15 Small hydropower sustainability evaluation for the Belt and Road Initiative

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Introduction

The question of whether large hydropower provides ecological protection is still controversial. However, small hydropower projects (less than 50MW) are flexible and can be operated either independently or can be connected to the main grid. Small hydropower projects may be adopted when specific environmental and ecological requirements have to be met and are a potential option for remote regions that cannot be connected to the main grid in the short term. They may also generate socio-economic and environmental benefits, such as electricity supply, poverty alleviation, energy structure optimization and carbon emissions reduction.

The Chinese government sees the development of small hydropower as an important step and has emphasized the importance of evaluating green hydropower to support the country's sustainable development. The National Energy Administration released the *13th Five-Year Plan for Hydropower Development of China* in November 2016. Based on the concept of watershed ecological protection, the plan argues that hydropower development should be determined scientifically to maintain the basic ecological functions of rivers. The Ministry of Water Resources published *The Guiding Opinions for Accelerating the Development of Green Small Hydropower* in December 2016, promoting its broad benefits in terms of protecting ecology and the environment, saving energy, reducing emissions and enhancing livelihoods.

An overall national and international assessment of small hydropower includes *The World Small Hydropower Development Report 2016,* prepared by the International Center on Small Hydro Power, and the *Global Hydropower Industry Annual Development Report 2017,* published by the National Research Center for Sustainable Hydropower Development. The first report examines global small hydropower from the perspective of hydropower resources and electrification rates (UNIDO 2016). The second report provides a comprehensive analysis and summary of the development of the global hydropower industry from the perspective of the development of the industry itself, climate change, technology, costs, employment, investment and financing (NRCSHD 2018).

Different from more traditional small hydropower assessments, those focusing on sustainability should fully encompass factors such as ecological protection, social perception, management and economics to ensure a coordinated relationship between protection and development.

Though other studies have proved useful, there is still much to do. For example, a set of quantitative indicators and methods is required to make a comprehensive evaluation of the sustainability of small hydropower at the national level. Further, our understanding of the overall level of small hydropower development in countries participating in the Belt and Road Initiative (BRI) is not sufficient. Therefore, we have built a small hydropower sustainability evaluation index system covering four areas: Ecology and Environment, Social, Economic and Political. We adopted the AHP-Fuzzy Comprehensive Evaluation Model (see below) to evaluate the sustainability of small hydropower development in specific countries.

Research region

In an important move, Chinese President Xi Jinping proposed the Silk Road Economic Belt and 21st Century Maritime Silk Road (BRI) when he visited Central Asia and Southeast Asia in September and October 2013. The initiative received a positive response from participant countries and the scheme was rapidly put into operation. The National Development and Reform Commission of China released *Vision and Proposed Actions Outlined on Jointly Building the Belt and Road*, a report that drew attention to the propitious cooperation evident in clean and renewable energy, particularly hydropower (NDRC 2015).

Connecting the Association of Southeast Asian Nations, the Arab League, the African Union and the European Union, the Asia-Pacific and European Economic Circles are on either side of the Belt and Road. The majority of the 65 BRI participant countries are emerging economies or developing countries (Fig. 1-2).

In 2014, the population of BRI countries was 4.4 billion and their aggregated economic volume was $21 trillion, equivalent to 63% and 29% of global totals, respectively (Yu et al. 2015). Most of these countries face problems of slow economic and social development, and degraded ecological quality. In addition, they suffer from isolated geo-political relationships which have led to regional power shortages.

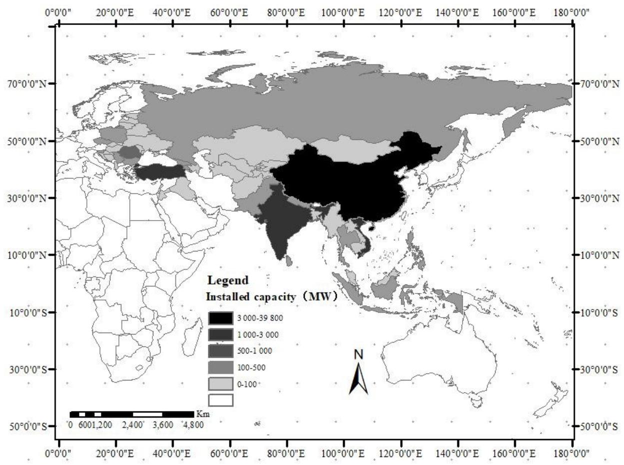

Figure 1 Installed Small Hydropower Capacity of participant BRI countries (MW)

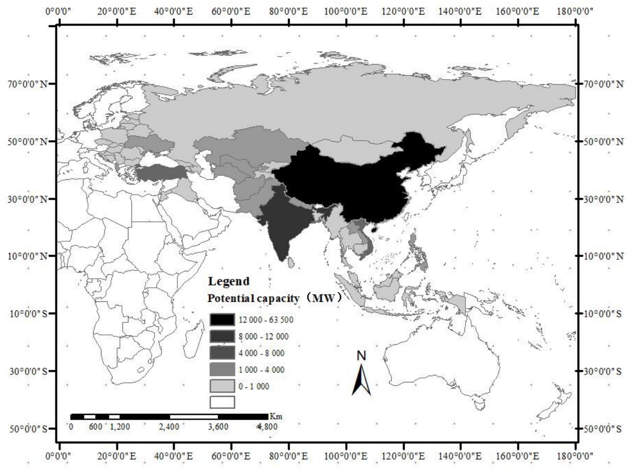

Figure 2 Small Hydropower Potential Capacity of participant BRI countries (MW) Source: Both base maps are from the Map Technology Review Center of the Ministry of Natural Resources.

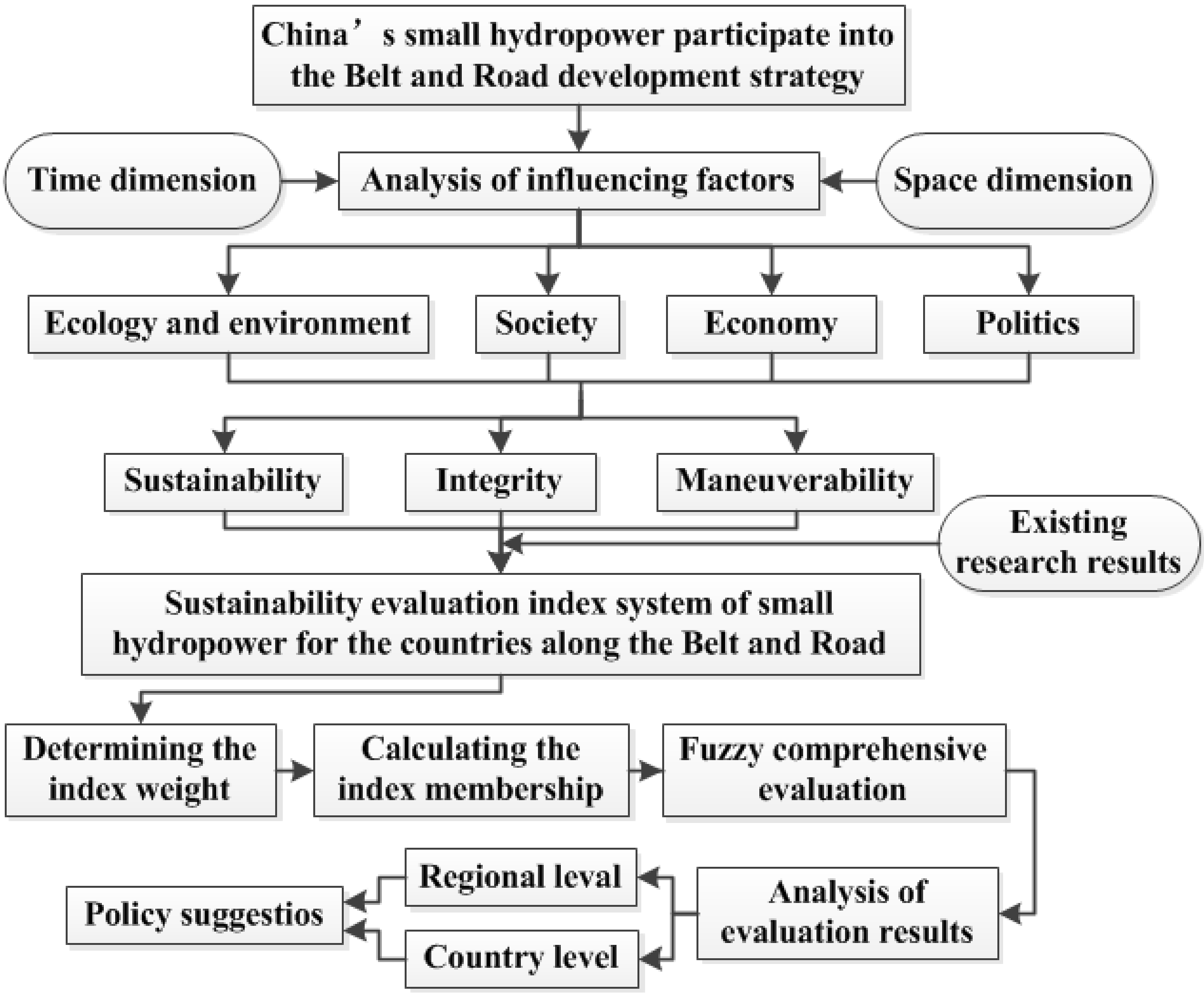

Figure 3 Logical framework of small hydropower sustainability evaluation for BRI participant countries.

Table 1 Review of small hydropower sustainability evaluation index systems, nationally and internationally.

Serial number	Name	Index type	Remarks
1	Low impact hydropower certification	Includes river flow, quality, fish flows, fish protection, watershed protection, endangered species protection, cultural resources preservation, public entertainment functions: eight aspects, 25 indices.	Qualitative analysis
2	Green hydropower certification	Includes hydrological characteristics, river connectivity, sediment and terrain, landscape and habitat, biotic community: five aspects, 11 indices.	Qualitative analysis
3	Hydropower sustainability assessment protocol	Includes environment, society, technology and economy/finance: four aspects, 23 indices.	Qualitative analysis
4	Indicator system for comprehensive evaluation of the sustainable development of small hydropower	Includes drivers, pressure, state, influence and response: five aspects, 28 indices.	Qualitative analysis
5	Indicator system for evaluating thesustainable development of small hydropower	Includes productivity, stability, protection, feasibility and acceptability: five aspects, 26 indices.	Qualitative analysis
6	Evaluation for green small hydropower station	Includes environmental protection, social development, economic benefit and safe operation: four aspects, 12 indices.	Qualitative analysis
7	Evaluation standard for green small hydropower station	Includes environmental evaluation, social evaluation, management evaluation and economic evaluation: four aspects, 14 indices.	Quantitative analysis
8	Indicator System for green small hydropower station	Includes natural ecology and social environment: two aspects, 16 indices.	Quantitative analysis

Many BRI participant countries have huge hydropower resources. Their installed capacity and potential capacity are 53.3GW and 130GW[1] (<10MW), accounting for 68.1% and 59.9% of 2014 global totals, respectively (UNDP 2015). In the context of the global response to climate change, the economic and social development of these countries' rural areas is on the rise and demand for small hydropower is significant (Zhu 2004, Liu 2016). Due to conceptual, economic and technical conditions, the potential of small hydropower has not been fully exploited. The promotion of the BRI will instigate new opportunities and challenges to how international cooperation plays a role in small hydropower development in China.

Methodology and data source

Evaluation index system

Research status

Most evaluation index systems for small hydropower are qualitative. The Evaluation Standard for Green Small Hydropower Stations of China and a number of other studies have conducted quantitative analyses. We summarize some of the qualitative and quantitative systems in Table 1.

Principles for index selection

Constructing a sustainability evaluation system for small hydropower should comply with the following principles: (1) Sustainability: the exploitation and utilization of hydropower resources and water resources should be based on a coordinated relationship between protection and development. (2) Integrity: all of the evaluation indices should be treated as a whole to increase the connections among them. (3) Maneuverability: the evaluation indices should be consistent with the development characteristics and current scenarios of small hydropower and the data to calculate the indices should be available. In line with these principles, we chose quantitative indices and set appropriate evaluation standards (Liu et al. 2010).

The design of the index system

In compliance with the above principles, from the dimensions of time and space and the aspects of economy, society, ecology and environment, and management, we analyzed the influencing factors of small hydropower sustainable development. We built a logical framework of small hydropower sustainability evaluation for BRI participant countries by drawing on research results while also taking into account the current scenarios in participant countries (Fig. 3).

On this basis, we built an index system that considers ecology and environment, society, economy and politics. Sixteen final indices were selected (Table 2). It should be noted that in research results the "management" index type is often used by single small hydropower stations. However, at the level of the Belt and Road, "management" should be envisaged as "macro-management,"

1 The installed capacity of small hydropower below 10 MW.

Table 2 Review of small hydropower sustainability evaluation index systems, nationally and internationally.

Primary index	Serial number	Secondary index	Definition
Ecology and environment status (A)	A1	Forest coverage	The ratio of forest area to total land area in a country
	A2	CO_2 emissions per capita	The ratio of total carbon emissions to total population in a country
	A3	Global Environment Facility (GEF) benefits index for biodiversity	A comprehensive index considering the diversity of national representative species, threatened conditions and habitat species
Social status (B)	B1	Renewable freshwater resources per capita	The ratio of renewable freshwater resources to total population in a country
	B2	Rural population proportion	The ratio of rural population to total population in a country
	B3	Rural electrification rate	The ratio of the population who receive power supply to total population in a country
	B4	Electricity consumption per capita	The ratio of electricity consumption to total population in a country
	B5	Human development index	A comprehensive index considering life expectancy, educational level and quality of life
Economic status (C)	C1	Per capita GDP	The ratio of GDP to permanent residents in a country
	C2	Waterpower utilization rate of small hydropower	The ratio of installed capacity to potential capacity of small hydropower in a country
	C3	Installed capacity proportion of small hydropower	The ratio of installed capacity of small hydropower to total installed capacity
	C4	National economic index	A comprehensive index considering import and export of natural resources, economic rent of natural resources, foreign direct investment, exchange rate volatility
	C5	Energy consumption intensity	Index refers to the amount of energy consumed by the unit of economic benefit. The lower the intensity, the higher the energy efficiency
Political status (D)	D1	National political index	A comprehensive index considering political risk, degree of corruption and criminal cost
	D2	Policy communication index	A comprehensive index considering the effects of political mutual trust, cooperation mechanisms and the political environment
	D3	People-to-people communication index	A comprehensive index considering tourism, science, education and folk exchanges, etc.

Remarks: in view of data availability at country level, the index system has the defect of time consistency.

namely the political status of a country.

Data source
This paper involved 16 indices corresponding to 65 BRI participant countries, and dealt with a total of 1040 sets of evaluation data. To ensure the reliability of the basic data, they were taken from databases, books and research reports in related fields, such as the databases of the World Bank, the United Nations Development Program and The World Small Hydropower Development Report 2016. Due to availability of data, in 2014 basic data for 46 countries were obtained in the data collection process (Table 3).

Table 3 List of BRI participant countries involved in this paper

Region	Nation
2 countries in East Asia	China, Mongolia
8 countries in Southeast Asia	Malaysia, Indonesia, Myanmar, Thailand, Laos, Cambodia, Philippines, Vietnam
6 countries in South Asia	India, Pakistan, Bangladesh, Afghanistan, Sri Lanka, Nepal
5 countries in Central Asia	Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan, Tajikistan
7 CIS countries	Russia, Ukraine, Belarus, Georgia, Azerbaijan, Armenia, Moldova
4 countries in West Asia	Iraq, Jordan, Lebanon, Turkey
14 countries in Central and Eastern Europe	Poland, Lithuania, Estonia, Latvia, Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Albania, Romania, Bulgaria

Evaluation model
American operations researcher Thomas Saaty proposed the AHP method in the 1970s, a hierarchical and structured decision-making method for systematic analysis of multiple indices in a programme. It is a method that combines qualitative and quantitative analysis (Klos and Trebiina 2014, Socaciu et al. 2016) and is a simple way to make complex decisions with multiple objectives and multiple criteria, or without structured features. The method employs the characteristics of applicability, simplicity, effectiveness and systemization, and is widely applied in the social, economic, management and military fields (Bouzon et al. 2016, Zhu 2008). As the index system deployed in the evaluation of small hydropower sustainability is more complicated, we chose to use the AHP-fuzzy comprehensive evaluation, which is widely deployed in multi-index and multi-level complex evaluations. Determining the evaluation grade and index weight according to the membership theory of fuzzy mathematics means compound operations on multi-levels can convert qualitative judgements into quantitative evaluation. We determined the grades of evaluation as follows:

1. Defining the evaluation index set. Constructing the index set $U = (u_1, u_2,...u_n)$, U_i, represents ecology and environment, social, economic or political index, n is the total number of indices.

2. Defining the assessment set. The decision assessment set is $V = (v_1, v_2, v_3, v_4, v_5) = (1, 2, 3, 4, 5)$, where V_j represents the grade of each index based on scores given by experts, and its value can range across the comment set "excellent, good, moderate, poor, very poor" (Table 4).

Table 4 Sub-layer index evaluation standard

Comment set	Very poor	Poor	Moderate	Good	Excellent
Primary index	0-1	1-2	2-3	3-4	4-5
Secondary index	a_0-a_1	a_1-a_2	a_2-a_3	a_3-a_4	a_4-a_5

Remarks: a_i is the threshold value for secondary indices

3. Defining the weight set. As required by the AHP method, experts compared every pair of indices in each level, providing results on a 1 to 9 scale (Table 5), and performed a consistency test. The weight of each indicator can be obtained via matrix calculation, and their weight set can be established as a weight vector $W = (w_1, w_2, \dots w_n)$, where W_i is the weight of the i-th factor.

Table 5 Score values of the judgment matrix

Score	Meaning
1	Indices *i, j* are similarly important
3	Indices *i* is slightly more important than *j*
5	Indices *i* is somewhat more important than *j*
7	Indices *i* is considerably more important than *j*
9	Indices *i* is vastly more important than *j*
2,4,6,8	Intermediate values between the values above
Reciprocal ($1/w_{ij}$)	The result obtained from comparing indices *j* and *i*

4. Determining the membership matrix. According to the characteristic of each index, we were able to derive the membership function. The evaluation function

$$R = \begin{pmatrix} r_{15} & \cdots & r_{15} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{n5} \end{pmatrix}$$

is calculated for each primary index. Where: R_{ij} is the membership of factor U_i to V_j;

1-5 represents the five different evaluation states - "excellent, good, moderate, poor, very poor" - that each secondary index corresponds to;

n represents the number of secondary indices under each primary index.

The threshold value in the evaluation standard is used as the inflection point to establish the linear membership function of each quantitative index. Where: x_i is the value of status of the secondary index.

$$r_1(x_i) = \begin{cases} 1, x_i \le a_0 \\ \dfrac{a_1 - x_i}{a_2 - a_1}, a_0 < x_i \le a_1 \\ 0, x_i > a_1 \end{cases} \quad 1$$

$$r_2(x_i) = \begin{cases} 1 - \dfrac{a_1 - x_i}{a_1 - a_0}, a_0 < x_i \le a_1 \\ \dfrac{a_2 - x_i}{a_2 - a_1}, a_1 < x_i \le a_2 \\ 0, x_i \le a_0 \text{ or } x_i > a_2 \end{cases} \quad 2$$

$$r_3(x_i) = \begin{cases} 1 - \dfrac{a_2 - x_i}{a_2 - a_1}, a_1 < x_i \le a_2 \\ \dfrac{a_3 - x_i}{a_3 - a_2}, a_2 < x_i \le a_3 \\ 0, x_i \le a_1 \text{ or } x_i > a_3 \end{cases} \quad 3$$

$$r_4(x_i) = \begin{cases} 1 - \dfrac{a_3 - x_i}{a_3 - a_2}, a_2 < x_i \le a_3 \\ \dfrac{a_4 - x_i}{a_4 - a_3}, a_3 < x_i \le a_4 \\ 0, x_i \le a_2 \text{ or } x_i > a_4 \end{cases} \quad 4$$

$$r_5(x_i) = \begin{cases} 0, x_i \le a_3 \\ 1\text{-}\dfrac{a_4 - x_i}{a_4 - a_3}, a_3 < x_i \le a_4 \\ 1, x_i > a_4 \end{cases} \quad 5$$

5. Fuzzy comprehensive judgment. First, the fuzzy judgment should be conducted from the secondary index to the primary index, that is, the membership vector of the primary index is:

$$B_i = W_i \cdot R_i = (w_1, w_2, \dots w_n) \cdot \begin{pmatrix} r_{15} & \cdots & r_{15} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{n5} \end{pmatrix} = (b_1, b_2, \dots, b_5) \quad 6$$

Wherein, i is the factors of the primary index, including ecology and environment *(i = 1)*, social status *(i = 2)*, economic status *(i = 3)* and political status *(i = 4)*.

n represents the number of secondary indices under each primary index. *when i = 1, n = 3; when i = 2, n = 5; when i = 3, n = 5; when i = 4, n = 3.* On this basis, we derive the fuzzy evaluation matrix $R = (R_1, R_2, R_3, R_4)^T$ of the primary index and membership vector B.

6. Using the fuzzy comprehensive index method to determine the comprehensive evaluation results of the sustainable development level of small hydropower in various countries:

$$FCI = B \cdot V = (B_1, B_2, B_3, B_4, B_5) \cdot \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{pmatrix} \quad 7$$

Wherein, FCI is the score of fuzzy comprehensive evaluation; B is membership vector; and V is evaluation standard vector.

Results

Index weight and evaluation results

In order to ensure the accuracy and rationality of index weight, experts from Chinese universities, research institutes and government - including departments of water conservancy, hydropower, water resources, ecology and environment, technology and information - were invited to independently determine the score of the comparison matrix of the evaluation index system using the 1-9 Scale Method (Table 5). A total of 50 expert judgment matrices were obtained, and the final score was calculated by weighted averaging. The judgment matrix had to pass the consistency test, and CR was used to indicate the consistency ratio. When $0 < CR < 0.1$, the consistency of the judgment matrix was considered acceptable. If the consistency test failed, the experts had to reuse the 1-9 scale method to determine scores, until the judgment matrix passed the consistency test to obtain the weight of each level of indices (Table 6).

Using the comment set and membership vector, the results of comprehensive evaluation and primary index evaluation of small hydropower sustainability in BRI participant countries were determined (Fig. 4).

Analysis of evaluation results

Regional level

The comprehensive evaluation scores of 14 Central and Eastern European countries, seven countries of the Commonwealth of Independent States (CIS), and five Central Asian countries are relatively high (>3). Rural electrification in these countries was achieved by extending main grids dominated by thermal power (Zhu 2008, Zhou et al. 2016). Their rural electrification rates have reached or are close to 100%, so the development potential of small hydropower is limited.

The comprehensive evaluation scores of four West Asian and North African countries, eight Southeast Asian countries, one East Asian country and six South Asian countries are relatively low (<3). Among them, the rural electrification rates of eight Southeast Asian countries, one East Asian country and six South Asian

Table 6 Weight of evaluation indices and evaluation criteria

Primary index	Weight	Secondary index	Weight	Very poor	Poor	Moderate	Good	Excellent
		A1	0.0475	0-20	20-40	40-60	60-80	80-100
A	0.25	A2	0.644	15.4-12.37	12.37-9.33	9.33-6.29	6.29-3.25	0-3.25
		A3	0.3085	0-20	20-40	40-60	60-80	80-100
		B1	0.031	1-500	500-1000	1000-2000	2000-3000	3000-30000
		B2	0.1656	80-100	60-80	40-60	20-40	0-20
B	0.25	B3	0.4796	0-20	20-40	40-60	60-80	80-100
		B4	0.2440	0-1390	1390-2750	2750-4110	4110-5470	5470-6900
		B5	0.0798	0-0.3	0.3-0.55	0.55-0.7	0.7-0.8	0.8-1.0
		C1	0.0401	0-975	975-3855	3855-7880	7881-11905	11905-23000
		C2	0.4316	0-20	20-40	40-60	60-80	80-100
C	0.25	C3	0.2845	0-4	8-4	12-8	16-12	20-16
		C4	0.0721	0-20	20-40	40-60	60-80	80-100
		C5	0.1717	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0
		D1	0.6413	0-20	20-40	40-60	60-80	80-100
D	0.25	D2	0.2375	0-4	4-8	8-12	12-16	16-20
		D3	0.1211	0-4	4-8	8-12	12-16	16-20

Remarks: a_i is the threshold value for secondary indices

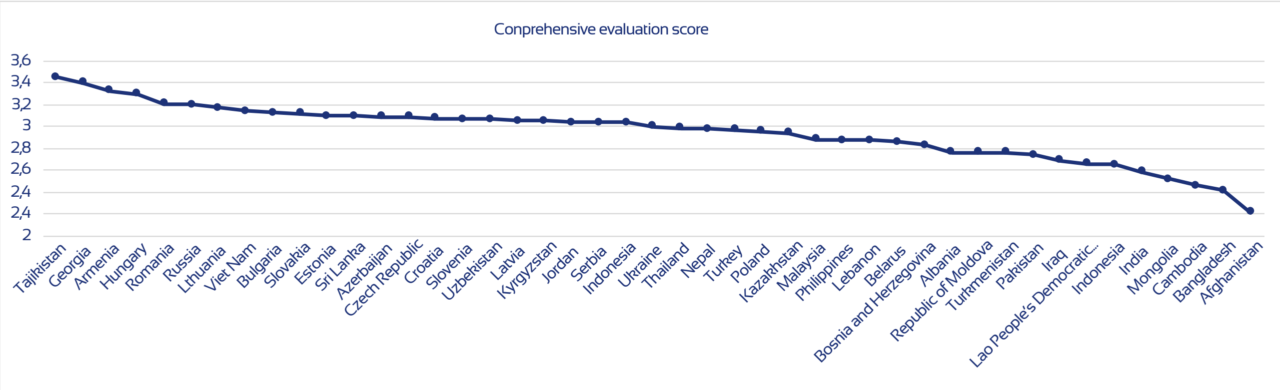

Figure 4 Small hydropower sustainability evaluation of BRI participant countries

Table 7 Evaluation results of small hydropower sustainability of BRI participant countries

Primary index	14 Central and Eastern European countries	7 CIS countries	5 Central Asian countries	4 West Asian and North African countries	8 Southeast Asian countries	1 East Asian country	6 South Asian countries	Average of 46 countries
Comprehensive status	3.06	3.09	3.05	2.89	2.84	3.03	2.67	2.96
Ecology and environmental status	3.05	3.24	2.91	3.37	3.63	2.61	3.63	3.25
Social status	4.26	4.00	3.68	3.92	2.91	3.53	2.53	3.63
Economic status	1.82	1.74	1.79	1.22	1.37	2.15	1.61	1.66
Political status	3.12	3.39	3.85	3.06	3.43	3.85	2.92	3.29

countries are 72.09, 69.9, and 66.52%, respectively. Therefore, rural electrification in these countries can be further improved. Meanwhile, waterpower utilization rates of small hydropower are 12.20, 38.46, and 14.19%, respectively, so the development potential of small hydropower is considerable. With industrialization process indices ranging from 23 to 51, they are in the early stage or starting the middle stage of industrialization. Thus, the economic and social development demand for small hydropower is strong. The rural electrification rate and industrialization process index of four West Asian and North African countries are 99.08% and 82.77%, respectively. Moving into the post-industrialization stage, the development space for small hydropower is limited (Table 7). Based on the above analysis, the key regions for Chinese small hydropower to participate in the BRI include eight Southeast Asian countries, one East Asian country and six South Asian countries.

On this basis, we analyzed the correlation between comprehensive, ecology and environment, social, economic and political evaluation results of BRI participant countries (Table 8). Comprehensive evaluation results are positively related to the four other evaluation results. From high to low, the correlations are society, economy, politics, and ecology and environment. On the one hand, the difference between any two of them is smaller than 0.08; on the other hand, a good social environment is important to the sustainable development of small hydropower. Ecology and environment evaluation results are negatively related to the other three types of evaluation. This phenomenon demonstrates that, at present, the development of small hydropower may damage the ecology and environment to different degrees in BRI participant countries. Coordination between protection and development has not been achieved in most of these countries.

Country level

Fourteen key countries were selected to further analyze the restrictive factors of small hydropower sustainability after filtering out countries whose rural electrification rates reached or approached 100%. Subsequently, we analyzed the status of their secondary indices (Table 9).

We filtered the key countries whose secondary indices were "poor" and "very poor". The proportions of "poor"

Table 8 Correlation analysis of the evaluation results for the primary indices

Primary index	Comprehensive status	Ecology and environmental status	Social status	Economic status	Political status
Comprehensive status	1				
Ecology and environmental status	0.0021	1			
Social status	0.6569	-0.4927	1		
Economic status	0.6464	-0.1429	0.2626	1	
Political status	0.4602	-0.2137	0.0865	0.1518	1

and "very poor" for the secondary indices show that the GEF benefits index for biodiversity (A3), rural population proportion (B2), electricity consumption per capita (B4), per capita GDP (C1), waterpower utilization rate of small hydropower (C2), installed capacity proportion of small hydropower (C3) and energy consumption intensity (C5) are restrictive factors for the sustainable development of small hydropower (Fig 5). Among these, the proportions of "very poor" for the GEF benefits index for biodiversity (A3), electricity consumption per capita (B4), waterpower utilization rate of small hydropower (C2) and installed capacity proportion of small hydropower (C3) are more than 70%, indicating that their degrees of restriction are higher than other indices. To date, the use of engineering and non-engineering measures to protect biodiversity has not been examined sufficiently in processes of small hydropower development. Small hydropower projects cause homogenization and discontinuity of river morphology, thus affecting habitat diversity and negatively impacting biodiversity. Waterpower utilization rates and installed capacity proportions of small hydropower should lead to the increment of rural electrification rates and electricity consumption per capita and should not be emphasized alone.

It should be noted that these restrictive factors have complex and non-linear characteristics. Influenced by both human activity and natural power, their development trends have uncertainty and time-space variation. Therefore, depending on current scenarios, different countermeasures should be implemented in countries to improve their small hydropower sustainability.

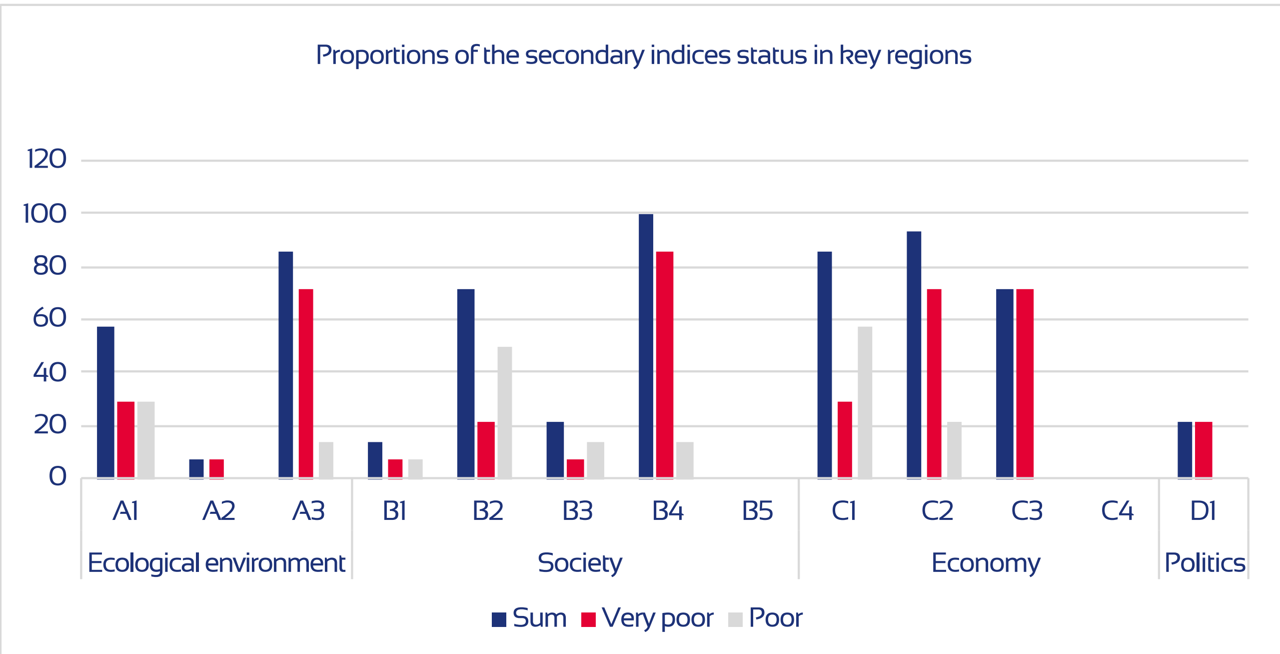

Figure 5 Proportions of the secondary indices status in key regions.
Remark: The key areas include the following countries: one country in East Asia (Mongolia), seven countries in Southeast Asia (Indonesia, Myanmar, Thailand, Laos, Cambodia, Philippines, Vietnam) and six countries in South Asia (India, Pakistan, Bangladesh, Afghanistan, Sri Lanka, Nepal).

Conclusions and discussion

Main findings

1. This study analyzes the index system quantitatively from the perspectives of ecology and environment, society, economy and politics, as well as providing a method to evaluate the sustainability of small hydropower in BRI participant countries. This study not only supports the role of China in small hydropower cooperation with other countries, but also provides a reference for promoting the sustainable development of small hydropower around the world.

2. From a regional perspective, China should participate in the construction of small hydropower in seven Southeast Asia countries, six South Asia countries and one East Asia country, all of which are included in the key BRI area.

3. From the perspective of secondary index countries, the main restrictive factors for key countries are economic factors, followed by social and political factors. The GEF benefits index for biodiversity, rural population proportion, electricity consumption per capita, per capita GDP, waterpower utilization rates of small hydropower, and installed capacity proportions of small hydropower and energy consumption intensity are restrictive factors for the sustainable development of small hydropower.

Policy suggestions

To facilitate China's small hydropower industry to take an active role in the Belt and Road Initiative in the future, we propose the adoption of the following policy initiatives:

1. In order to promote the sustainable development of small hydropower in key countries, and because economic and social indices are the main restrictive factors for the sustainable development of small hydropower in countries along the Belt and Road, we believe a new development mode for small hydropower should be deployed, namely "marginal industries + small hydropower". By combining small hydropower development with rural infrastructure construction, not only can the economic and social development of key countries be advanced, but China's surplus production crisis can also be resolved. Preliminary planning and feasibility studies should be initiated. By helping key countries develop comprehensive planning for medium and small rivers, China's small hydropower industry can successfully gain access to overseas markets. Small hydropower projects should be a funding priority for the Asian Infrastructure Investment Bank, BRICS New Development Bank and other emerging financial institutions. These financial institutions should provide financial support and investment insurance to key countries.

2. The International Center on Small Hydropower should bring together experts to build an index system for small hydropower sustainability, an initiative that can be seen as an important way of contributing to the UN Sustainable Development Goals (SDGs). The index system can then be disseminated to relevant countries, and an information platform of small hydropower sustainability can be built so that country data to evaluate the sustainability of small hydropower can be integrated to obtain relevant and accurate data in real time.

Study limitations and future directions

Overall, this paper can provide a reference for China's small hydropower industry to actively participate in the BRI. However, there is still room for further improvement in the index system and model construction, and conclusions thereof.

1. The study's index system requires further improvement. For example, in the economic field, indices of the investment and financing support for small hydropower, feed-in tariffs of small hydropower, development costs and the demand for water in various countries have considerable scientific value for measuring the economic benefit-to-cost ratio of small hydropower development. However, due to limits of data availability, such data were not included in this study. By strengthening statistical efforts in departments active in the BRI, it is expected that more representative evaluation indicators will be included.

2. The small hydropower sustainability evaluation method outlined in this paper is universal. For example, the method can be adopted to evaluate small hydropower sustainability in sub-Saharan Africa. The sustainable development potential of small hydropower in a specific country can be calculated by using this method. However, the AHP method has its limitations. Weight sets of indices were determined by scores that experts provided, so results are subjective. AHP should be scrutinized and corrected when it is applied in an analysis of the development status of countries within the Belt and Road.

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