85	0.7		0.95
$T_2(w_2^3)$	0.01		0.02		0.03
$T_2(w_3^1)$	0.03		0	0.05	0.08
$T_2(w_3^2)$	0		0	0.92	0.92
$T_2(w_3^3)$	0.01	-0.01	0	0.03	0.04
$T_2(w_4^1)$	10.85	-2.73	-1.53	0.1	9.42
$T_2(w_4^2)$	0.58	-0.6	-0.08	0.2	0.7
$T_2(w_4^3)$	0.9	-0.55	-0.1		0.8
$T_2(w_4^4)$	0.5	-0.27	-0.1		0.4
Total	13.93	-7.06	-0.06	2.13	16

Table 3 The first innovation T_3 and T_4 of extension-exchange matter-element (unit: hundred million m^3)

T_3	k_{12}	k_{13}	k_{14}	k_{15}	k_{16}
$T_3(w_1^1)$	0.53	-1.4	0.8	0.4	1.73
$T_3(w_1^2)$	0.27	-0.65	0.23	0.37	0.87
$T_3(w_2^1)$	0		0	0.06	0.06
$T_3(w_2^2)$	0.25	-0.85	0.7		0.95
$T_3(w_2^3)$	0.01		0.02		0.03
$T_3(w_3^1)$	0		0	0.08	0.08
$T_3(w_3^2)$	0		0	0.92	0.92
$T_3(w_3^3)$	0	-0.01	0	0.04	0.04
$T_3(w_4^1)$	9.95	-2.73	-1.53	1	9.42
$T_3(w_4^2)$	0.18	-0.6	-0.08	0.6	0.7
$T_3(w_4^3)$	0.9	-0.55	-0.1		0.8
$T_3(w_4^4)$	0.5	-0.27	-0.1		0.4
Total	12.59	-7.06	-0.06	3.47	16

T_2	k_{12}	k_{13}	k_{14}	k_{15}	k_{16}
$T_4(w_1^1)$	0.53	-1.4	0.8	0.4	1.73
$T_4(w_1^2)$	0.27	-0.65	0.23	0.37	0.87
$T_4(w_2^1)$	0		0	0.06	0.06
$T_4(w_2^2)$	0.25	-0.85	0.7		0.95
$T_4(w_2^3)$	0.01		0.02		0.03
$T_4(w_3^1)$	0		0	0.08	0.08
$T_4(w_3^2)$	0		0	0.92	0.92
$T_4(w_3^3)$	0	-0.01	0	0.04	0.04
$T_4(w_4^1)$	9.83	-2.73	-1.53	1	9.3
$T_4(w_4^2)$	0.18	-0.6	-0.08	0.6	0.7
$T_4(w_4^3)$	0.9	-0.55	-0.1		0.8
$T_4(w_4^4)$	0.5	-0.27	-0.1		0.4
Total	12.47	-7.06	-0.06	3.47	15.88

sible as they can. Transformation T_4 has adopted the water-saving technologies to Agriculture on the basis of transformation T_3.

Transformation T_2 is substitution on the basis of transformation T_1. Firstly, if the value of Later user k_6 is not "None", then the corresponding user should take some measures to retrieve part of the utilized water, and then we get that the sum of Recovered amount k_{13} is 7.06 hundred million m^3. Secondly, if the value of Former user k_5 is "None", then the value of corresponding Increment k_{14} should be prior from Recovered amount k_{13} that can be utilized, and we obtain the sum of Recycle volume k_{15} is 2.13 hundred million m^3.

Transformation T_3 is a synthesis of substitution and decomposition on the basis of Transformation T_2, i.e. if the value of Former User k_5 is not "None", then part of consumption water of the corresponding Use volume k_{12} is from Recovered amount k_{13}. Therefore, the water resources of Recycle volume k_{15} has been consumed 3.47 hundred million m^3 and the remaining part is 3.59 hundred million m^3. Apparently, the total consumption water of Transformation T_2 is the same as the one of Transformation T_3 which is 16 hundred million m^3. Adding the water consumed by ecological environment construction of target basic-elements, which is 4 hundred million m^3, the total water consumed in Region A is 20 hundred million m^3.

Transformation T_4 is a decrease on the basis of Transformation T_3, where the highest consumer of water resources Agriculture adopts a certain water-saving technology to reduce the consumption of initial water. Then, Agricultural expends Initial water 9.83 hundred million m^3. Transformation T_4 consumed the sum of Initial water 12.41 hundred million m^3 and recycle water 3.47 hundred million m^3, i.e., the actual amount of consumed water is 15.88 hundred million m^3.

4) Assessment and optimal selection of innovation strategies

In order to evaluate these four innovation strategies, we establish a set of to measurement criterions: A_1: Technological feasibility; A_2: Economical feasibility and A_3: To meet basic needs of regional water resources, where A_1 and A_2 are prerequisites, and A_3 contains two meanings: first, the initial water utilized by target basic-elements is no less than 0.4 hundred million m^3; Second, The initial water consumed by condition basic-elements should meet the basic needs. Furthermore, the first meaning is also prerequisite, which means that the initial water consumption of condition basic-elements is not more than 1.26 hundred million m^3. In addition, because the total water demands of the target basic-elements is 4 hundred million m^3, its Recycle volume is not more than 3.6 hundred million m^3. Apparently, the four innovative strategies satisfy the conditions both A_1 and A_2, but T_1 and T_2 do not meet the first meaning of A_3, so they can be deleted firstly. Following, we select the optimal one between T_3 and T_4.

In general, the pros and cons of extension strategies can be evaluated by using Priority degree evaluation method, Comprehensive evaluation method, or others. However, in this case, speaking on the water consumption of the two innovative strategies T_3 and T_4, only Agriculture is different from each other. Therefore, the optimal strategy selection is only to compare the costs of between 0.12 hundred million m^3 water resources that T_3 is surplus to T_4 and the amount of saving water by doing the technological reform of T_4. Since the study area is located in the arid and semi-arid regions, the sustainable utilization of water resources occupies the prime location in natural, economic and social systems. Therefore, the technological reform to save water in this region is the main goal of future work. Then we choose T_4 as the optimal strategy.

5) Draw up the action programs

According to Table 1 and the strategy T_4 of Table 3, we formulate the specific

Five-Year action programs of water resources in the study area below:

(1) Residents are limited the total amount of 1.83 hundred million m^3 of water utilization, where the quotas of rural residents and urban residents are 1.33 and 0.5 hundred million m^3, respectively. Under the situation of water ratio systems, we should retrieve the wastewater. The amount of Recycled water from residents is 2.05 hundred million m^3, of which 0.77 hundred million m^3 is utilized as non-drinking, such as washing (courtyard, toilet), etc. On the other hand, 1.28 hundred million m^3 of water resources will be allocated to Green belt, Waste treatment, Transportation belt, Agriculture and Livestock.

(2) Land should strictly limit their consumption of initial water, and only utilizes about 0.06 hundred million m^3 of Recycle water from Agriculture. The retrieved water will be utilized to conserve water, prevent land from desertification and semi-desertification.

(3) Rationally develop Mineral resources. Within the 30 plus kinds of mineral resources in the studied area, we preferentially choose Coal, Tungsten and Molybdenum, which have great development potentiality and mature technology, to be exploited. All water to develop mineral resources is of 0.95 hundred million m^3, and the enterprises should adopt retrieved measures to collect wastewater about 0.85 hundred million m^3, which will be utilized for Green belt, Waste treatment and Transport belt.

(4) Protect the wildlife habitat and properly feed wild animals. The program will be carried out simultaneously with the ecological and environmental protection. At the same time, an additional water of 0.03 hundred million m^3 is supplied to supplement wildlife habitat.

(5) Green urban and rural regions. In the towns and villages surrounding residential areas, plenty of trees and flowers should be planted. All required water of about 0.08 hundred million m^3 should be from Recycled water provided by the residents, and Initial water is strictly prohibited for irrigation.

(6) Purify the living environment and let it be a healthy region, and vigorously clear up Waste water, Waste gas and Waste disposal. The water of 0.92 hundred million m^3 utilized to improve the health of towns and villages is provided by Residents, Transportation belt and Minerals, and Initial water is prohibited to purify the living environment.

(7) Protect and reinforce roads. Shelterbelts will be planted and garbage should be collected on both sides along the roads. The water of 0.04 hundred million m3 to plant trees and clean roads is entirely provided by Recovered water from Residents. At the same time, the water which was secondly recovered by using water-saving measures will be utilized to clear up Waste water, Waste gas and Waste disposal.

(8) Supported by scientific and technological progress and oriented by market,

the structure of agricultural production will be adjusted greatly. Firstly, on the basis of ensuring the basic supply of grains, vegetables, fruits as well as other agricultural products, we should vigorously adjust the agriculture structure and develop water-saving agriculture; Secondly, we may adopt water-saving technologies and measures on agricultural production in order to implement water- saving and recycling irrigations. The total of agricultural water would be less than 9.30 hundred million m^3, where Recycle volume is 1 hundred million m^3 and Initial water is not more than 8.30 hundred million m^3. Initial water has been saved 2.55 hundred million m^3 than before, and Recovered amount is 2.73 hundred million m^3, where a small part was directly discharged to Land and the majority is utilized for planting new vegetations.

(9) Appropriately reduce the development scale of Livestock in order to save water resources and protect vegetation. Arrange Livestock for initial water of 0.10 hundred million m^3 and Recycle volume of 0.60 hundred million m^3, where Recycle water comes from Recovered amount of Residents and Catering industry, and Recovered water of 0.60 hundred million m^3 from Livestock by using water-saving measures is provided for Agriculture.

(10) Control the development scale of Building industry and pay attention to retrieve its utilized water. Since Building industry must utilize the initial water, we should appropriately control its scale of development. The water consumption amount of Building industry was reduced from the original 0.90 hundred million m^3 to 0.80 hundred million m^3, and about 0.55 hundred million m^3 of retrieved water by adopting saving-water measures is utilized for Waste treatment.

(11) Maintain and reduce water consumption amount of Catering industry. Catering water should consume Initial water, so we may pay attention to water conservation and against waste. The quota of Initial water was reduced to 0.4 hundred million m^3 and 0.27 hundred million m^3 of water is retrieved for Livestock by improving water-saving measurements.

In order to effectively perform the schemes above, the local government needs to formulate the following supportable measures:

(1) Promote the establishment of water-saving society and encourage broad participation of resident. Since the programs need to use a lot of Recycle volume, residents and other water users must actively cooperate to retrieve the utilized water. Full of Recovered amount is a necessary condition for sustainable utilization of water resources.

(2) Develop relevant laws and regulations, and constraint the user behavior. Under the rigid constraints to limit amount of available water resources, the integrated management of water resources should be comprehensively improved. Regulatory reforms need to be clear the ways and patterns of water utilization, and determine the quota, and clear water rights, and implement the total control

and quota management.

(3) Strengthen water conservation measures and transform water-saving technology, and vigorously popularize the water-saving infrastructure projects. By laying recovery line, we can provide the necessary conditions for residents to retrieve and re-utilize water resources. At the same time, by adopting water-saving technologies, such as the drip and the timing spray irrigations, we can improve water efficiency and effectiveness.

(4) Optimize the agricultural structure and enhance the development level of agricultural economics. Agriculture is the largest water user and its effectiveness is also the lowest. To adjust the farming structure and enhance the water-saving technology is a sufficient condition of sustainable utilization of water resources.

6 Conclutions

The paper provided a formal approach to generate strategies for the sustainable utilization of regional water resources in a planning period. Under the condition to maintain the development of regional population, resources, environment and economy, it can help the relevant departments to clarify their ideas and effectively resolve the contradictory problem between water crisis and ecological environment construction. In real applications, the relevant departments can adjust the contents and values of characteristics of the condition basic-elements. The extension analysis result of water utilization is an open thinking way. It can make the decision-making of relevant departments be more standardized and scientific. The approach is also compiled into software that enables the decision-making process be intelligent. The extension generation strategy of sustainable utilization of regional water resources alters the only method of qualitative analysis in the past to the perfect combination qualitative analysis with quantitative calculation. This method is also suitable for the strategy generation of sustainable utilization of river basin.

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