A Comparative Analysis of the Water Eco-civilization of the Major Cities in Laos-Based on a Hybrid Evaluation Method

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Abstract

As one of the most important countries along the Mekong River, Laos' proximity to the river means its great influences, and thereby the water ecological civilization in Laos could be of great importance to the river. Therefore, the quantification and comparison of the water ecological civilization of the major cities in Laos would be beneficial to facilitate those cities to engage more actively. To quantify the water ecological civilization in Laos' cities, this study utilizes a hybrid evaluation method that consists of entropy method and set-pair method to construct an evaluation indicator system for water ecological civilization of the major cities in Laos. This research aimed to study the Comparative Analysis of the Water Eco-civilization of the Major Cities in Laos-Based on a Hybrid Evaluation Method. We find that: (1) there are significant differences in water ecological civilization development among the major cities in Laos; (2) the boost of water eco-civilization in Laos should not merely rely on water ecology system, but also the balance improvement of water ecology system, water security system, water management system and water culture system.

Keywords: Evaluation System, Water Ecological Civilization, Major Cities in Laos, Entropy Method, Set-pair Method

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Introduction

With the constant influx of investments from China and accelerating growth of its economy, Laos the less developed country gradually exhibits its demand for water resources. Over 90% of the territory covered by the Mekong River basin, Laos plans to fully exploit the Mekong River, such as extract waters for industry development and build numerous hydropower stations which seriously threaten the water ecology not only in Laos but also in the downstream countries, such as Vietnam and Cambodia (Baird & Barney, 2017). This issue could trigger further political and diplomatic problems, and even damper the region's stability. In this case, to archive, the harmony between humans and nature, and the sustainability of Laos' economy and society, the establishment of water eco-civilization in Laos should be paid particular attention (Priscoli, 2000). To promote the cities in Laos, engage more actively, it is of necessity to quantify and compare the development of water eco-civilization of different cities in Laos. However, currently, there are no suitable indicator systems that can properly evaluate the water ecological civilization in Laos' cities. To bridge this gap, we develop an evaluation indicator system for water ecological civilizations of Laos' cities and employ information entropy and Delphi method for weighing the indicators. Based on the samples of the top ten cities in Laos, we apply our evaluation indicator systems and obtain the scores of water eco-civilization in those cities. In the final, we discuss our findings and offer suggestions.

Indicator Selection

1.Water Ecological Civilization in Major Cities of Laos: Water ecological civilization refers to the ideology that follows human and water harmonious culture ethics, aims to the sustainable use of water resources, support the peaceful development of economy and society, and guarantee the virtuous circle of ecosystems, which is an important part and primary content of ecological civilization. Ecological civilization construction is closely related to economic development, political construction, cultural construction, social construction, etc. Ecological civilization is an essential foundation and basis of material culture, political civilization, spiritual civilization, and human civilization. Meanwhile, as an indispensable resource for human survival and development, water resource plays a crucial role in sustainable economic and social development. The water ecosystem is the primary carrier for the formation and transformation of water resources. Therefore, protecting the aquatic ecosystem and building a water ecological civilization is an essential guarantee for the sustainable development of Laos' economy and society.

2. Principle of Evaluation System Construction: To accurately and properly quantify the water eco-civilization development in Laos' cities, the construction of the evaluation system adopts the following principles. (1) The water ecological civilization system is an overall system that emphasizes the harmonious development of human and water ecology. Therefore, the choice of indicators for urban water ecological civilization should always maintain an ecological, economic, and social balance. Due to its unique geographical location and strategic value, the selection of indicators for the water ecological civilization of Laos should fully consider the interests of its downstream countries. According to this logic, the construction of the Laos water ecological civilization evaluation system should follow the overall principle and proceed under a more macro framework. (2) Scientific principles are the most necessary principles for constructing an evaluation indicator system. Water ecological civilization has its particular content, including the universality of social culture and the particularity of water-environmental conditions. Therefore, the selection of indicators should rely on the content of the water ecological civilization in Laos. (3) In addition to the above principles, the design of the evaluation indicator system should center on the operability of the selected indicators, particularly the data obtainability. In most cases, the final indicator choice is the trade-off between description accuracy and data availability. In this study, the evaluated cities are located in Laos, which means that some indicators could miss data. Therefore, the construction of the corresponding evaluation system should follow the operational principle and select appropriate indicators according to data obtainability. (4) The purpose of constructing evaluation systems is to compare the evaluated objects from different perspectives and unveil the overall situation of water ecological civilization. Accordingly, the indicator system should be suitable for analyzing and judging the development level of water eco-civilizations in Laos' cities from various aspects and dimensions. Considering the practical circumstances of the major cities in Laos, we interview relevant experts and government officials. Based on their opinions, we select the water ecology system, water economy system, and water society system as our rule layer indicators (Table 1in part 3.4).

Research Objective

This research aimed to study the Comparative Analysis of the Water Eco-civilization of the Major Cities in Laos-Based on a Hybrid Evaluation Method

Research Methodology

1. Data and Sample: We collect our data primarily from Laos' statistical yearbook, public report, and questionnaire. Considering the influence of cities and the operability of data collection, we choose the top ten cities of Laos to evaluate the development levels of water ecological civilizations. The evaluated cities are Vientiane, Pakse, Thakhek, Savannakhét, Luang Prabang, Xam Nua, Muang Phônsavan, Muang Xay, Vang Vieng, and Muang Pakxan. For survey data, we employ a questionnaire to collect data via e-mail, an online survey, and a face-to-face interview. We conduct the whole survey with assistance from our research teams' social network in Laos; we distribute 60 questionnaires to each city and collect 433 respondents (72.17%). Also, a 10-point system is used to evaluate each item on the scale. We collect the archival data from statistical yearbooks, environmental conditions bulletin, and water resources reports.

2. The Weight of Evaluation Indicators: To address the particularity of water ecological civilization in Laos' cities, we employ the entropy method and Delphi method to obtain the weights of evaluation indicators (Skulmoski, Hartman, & Krahn, 2007; Zou, Yi, & Sun, 2006) . We apply entropy method to ascertain the first-order weights, and its steps are as follows:

Assume m objects are needed to be evaluated (i=1, 2, ..., m). Each object has n evaluating parameters (j= 1, 2, ..., n). In this way, we can obtain an original matrix X. For positive indicator, we obtain a normalized function:

$$X`_{ij}=\frac{X_{ij}-\min\{X_j\}}{\max\{X_j\}-\min\{X_j\}} \quad (1)$$

For negative indicator:

$$X`_{ij}=\frac{\max\{X_j\}-X_{ij}}{\max\{X_j\}-\min\{X_j\}} \quad (2)$$

Then, the ratio of indicator value of the j parameter in *i* object is:

$$Y_{ij}=\frac{X`_{ij}}{\sum_{i=1}^{m}X`_{ij}} \quad (3)$$

Then, we calculate the information entropy Ei, the formula is as follows:

$$e_j=-k\sum_{i=1}^{m}(Y_{ij}\times\ln Y_{ij}) \quad (4)$$

Then, we calculate information redundancy:

$$d_j=1-e_j \quad (5)$$

Finally, we calculate indicator weight Wi:

$$W_i=d_j/\sum_{j=1}^{n}d_j \quad (6)$$

3. Set-pair analysis evaluation: Besides the entropy method, we also employ the set-pair analysis method, which is suitable for evaluating multiple targets. Therefore, a set-pair analysis evaluating model is built to assess the water eco-civilization of the major cities in Laos.

Given objects to be evaluated and a set of $E=\{e_1, e_2, \ldots, e_n\}$, of which e_n is the nth object. Each object has evaluation indicators $F=\{f_1, f_2, \ldots, f_m\}$ and f_m represents the m^{th} indicator. d_{ij} (*i*=1, 2, ..., *n*; *j*=1, 2, ..., *m*) refers to the value in the evaluation matrix. Based on the set-pair analysis, we obtain the multi-target evaluation matrix Q :

$$Q = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ \dots & \dots & \dots & \dots \\ d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix} \quad (1)$$

After extracting values in the matrix Q , we acquire the optimal set $U = [d_{u1}, d_{u2},..., d_{un}]^T$ which contains optimal evaluation indicators within all evaluation plans. This set, d_{uj} refers to the c_{pk} th index value in the optimal evaluation set $U = [d_{u1}, d_{u2},..., d_{un}]^T$. Similarly, we also get the worst evaluation set $V = [d_{v1}, d_{v2},..., d_{vn}]^T$, in which d_{vj} represents the value of the indicator c_{pk} .

In order to obtain a similar degree matrix A and the set $[U, V]$ unweight, the evaluation index value w_p and the optimal value d_{uj} would be further analyzed.

If d_{ij} is a positive indicator,

$$\begin{cases} a_{ij} = \dfrac{d_{ij}}{d_{uj} + d_{vj}} \\ b_{ij} = \dfrac{d_{uj} d_{vj}}{d_{ij}(d_{uj} + d_{vj})} \end{cases} \quad (4)$$

If d_{ij} represents a negative indicator,

$$\begin{cases} a_{ij} = \dfrac{d_{uj} d_{vj}}{d_{ij}(d_{uj} + d_{vj})} \\ b_{ij} = \dfrac{d_{ij}}{d_{uj} + d_{vj}} \end{cases} \quad (5)$$

Combining with weights from information entropy $W=(w_1,w_2,...,w_m)$, a similar degree matrix A would be transferred into a weighted similar degree matrix A_w. Then we get set $[U, V]$ in the below:

$$A_w=W\times A=(w_1 \;\; w_2 \; ... \; w_m)\times\begin{bmatrix} a_{11} & a_{12} & ... & a_{1n} \\ a_{21} & a_{22} & ... & a_{2n} \\ ... & ... & ... & ... \\ a_{m1} & a_{m2} & ... & a_{mn} \end{bmatrix}=(a_1,a_2,...,a_n) \quad (6)$$

a_j is the similar degree of the j th object in the formula (6).

Similarly, the weighted opposite degree matrix B_w of the objects and the set $[U, V]$ would be obtained.

$$B_w=W\times B=(w_1 \;\; w_2 \; ... \; w_m)\times\begin{bmatrix} b_{11} & b_{12} & ... & b_{1n} \\ b_{21} & b_{22} & ... & b_{2n} \\ ... & ... & ... & ... \\ b_{m1} & b_{m2} & ... & b_{mn} \end{bmatrix}=(b_1,b_2,...,b_n) \quad (7)$$

b_j is the opposite degree of the j th object in the formula (7).

Then we calculate the relative closeness degree of each object. r_j represents the relative closeness degree of the j th object and the optimal evaluation which is calculated as follows:

$$r_j=\frac{a_j}{a_j+b_j} \quad (8)$$

Then we get the relative closeness degree matrix R:

$$R=(r_1,r_2,...,r_m) \quad (9)$$

In this matrix, the object which is closer to the optimal plan would have a bigger r_j value. Then the object with a bigger r_j value would have a higher ranking among all objects evaluated.

4.The indicator weight: After the entropy method and set-pair method, we invite experts in relevant fields to further adjust and hence determine the final weights for the evaluation system of cities in Laos (Table 1).

Table 1 Indicator weight for water ecological civilization of Laos' cities

Rule Layer (B)	**Rule Layer Weight**	**Indicator Layer (C)**	**Weight**
Water Ecology System (B1)	0.3984	Overall Water Quality (C1)	0.0915
		Overall Fish Species Loss (C2)	0.0558
		Overall Species Loss (C3)	0.0730
		Water and Soil Conservation (C4)	0.0401
		Forest Coverage (C5)	0.0423
		Restoration of Biodiversity (C6)	0.0331
		Exit-boundary Water Quality (C7)	0.0405
		Water Damage Restoration (C8)	0.0220
Water Security System (B2)	0.2385	Water Resources per Capita (C9)	0.0672
		Water Quantity Security (C10)	0.0729
		Stability of Water Supply (C11)	0.0278
		Flood Prevention Ability (C12)	0.0377
		Water Pollution Abatement (C13)	0.0330
Water Management System (B3)	0.2421	Water Resources Management Mechanism (C14)	0.0662
		Implementation of Policies and regulations (C15)	0.0383

Rule Layer (B)	Rule Layer Weight	Indicator Layer (C)	Weight
		Water Consumption per Unit GDP (C16)	0.0522
		Water Conservancy Development Mechanism (C17)	0.0220
		Overall Water Consumption per Capita (C18)	0.0126
		Coordination of Water Related Organizations (C19)	0.0508
Water Culture System (B4)	0.1210	Water Protection Culture (C20)	0.0628
		Public satisfaction to WEC (C21)	0.0254
		WEC education coverage (C22)	0.0328

Results

Table 2 reports the results on water ecological civilization of the top ten cities in Laos, including the scores of water ecology system, water security system, water management system, water culture system, and overall score. Furthermore, we rank those cities based on the evaluation scores of water ecological civilizations.

For Overall score, Vientiane (0.7539), Luang Prabang (0.7420), and Savannakhét (0.6853) rank the top three while Muang Pakxan (0.3464) ranks the last one, considering the general situation of overall water ecological civilizations and natural environment in those cities, the evaluation results are relatively feasible and reliable. As the capital of Laos, Vientiane outperforms other towns, especially Muang Pakxan that inhabitants the least people among the ten cities. Meanwhile, it is worth noting that the difference in water eco-civilization between Vientiane and Muang Pakxan does not merely derive from their difference in population, the local institutional framework such as social normative and cultural recognition also differs between those cities. The more developed cities usually inhabitant more pro-social residents, NGOs, social media, and other stakeholders (Carlino, Chatterjee, & Hunt, 2007), which could enhance the local institutions that promote the local water eco-civilizations.

Table 2 Overall results on water ecological civilization of Laos' cities

City	Overall Score	Water Ecology	Water Security	Water Management	Water Culture
Vientiane	0.7539	0.3618	0.1647	0.1915	0.0358
Luang Prabang	0.7420	0.2881	0.2081	0.1785	0.0673
Savannakhét	0.6853	0.2528	0.2350	0.1472	0.0503
Pakse	0.5831	0.1732	0.0864	0.2241	0.0994
Thakhek	0.4940	0.2683	0.1240	0.0244	0.0773
Xam Nua	0.4276	0.0322	0.0662	0.2346	0.0945
Muang Phônsavan	0.3940	0.0232	0.0974	0.2094	0.0640
Muang Xay	0.3511	0.0522	0.0575	0.1679	0.0736
Vang Vieng	0.3465	0.1411	0.1204	0.0673	0.0177
Muang Pakxan	0.3464	0.0617	0.0597	0.1516	0.0735

Although Vientiane scores the highest in water ecology and overall scores, its performance (0.1915) in water management still falls far behind that of Xam Nua (0.2346), which performs poorly in water ecology (0.0322). Therefore, those cities should enhance their communication and connections, learn from each other and improve their weakness. The improvement of water eco-civilization should not just depend on water ecology; it relies more on the balance of those subsystems.

Discussion

In this research, we construct an evaluation indicator system for the water ecological civilization of cities in Laos based on the commonality of water eco-civilizations and the particularity of Laos' cities. Taking the top ten largest cities in Laos as an example, we evaluate and compare the development levels of water ecological civilizations in those cities. Draw on results analysis and comparison, and we majorly have two findings.

First, the development of water ecological civilization in major cities of Laos is quite unbalanced. The development level of water ecological civilization varies greatly by cities, not only in the overall development level but also in other aspects such as water ecology, water management, water culture, and water security. Also, the construction of water ecological civilization in major cities of Laos has its advantages and disadvantages, and there is no single city that could dominate. Different cities perform differently in each sub-system. Therefore, in the future, we can further promote exchanges and learning between cities and realize the overall development of water ecological civilization in major cities of Laos.

Second, in the construction of the water ecological civilization in Laos, policy-makers should not only focus on the development of water ecology but also should focus more on water security, water management, and water culture. The construction of water ecological civilization includes not only the construction of water ecology but also the development of water civilization, while the latter requires the participation of the entire society. Therefore, the Lao government must realize that the construction of water ecological civilization is not just a government action but requires the participation of other stakeholders such as news media, NGOs, citizens, and universities. Only by achieving coordinated development of water ecology, water security, water management, and water culture can Laos' water ecological civilization level be continuously improved.

Suggestions

The results of this research can be used to plan the prevention and correction of the use of water resources to maximize efficiency especially the measures for maintenance of water resources in urban areas. These are the roles of the government and the public sector that need to work together.

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