Evaluating water resources allocation in arid areas of northwest China using a projection pursuit dynamic cluster model

Chun-fang Yue, Qing-jie Wang and Yi-zhen Li

ABSTRACT

Water resources allocation decision-making in an arid region should consider the interaction of the economy, the environment, society, resources and other factors. In this paper, an index system for the comprehensive evaluation of water resources allocation in arid areas is established in response to the shortage of water resources, over-utilization of groundwater, and an unreasonable structure of agricultural water demand in the arid region of northwest China. It has been formulated based on current river basin water resources allocation practices and consideration of the fairness, efficiency and resource utilization rationality of water resources allocation. The projection tracking dynamic clustering approach was applied to analyze alternative water resource allocation schemes in the Kiz River Basin. It is concluded that the evaluation results demonstrate the following. (1) The PPDC model takes the actual measured value of the index as the basis for comprehensive evaluation, and it avoids the bias caused by the subjective formulation of weights. An optimal allocation scheme that has higher annual comprehensive benefits can better serve regional water resources management. (2) A projection pursuit dynamic cluster approach can deliver results which are more objective and reliable than existing evaluation approaches for water resources allocation. (3) Grey correlation analysis and projection tracking dynamic clustering are basically consistent with the evaluation results for water resources allocation in the Kiz River Basin. This suggests that the projection pursuit dynamic cluster is suitable for the evaluation of water resources allocation schemes.

Key words | index system, Kiz River Basin, projection pursuit dynamic cluster, water resources allocation

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INTRODUCTION

In northwest China, there are many problems such as shortage of water resources, uneven distribution over time and space, over-exploitation of water resources and low level of water resources management. With the development of the social economy, the contradiction between supply and demand of water resources is sharp, and the ecological environment is deteriorating. Severe water resources problems have become the main bottleneck of sustainable development. The rational allocation of water resources is one of the measures to effectively alleviate the above water resources problems. Water resources allocation involves multi-dimensional coordination between different subsystems and different levels of a composite giant system which includes water resources, the environment and the social economy (Yu *et al.* 2009). Due to the complexity of decision-making and operation, the evaluation of the performance of water resources optimization becomes an important part of the optimization process.

Since the system analysis method was applied to water resources planning in 1962 by Maas, a lot of scholars have

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enriched the theory and practice of the rational allocation of water resources. Researchers in China and in other countries have used different approaches to a comprehensive evaluation combined with the actual conditions in different areas. While researchers outside China commenced the study of water resources allocation earlier than Chinese researchers, most of the research was based on an evaluation approach to the market economy and hydrology, such as by Yates, George and Davidson (Wu *et al.* 2016). Some researchers in China have formulated approaches to the evaluation of water resources allocation schemes which respond to the actual situation of China's development. These include the grey clustering approach (Huang *et al.* 2006), a fuzzy matter-element model (Guo *et al.* 2007), the fuzzy optimization model (Yu *et al.* 2009), and a comprehensive evaluation model which introduced the theory of lattice order (Wu *et al.* 2013). When it comes to the application of water resources allocation evaluation in arid areas, many scholars have done a lot of work. He & Tang (2012) proposed an improved matter-element extension model to evaluate the allocation of water resources in the Tailan Irrigation District. Xue *et al.* (2015) introduced a grey correlation model and applied it to the Yarkand River Basin. Wei (2015) introduced the hierarchical fuzzy integral model to evaluate the allocation of water resources in the Xinjiang area. Zhang *et al.* (2015a, 2015b) applied the fuzzy grey element model, which is based on three theories of fuzzy mathematics, grey system and matter-element analysis, to the evaluation of the water resources allocation scheme in Ordos City. Nabinejad *et al.* (2017) combined a particle swarm optimization (PSO) algorithm and MODISM watershed decision support system (DSS) to determine the best watershed water resources allocation evaluation. The authors are of the view that there are still two shortcomings in these approaches. The first shortcoming is that in the grey clustering approach the evaluation index belongs to different categories, which causes a multiplicity of evaluation results, while the fuzzy comprehensive evaluation approach relies too much on the effect of extreme value when using the maximum membership degree principle to determine the level, and the evaluation result could be easily distorted and would decrease the credibility of the evaluation (Wu *et al.* 2016). The second shortcoming is that the evaluation process for these approaches requires the weights of evaluation indices to be determined first, which means that the decision results are vulnerable to the subjectivity of the approach to determine the weights. To address these shortcomings a dynamic clustering approach is used to evaluate the water resources allocation in arid areas.

Projection pursuit dynamic clustering (PPDC) is a comprehensive evaluation approach for the utilization of inherent structures in data which is combined with a projection dimension reduction technique and dynamic clustering algorithm (Friedman 1987). This evaluation process does not rely on weights and thus avoids any subjective decisions when determining weights, so objective evaluation results can be obtained. In this work, a PPDC method was used to make decisions on a water resources allocation scheme in an arid area. The remainder of this paper is organized as follows: the projection pursuit cluster model is described at length, an evaluation index system of drought water resources is constructed, the validation of the model in a case study is discussed, then the conclusions are reached and the outlooks of the study are given.

METHODOLOGY

Building a water resource allocation evaluation index system

The evaluation index system is the key to the evaluation of a water resources allocation scheme. It reflects a set of various indices for water resource allocation in a region or a basin. In terms of the evaluation of regional water resources allocation schemes, there is no unified evaluation index system. Considering the shortage of water resources, industrial water diverted agricultural use, agricultural water diverted from environmental use which causes discontinuous flows, the over-utilization of groundwater, degradation of riparian vegetation and other issues in the arid areas of northwest China, and recognizing the need for sustainable development of the regional economy and the need recovery of the environment and considering China's water resources management policy, an evaluation index system of water resources in arid areas has been constructed. It strives to comprehensively characterize and measure the interaction between society, the economy and the environment under different water resources allocation schemes and to assist decision-making for the allocation of water resources. The index system consists of a target layer, a criterion layer and an index layer as follows:

> Target layer: the reasonable allocation of water resources in an economic zone, which relies on determining the reasonable allocation of water resources.
>
> Criterion layer: Criteria should be based on the principles of ecological sustainable development. To balance equity, efficiency and resources rationality, the fairness principle, efficiency principle and resources rationality principle were adopted.
>
> Indicator layer: based on the criteria, select evaluation indicators which characterize each criterion.

The index system is shown in Table 1.

Projection pursuit dynamic clustering model

Model theory

The PPDC model is based on projection pursuit technology. The principle is to project the high-dimensional data samples into lowdimensional space through some projection combinations and form projection characteristic values. The dynamic clustering algorithm is used to classify the samples and the projection objective function is used to measure the classification results, and then the sample sets can be classified and evaluated according to the projection eigenvalues under the projection combination which optimally achieves the objective function.

Dynamic clustering process

The clustering analysis is based on the attribute of the eigenvalues of the sample projection, and a mathematical method is used to determine the relationship between the eigenvalues of the sample according to a certain similarity or difference index to classify the samples. $\Omega = \{Z_1, Z_2, \ldots, Z_n\}$

Table 1 | Evaluation index system of water resources allocation in arid areas

Target	Evaluation criteria	The evaluation index	Unit	Note
The reasonable allocation of water resources	Fairness	A guaranteed ecological base flow in a river	%	Number of years of the ecological base flow in the river is met/(total number of years +1)
		A guaranteed rate of abstraction of water from a river	%	Number of years that abstraction from the river for water supply is met/(total number of years +1)
		The assurance rate of water supply	%	The percentage of years of normal water supply to the total number of years
		A guaranteed rate of irrigation	%	The percentage of years of normal irrigation water supply to the total number of years
	Efficiency rationality	Total generating capacity	kw/h	
		The total water deficit	10^4 m^3	
		Water consumption for industrial output of 10,000 RMB	$m^3/10^4$ RMB	The amount of water used by industrial enterprises to produce 10,000 RMB of output value
	Resource rationality	Total amount of water loss	10^4 m^3	Loss of water in the process of water distribution
		The difference between surface water and quota	10^4 m^3	The difference between actual surface water use amount and the limit under the watershed management policy
		The difference between groundwater and quota	10^4 m^3	The difference between actual groundwater use amount and the limit under the watershed management policy

is the set of sample eigenvalues, the dynamic clustering algorithm is used to cluster the projection eigenvalues into N $(2 \leq N \leq n)$ clusters, and the realization process is as follows (Ni et al. 2006):

(1) N points are randomly selected as N cluster cores, as $L^0 = (A_1^0, A_2^0, \cdots, A_N^0)$ where L^0 is the set of cluster cores.
(2) The points in the set Ω are divided into N clusters according to the cluster cores, as $\Theta^0 = (\Theta_1^0, \Theta_2^0, \cdots, \Theta_N^0)$, where Θ_i^0 represents the set Z_i in the classification result of clusters i:

$$\Theta_i^0 = \left\{Z_i \in \Omega | d(A_m^0 - Z_i) \leq d(A_j^0 - Z_i), \forall j = 1, 2 \cdots N, j \neq m\right\}$$

where $d(A_j^0 - Z_i)$ is the absolute distance between point A_j^0 and any point in set Ω.
(3) A new set of cluster cores is calculated from Θ^0, $L^1 = (A_1^1, A_2^1, \ldots, A_N^1)$, where $A_i^1 = (1/n_i)\sum_{Z_i \in \Theta_i^0} Z_i$, n_i is the number of points in Θ_i^0.
(4) The result in step (3) is used as a new set of cluster cores, repeating the above steps to get a sequence of classification results $V^k = (L^k, \Theta^k)$, where k indicates the number of repetitions of the above steps. Define:

$$D(A_i^k, \Theta_i^k) = \sum_{Z_i \in \Theta_i^k} |Z_i - A_i^k|, \quad u_k = \sum_{i=1}^{N} D(A_i^k, \Theta_i^k)$$

the termination condition of the algorithm is $(|u_{k+1} - u_k|)/(u_{k+1}) \leq \varepsilon$, where ε is a sufficiently small error permissible value. And it is proved theoretically that this algorithm is convergent (Ren & Wang 1997).

Objective function

When projection pursuit technology is used to project the high-dimensional data samples to the low-dimensional space, each projection combination corresponds to one set of projection eigenvalues, and the result of the projection eigenvalues classification based on a certain clustering criterion is determinate, that is, one projection direction corresponds to one sample classification result. The aim of the PPDC modeling is to make the projection eigenvalues of the whole sample sequence as far away as possible while the eigenvalues of the similar samples are made as close to each other as possible. The construction of an objective function is the key to realizing this idea. The objective function $QQ(\vec{a})$ is expressed by the difference between the scatter degree of the projection eigenvalues of the whole sample and the aggregation degree of the projection eigenvalues of the intra-cluster samples (Zhao et al. 2014):

$$QQ(\vec{a}) = SS(\vec{a}) - dd(\vec{a}) \tag{1}$$

where $SS(\vec{a}) = \sum_{\substack{Z_i \in \Omega \\ Z_j \in \Omega}} d(Z_i - Z_j)$ is the degree of projection dispersion, and the larger the value is, the greater the dispersion of the samples within clusters; $dd(\vec{a}) = \sum_{1}^{N} \sum_{\substack{Z_i \in \Theta_i \\ Z_j \in \Theta}} d(Z_i - Z_j)$ is the intra-cluster aggregation degree, and the smaller the value is, the higher the aggregation degree of similar samples.

Model calculation steps

The sample set of water resource allocation indicators is $\{x_{ij}^0 \mid i = 1, \ldots, n; j = 1, \ldots, m$, where x_{ij}^0 is the jth index value of the ith sample, m and n correspond to the total number of evaluation indices and evaluation schemes respectively. The steps of the PPDC model are as follows.

Step 1: Data standardization. Considering the dimensional differences between the various evaluation indices, the extreme normalization method is used to non-dimensionalize each index. Generally, the evaluation index for water resources allocation can be divided into two categories (Zhang et al. 2015a, 2015b; Zhu et al. 2016), and when the index is positively related to the study subjects, it is calculated as follows:

$$x_{ij} = \frac{x_{ij}^0 - x_{j\min}}{x_{j\max} - x_{j\min}} \tag{2}$$

However, when the index shows a negative correlation with the study subjects, it is calculated as follows:

$$x_{ij} = \frac{x_{j\max} - x_{ij}^0}{x_{j\max} - x_{j\min}} \quad (3)$$

where $x_{j\max}$, $x_{j\min}$ correspond to the maximum and minimum of the evaluation index and x_{ij} is a dimensionless target.

Step 2: Linear projection. Linear projection is used to project high-dimensional evaluation data to one-dimensional linear space. Assuming that $\vec{a}$ is the unit projection direction vector of m-dimensional, its components are a_1, $a_2 \ldots a_m$. The calculation equation of the projection eigenvalue Z_i of x_{ij} can be described as:

$$Z_i = \sum_{j=1}^{m} a_j X_{ij} \quad (4)$$

where $-1 \leq a_j \leq 1$, and $\sum_{j=1}^{m} a_j^2 = 1$.

Step 3: Optimizing the index projection direction. As discussed previously, the dynamic clustering model can be described as the nonlinear optimization problem shown in Equation (5):

$$\begin{cases} \max QQ\,(\vec{a}) \\ |\vec{a}| = 1 \end{cases} \quad (5)$$

Step 4: Comprehensive analysis. The optimal projection direction $\vec{a}^*$ obtained by Equation (5) is applied in Equation (4) to get the projection value Z_i^* of each sample (Wang & Ni 2008; Zhang 2012), and then according to the sorting situation, the cluster results can be further analyzed.

APPLICATION

Area description

The Kzi River Basin is located in northwest China. The climate of the basin is temperate continental climate type, that is, the climate is dry, precipitation is small and evaporation is strong. The runoff of the Kiz River is a glacial–snowmelt runoff with a mean annual runoff of 21.38×10^8 m^3, the inter-annual variation of runoff is small, and the variation within the year is large. There are mountainous reservoirs and plain reservoirs in the Kiz River Basin to regulate water resources. Water mainly includes industrial and urban domestic water, agricultural water, power-generation water and ecological water. The total water consumption of the basin is 23.24×10^8 m^3, of which agricultural water accounts for 97.46%. Therefore, the main problem for the utilization of water resources in the basin is that the agricultural water occupies the ecological water. According to the control target of total water use of the 'most stringent water resources management system' proposed by the Chinese government in 2010, the total water consumption limit of the Kiz River Basin is 18.48×10^8 m^3, of which the surface water control limit is 15.39×10^8 m^3, the groundwater control limit is 2.97×10^8 m^3, and the water control limit for other water sources is 0.12×10^8 m^3. Therefore, the allocation of water resources in the Kiz River Basin should consider the joint dispatching of the mountain reservoirs and the plain reservoirs, as well as the water quota, so as to meet as much as possible the requirements of reservoir irrigation and industrial water use in the plain area.

The generation of water resource allocation scheme

An optimal allocation model of water resource was built based on the runoff data from 1958 to 2007, in which the least total amount of water shortage and the maximum power output after the long series of scheduling were taken as the general goal, and the constraints of surface water and groundwater limit, system water balance, reservoir water balance, reservoir capacity, industry water supply and water supply guarantee rate were taken as constrained conditions. Starting from the whole water resources allocation in the basin and focusing on the Kashgar irrigation area, different levels were set for the proportion of groundwater use for industry and the proportion of pure well irrigation for agricultural drip irrigation, and ten water resource allocation schemes were obtained through model simulation optimization (Zhang & Yue 2013), as shown in Table 2.

Table 2 | The evaluation indices for schemes

	Parameter design of scheme set		Evaluation index					
Scheme	Proportion of pure well irrigation for agricultural drip irrigation	Proportion of groundwater use for industry	Assurance rate	Water loss due to reservoir evaporation and leakage	The difference of surface water	The difference of groundwater	Total generating capacity	The total water deficit
1	0.74	0.55	84.17	74,406.1	−0.1	−294.9	20,588,984	45,375.2
2	0.76	0.55	89.9	74,535.2	0	−250.6	20,642,768	2,706.2
3	0.79	0.4	88.02	74,921.2	350.5	−682.3	20,728,822	18,687.1
4	0.79	0.45	89.27	77,773.6	73.2	−405.5	20,730,322	18,470.6
5	0.79	0.5	88.44	78,502.6	−117.3	−183.4	20,622,378	3,935.6
6	0.79	0.55	94.79	76,964.8	−99.7	−186.5	20,645,014	1,761.8
7	0.79	0.59	94.79	76,529	−328.7	43	20,646,610	1,745.1
8	0.45	0.8	84.69	75,257	423.3	−318.7	20,624,320	3,853.5
9	0.5	0.8	84.17	75,440.4	0	7.9	20,720,842	22,740.8
10	0.85	0.55	94	79,390.7	−398.8	32	20,648,652	2,221.7

Build index system for evaluation of water resources allocation in the Kiz River Basin

Based on the evaluation index system for water resources allocation in arid regions, the following evaluation index system was constructed according to the main difference in the ten schemes.

(1) Fairness indices for water resources allocation

Reasonable water resources allocation schemes should ensure the water demands for life and production (industry, agriculture, the environment) are distributed preferentially before distribution of water for agricultural irrigation, i.e., the guaranteed rate of irrigation water is selected as the equity index in the end.

(2) Resource indices for water resources allocation

From the perspective of sustainable utilization of water resources, two resources rationality indices were selected as follows: the difference between surface water and its quota, the difference between ground water and its quota. In addition, considering regional reservoir operation and climate characteristics, reservoir leakage and evaporation losses were selected as one of the resource rationality indices.

(3) Efficiency indices for water resources allocation

Considering the feasibility of obtaining evaluation index data, the two efficiency indices adopted were regional total hydropower generating capacity and regional total water deficit.

The evaluation index system is shown in Table 3.

Table 3 | Evaluation index system for water resources allocation in Kiz River Basin

Target	Evaluation criteria	The evaluation index	Unit	Index properties
The reasonable allocation of water resources	Fairness	The guaranteed rate of irrigation for each irrigation district	%	∨
	Efficiency	Total generating capacity	kW/h	∧
		The total water deficit	10^4 m^3	∧
	Resource	Total amount of water lost due to reservoir leakage and evaporation	10^4 m^3	∧
		The difference between surface water and its quota	10^4 m^3	∨
		The difference between groundwater and its limit	10^4 m^3	∧

'∨' means the bigger the indicators are, the lower the cost; '∧' means the smaller the indicators are, the higher the benefit.

Evaluation

Evaluation of projection pursuit dynamic clustering

The sample data ($m = 6$, $n = 10$, $N = 3$) was entered into the PPDC model, and by iteration, the cluster index value was maximized and MaxQQ = 25.39, with a corresponding optimal projection direction of $\vec{a}^* = (0.7569\ 0.0018\ 0.0019\ 0.0166\ 0.4089)$ and the projected eigenvalues are shown in Table 4. The PPDC model divides the sample directly into three grades:

Grade I indicates that the water resource allocation is reasonable; the water supply guaranteed, the amount of groundwater in the surface water and the utilization rate of water resources are excellent;

Grade II indicates that the water resource allocation is general, the indicators are basically satisfied, and there are individual indices that do not meet the requirements, and the water resource allocation of some water departments needs to be adjusted;

Grade III indicates that water resource allocation is unreasonable and water resource allocation is inefficient and poses a threat to the environment. The classifications of each scheme are shown in Table 4.

The above calculation results show that scheme 7 of the water resources allocation schemes in the Kiz River Basin was the best, and in addition, schemes 6, 7, and 10 of the water resources allocation schemes were the most reasonable, and schemes 2, 4 and 5 were relatively poor, while the water resources allocation of schemes 1, 3, 8 and 9 were poor. The comparison of the evaluation results with the actual allocation of each scheme shows that the results of the PPDC model are clear and objective, and have good intra-cluster aggregation and inter-cluster separability, and can reasonably reflect the structural characteristics of the allocation results of each water resource allocation scheme.

Evaluation of grey relational analysis

In order to test the rationality of the PPDC model in water resource allocation evaluation, the water resource allocation of the Kiz River Basin was evaluated by the traditional grey relational analysis method. In the process of evaluation, two different scenarios were set up on the determination of weight. The calculation process of grey relational analysis is shown in the literature (Deng & Liu 2009).

Scenario 1: grey relational analysis based on AHP. The grey correlation analysis (AHP-GR) in which the index weight was determined by AHP was used to evaluate the water resources allocation in the Kiz River Basin. The results of the weight calculation are shown below.

The analytic hierarchy process determined the index weight and introducing a 1–9 scaling approach to quantitative evaluation index importance factors, and a feature vector approach was used to calculate the quantitative index matrix. It was concluded that the weight of the three indicators of the difference of surface water, the difference of groundwater, and reservoir water loss were $P_0 = [0.4\quad 0.4\quad 0.2]^{\mathrm{T}} P_1 = [0.45\quad 0.55]^{\mathrm{T}}$. The grey correlation value R' under this method is shown in Table 4.

Table 4 | Evaluation results of water resources allocation

Scheme	1	2	3	4	5	6	7	8	9	10
AHP-GR (R')	0.27	1.08	0.59	0.85	1.03	1.5	1.64	0.43	0.49	1.62
gradation	III	II	III	II	II	I	I	III	III	I
$\vec{a}^*$-GR (R'')	0.54	0.64	0.62	0.52	0.5	0.69	0.75	0.5	0.51	0.7
gradation	III	II	III	III	II	I	I	III	III	I
PPDC(Z_i^*)	0.27	1.08	0.59	0.85	1.03	1.5	1.64	0.43	0.49	1.62
gradation	III	II	III	II	II	I	I	III	III	I

Scenario 2: grey correlation analysis based on projection pursuit dynamic clustering. The optimal projection direction obtained by the PPDC model was used as the weight, and then the grey correlation analysis ($\vec{a}^*$-GR) was used to evaluate the water resource allocation in the Kiz River Basin. The weight s_j of an index is expressed as $s_j = (a_{\rm j})/(\sum_{j=1}^{m} a_j)$, where a_j is the projection component of each index in the optimal projection direction. The weight $s = (0.4464\ 0.0011\ 0.3004\ 0.0011\ 0.0098\ 0.2412)$ and the grey correlation value R' for the optimal projection direction were obtained. The corresponding classification results of the water resources allocation scheme are shown in Table 4, and Figure 1 reflects the distribution of the comprehensive evaluation values of the water resource allocation schemes.

The comparison with the results

According to the evaluation results of water resources allocation in the Kiz River Basin, it is found that on the one hand, the results of the three evaluation methods show that the optimal scheme is scheme 7 and the suboptimal scheme is scheme 10. However, the results of the worst scheme are inconsistent, in which PPDC and $\vec{a}^*$-GR determine the worst scheme to be scheme 1, while AHP-GR determines schemes 5 and 8 to be the worst. On the other hand, on the grade division, it is clear from Table 4 that the schemes in grade I are exactly the same, but scheme 3, scheme 4, and scheme 5 are different in grade II and grade III classification. Generally speaking, the two evaluation methods of projection pursuit dynamic cluster evaluation and grey correlation analysis are similar in the evaluation of water resources allocation in the Kiz River Basin.

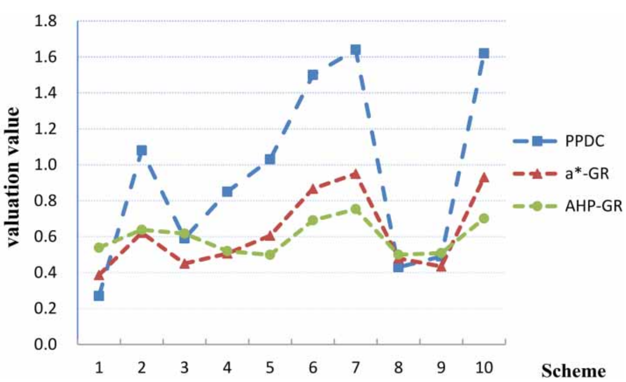

Figure 1 | Sample rating value distributions.

It can be clearly seen from Figure 1 that the curve of AHP-GR is smooth and the grey relational values of each scheme and grade are close, while the difference between the evaluation results of $\vec{a}^*$-GR and AHP-GR is obvious, which indicates that the weight directly affects the final evaluation results in the grey correlation analysis. The similarity between the two curves expressed by PPDC and $\vec{a}^*$-GR is higher, and the evaluation values of each scheme present three distinct gradients, and the schemes in each gradient are the same as those of the various grades in Table 4. The evaluation values of the schemes in each gradient are close, and the projection eigenvalue of each gradient is very different. This shows that the optimal projection direction can clearly quantify the comprehensive differences in social, economic and ecological environments. At the same time, the distinction among the schemes is high, indicating that the evaluation results are stable and the pursuit dynamic cluster evaluation has good adaptability in the evaluation of water resources allocation.

CONCLUSIONS

An evaluation index system of water resources allocation in arid areas has been formulated based on current river basin water resource allocation practices and consideration of the fairness, efficiency and resource utilization rationality of water resource allocation. The projection tracking dynamic clustering approach was applied to analyze alternative water resource allocation schemes. It is concluded that the evaluation results demonstrate the following:

(1) An index system for the evaluation of water resources allocation in arid areas can fully reflect the allocation of water resources in the context of regional social, economic and environment conditions. The PPDC model takes the actual measured value of the index as the basis for comprehensive evaluation, and it avoids the bias caused by the subjective formulation of weights. An optimal allocation scheme that has higher annual comprehensive benefits can better serve regional water resources management.

(2) A projection tracing as an approach to exploration data analysis can effectively deal with high-dimensional nonlinear problems. The projection pursuit dynamic cluster approach can deliver results which are more objective and reliable than existing evaluation approaches for water resources allocation.
(3) Grey correlation analysis and projection tracking dynamic clustering are basically consistent with the evaluation results for water resources allocation in the Kiz River Basin economy. This suggests that the projection pursuit dynamic cluster is suitable for the evaluation of water resources allocation schemes.

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