



# Assessing ecological literacy and its application based on linguistic ecology: a case study of Guiyang City, China

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## Abstract

To address the frequent emergence of ecological problems, ecology has intersected with various disciplines. From the perspective of linguistic ecology, ecological literacy is an important concept that combines the subjects of ecology and linguistics. It not only discusses ecological issues, but also establishes a linguistic framework. Here, we constructed a quantitative method of assessing ecological literacy from the perspective of linguistic ecology. Ecological literacy was divided into five parts: ecological knowledge literacy, ecological awareness literacy, ecological ethics literacy, ecological emotional literacy, and ecological behavioral literacy. Each of these was set with four quantitative indicators that were evaluated through eight questions. A case study was conducted to investigate the ecological literacy of the inhabitants of Guiyang City, one of China's top ten ecologically advanced cities. The results showed that the proposed assessment method was an effective way to evaluate the level of ecological literacy comprehensively. In the case analysis, the overall ecological literacy level of Guiyang inhabitants was relatively good, and the levels of the five specific dimensions of them in descending order were as follows: ecological ethics literacy, ecological emotional literacy, ecological awareness literacy, ecological knowledge literacy, and ecological behavioral literacy. The results of this study are conducive to the production of targeted ways to improve the level of ecological literacy for sustainable development.

**Keywords** Ecological literacy · Linguistic ecology · Environmental literacy · Sustainable development · Ecologically advanced city · Guiyang City

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## Introduction

Since the 1900s, with the accelerated development of the economy, science, and technology, human life has greatly improved. Meanwhile, it has also brought about many global ecological problems pertaining to population, resources, and the environment. In particular, the outbreak of coronavirus disease 2019 (COVID-19), which began at the end of 2019, has once again sounded the alarm regarding human attitudes and behavior toward nature. In the context of the tense relationship between humans and the natural environment, researchers in many countries and different fields have started looking at the surrounding world from an ecological perspective, re-examining the thoughts and behavior of humankind, and working hard to solve environmental problems. Thus, the phenomenon of so-called ecologicalization in contemporary science has formed many emerging interdisciplinary subjects related to ecology (Li and Yuan 1988), including environmental ecology (Jin 1992), human ecology (Wang 1998), urban ecology (Wu et al. 2014), and linguistic ecology

(Alexander and Stibbe 2014; Huang 2016). The key point is to study many problems in human production and life from the perspective of ecology or by using the principles of ecology.

It is crucial to our survival and development to establish integrity in the relationship between humans and nature. Therefore, we must understand life-sustaining ecosystems and their operating methods, while gaining ecological knowledge. This is the basis for ecological literacy, which plays an important role in the sustainable development of society. With the emergence of multiple negative factors, such as industrialization, urbanization, population growth, resource consumption, and the endangerment and extinction of species, the current epoch has been named the Anthropocene (Crutzen and Stoermer 2000; Steffen et al. 2007; Scholz 2011; Huang and Xiao 2017), signaling a series of changes to the relationship between humans and nature. People are generally worried that the overall level of ecological literacy in many countries and regions is insufficient to make effective decisions for an ecologically sustainable lifestyle. Although ecological knowledge and ecological literacy are only contributing factors to sustainable development, they are fundamental and cannot be replaced by other factors. This has prompted various countries and regions to assess the level of ecological literacy and promote research in this area.

Ecological literacy involves many factors, making its assessment especially complicated. In recent years, many researchers have developed ecological literacy assessment tools and applied them to research on middle school and secondary education (NAAEE 2011a, 2011b; Shen et al. 2020). At the same time, some researchers have focused on the ecological literacy of adults (Arcury 1990; McDaniel and Alley 2005; Davidson 2010; Pitman and Daniels 2016; Pitman et al. 2016, 2017). Other studies on ecological literacy have covered a more comprehensive age range, by including both adolescents and adults (Wang et al. 2017; Lin and Cai 2019). But because such studies cover a wider range of ages, the scope of other factors, such as regional selection, is usually relatively small.

In China, research on ecological literacy and the related characteristics of inhabitants in ecologically advanced cities is important because it is conducive to the generation and optimization of sustainable decisions. Here, we concentrated on ecological literacy in Guiyang City, China. We proposed an assessment method based on linguistic ecology. We applied the proposed method to a case study of the inhabitants in Guiyang. We asked three questions: (1) What does the term “ecological literacy” mean in the perspective of linguistic ecology? (2) How can ecological literacy be assessed in an efficient and meaningful way in China? (3) What can we learn from the case study of Guiyang City about the inhabitants’ ecological literacy level? These research questions are answered in the next two sections.

## Concepts and methods

### Linguistic ecology

In the expansion of ecology to the humanities, the combination of ecology and linguistics has formed an emerging discipline, called linguistic ecology or the ecology of language. From the perspective of ecology, the roots of linguistic ecology can be traced back to research on human ecology. Human ecology advocates the use of ecological methods to explore the relationship between humans and nature. Rusong Wang (1998), a well-known ecologist in China, described human ecology as the combination of ecology, sociology, economics, and other disciplines at different levels. Although these disciplines have different origins, they all involve the subject of the relationship between humans and nature, and they require the application of systematic, comprehensive, and evolutionary ecological methods.

Linguistic ecology emphasizes the influence of language on the sustainable relationship of life, including the relationships between language and humans, humans and other species, and humans and the physical environment. Linguistic ecology aims to reveal the interaction between language and the environment, mainly through the study of the ecological factors of language and the relationship between language and the ecological environment (Alexander and Stibbe 2014; Huang 2016), with the ultimate aim of enhancing ecological awareness and ecological literacy. This means that ecological philosophy is an important guiding factor. Linguistic ecology also refers to the problem of ecological thought. Such practices can serve as a guide to achieve agreement between knowledge and action, solving the ecological problems, and changing the ecological status quo.

### Ecological literacy

#### Literacy and environmental literacy

The term “literacy” first appeared in the late nineteenth century. It was originally exclusive to the fields of reading and writing and referred to the ability to read and write (Stibbe 2009). It was thus terminology that first pertained to linguistics. Since the Industrial Revolution, usage of the term “literacy” has gradually expanded. In the 1960s, a literate citizen was thought to have knowledge and capability in a particular field or fields, and to be able to take effective action on many complex issues facing society (McBride et al. 2013). Therefore, the term “literacy” has expanded to include knowledge of specific disciplines or problems, and it can now refer to one’s level of knowledge and capability in such fields. The terms “environmental literacy” and “ecological literacy” have since appeared in ecological research. Ecological literacy

evolved from environmental literacy, and these two concepts are inseparable.

The term “environmental literacy” was first used by Charles Roth in research on the topic of understanding environmentally literate citizens (Roth 1968; Roth 1992; Morrone et al. 2001; O’ Brien 2007). But attention to the issue began in the early 1960s. Rachel Carson questioned the abnormal phenomena of the natural environment in America in her book, "Silent Spring" (Carson 1962). At present, the most widely used definition of environmental literacy is the one proposed by the NAAEE, which indicated that environmental literacy includes awareness and concern about the environment and environmental issues, as well as knowledge, skills, and the motivation to solve current related problems and prevent new problems (NAAEE 2000/2004, 2011a, 2011b; Scholz 2011). Although this research does not discuss the content and framework of environmental literacy directly, environmental literacy is a broader concept. Ecological literacy is a secondary concept, and it is also the development of the connotation of environmental literacy. Ecological literacy provides the necessary ecological foundation for environmental literacy.

**Concepts and framework of ecological literacy in linguistic ecology**

Ecological literacy is a relatively abstract concept, and scholars differ in understanding the concept and framework of ecological literacy. After Paul Risser pointed out in 1986 that America had certain shortcomings in scientific literacy, especially ecology-based literacy, many researchers began discussing the concept of ecological literacy (Risser 1986; Orr 1992; Berkowitz et al. 2005; Coyle 2005; Bruyere 2008; McBride et al. 2013; Pitman and Daniels 2016; Huang and Zhao 2019; Huang and Ha 2021). Coyle (2005) proposed a visual pyramid to discuss personal ecological literacy. The pyramid is composed of three levels from bottom to top: environmental knowledge, environmental attitudes, and ecological literacy. Ecological literacy is at the top of the pyramid because it is developed through personal environmental knowledge, values, and actions taken in response to environmental problems. Other researchers have divided ecological literacy into different categories: ecological knowledge, ecological attitudes, and ecological behavior (Bruyere 2008); or ecological knowledge literacy, ecological ethics literacy, ecological emotional literacy, and ecological behavioral literacy (Huang and Zhao 2019).

We submit that ecological awareness is another important part of the framework of ecological literacy in linguistic ecology. Thus, we propose the following five factors: (1) ecological knowledge literacy; (2) ecological awareness literacy; (3) ecological ethics literacy; (4) ecological emotional literacy; and (5) ecological behavioral literacy. In essence, ecological

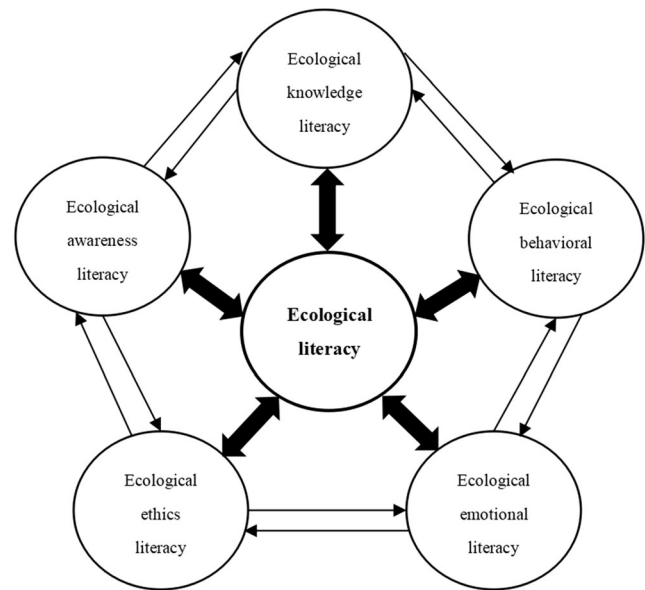


Fig. 1 Formation process of ecological literacy

literacy refers to the acquisition and dissemination of ecological knowledge, enhancing awareness of ecological protection, and ultimately guiding the sustainable development of ecological behavior to achieve a higher level of ecological literacy. In other words, the five dimensions of ecological literacy comprise a unified whole, and each of them is almost equally important theoretically (Figure 1). They influence each other interactively. Of these, ecological knowledge literacy is foundational, ecological awareness literacy indicates the direction of action, ecological ethics literacy emphasizes moral standards, ecological emotional literacy is the internal driving force, and ecological behavioral literacy is the ultimate goal.

People acquire ecological knowledge through various channels such as national or local policies, social-level publicity and education, family guidance, and gradually formed ecological knowledge literacy. As ecological problems become more and more serious, ecosystems continue to be destroyed, and natural disasters frequently occur, people will have a sense of crisis and indirectly realize the importance of harmonious coexistence between humans and the natural environment. Through their own ecological knowledge, they will enhance their awareness and emotions regarding environmental protection. With strong ecological awareness, people will also be restricted by ecological ethics and morals, and their ecological awareness literacy will be regulated. Moreover, people affected by ecological ethics will continue to judge their own psychological direction based on their own emotional attitudes or ecological philosophy. Positive emotional factors will form a certain ability for ecological emotional literacy, which will provide a strong motivation for ecological behavior. Under the comprehensive effects of various national and regional regulations, as well as their own

ecological knowledge, ecological awareness, ecological ethics, and ecological emotional literacy, people will carry out their own ecological protection behavior and form their own ecological behavioral literacy. Ecological literacy levels will thus be improved. After ecological literacy levels improve, further self-reflection is needed to continue to strengthen the acquisition of ecological knowledge, the enhancement of ecological awareness, the consolidation of ecological ethics, and the improvement of ecological emotion and ecological behavior. This will be more conducive to the development of ecological society, and it will produce a higher level of ecological literacy to realize the effect of ecological literacy on ecological knowledge literacy.

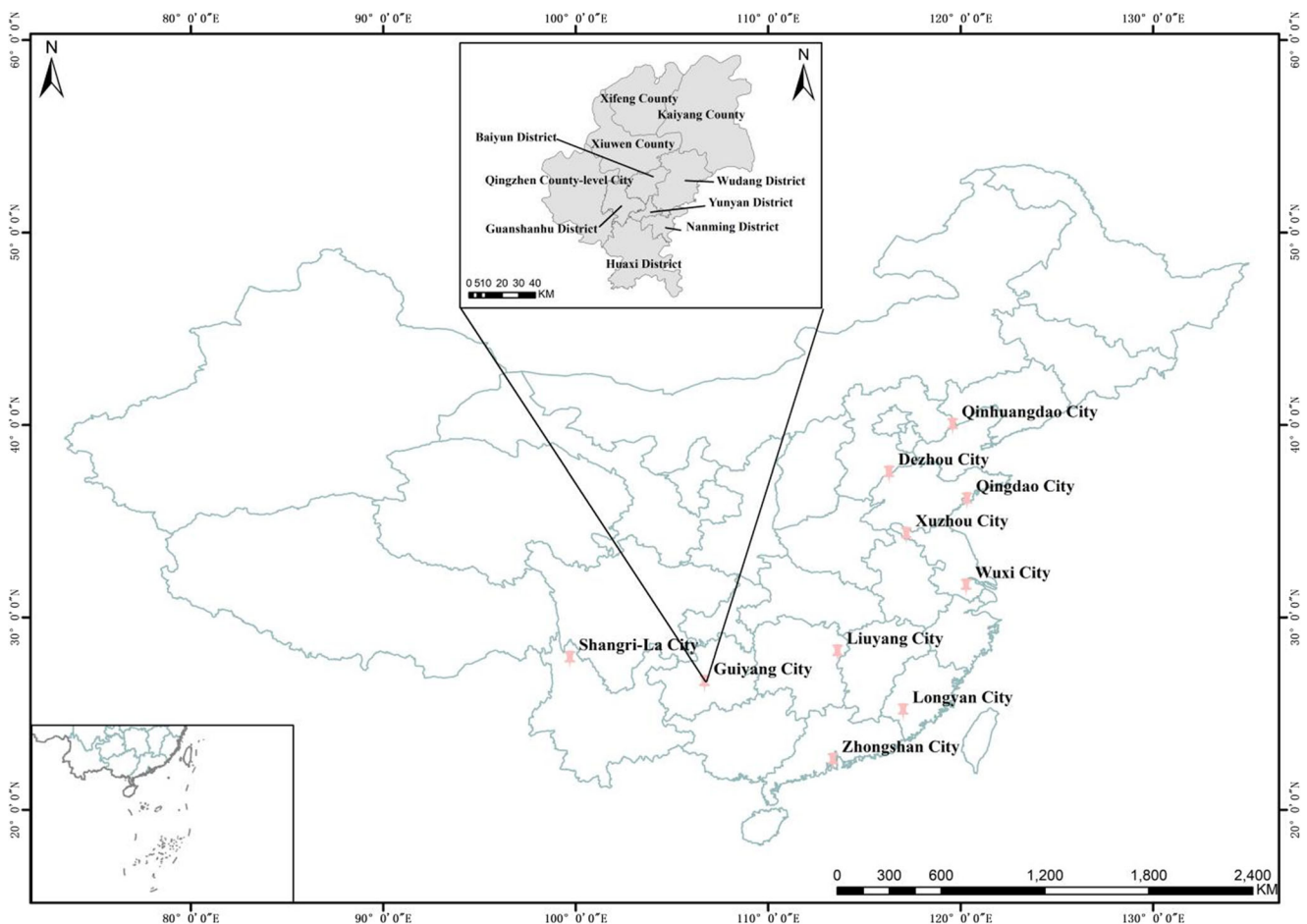
## Study area

In July 2015, the first National Ecological Civilization Construction Summit Forum and the City and Scenic Area Ecological Civilization Achievement Conference was held in Beijing, China. The theme of the meeting was “Promoting the Construction of Ecological Civilization and Building a

Beautiful Green Home”. The following cities in China were named the most ecologically advanced (i.e., “ecologically civilized”): Longyan City, Zhongshan City, Guiyang City, Qinhuangdao City, Liuyang City, Wuxi City, Xuzhou City, Dezhou City, Qingdao City, Shangri-La City (Figure 2).

Combining the actual situation of the surveyed cities and the feasibility of the survey process, we selected Guiyang City as a case study. The participants were local inhabitants, and according to the overall sampling statistics method, an effective sample size of inhabitants was randomly selected for the research.

Guiyang City is the capital of Guizhou Province. It is located in the southwestern region of China and in the center of Guizhou Province, at  $106^{\circ}07'–107^{\circ}17'$  E,  $26^{\circ}11'–26^{\circ}55'$  N (Figure 2). It is the political, economic, cultural, scientific, educational, and transportation center of Guizhou Province. The construction of ecological civilization in Guiyang City started early, beginning with the completion of two forest belts around the city in the 1980s. In 2002, it was designated by the State Environmental Protection Administration as the country’s first pilot unit for an ecological city with a circular



**Fig. 2** Distribution of China’s top ten ecologically advanced cities and administrative district division of Guiyang City

economy. In 2009, there was an ecological civilization conference held in Guiyang City, and this was upgraded to the Guiyang International Forum on Ecological Civilization in 2013, the only national-level international forum on ecological civilization in China at that time. In 2018, Guiyang City was listed among the “2018 Top Ten Cities for Green Development and Ecological Civilization Construction”.

As of the end of 2018, Guiyang City has a land area of 8043.37 km<sup>2</sup> and a forest coverage rate of 39.19%, including six districts, three counties, and one county-level city (Figure 2). The permanent population (i.e., inhabitants for 6 months or longer) is 4,881,900, including an urban population of 3,682,400 and a rural population of 1,199,500, covering more than 30 ethnic minorities. We conducted a sample survey of the inhabitants of Guiyang City, taking six districts, three counties, and one county-level city in Guiyang City as the sampling level, and stratifying the inhabitants of each district (city, county) according to a certain proportion. Random sampling was used to reflect the overall level of the ecological literacy of the inhabitants in Guiyang City. One issue that needs special attention here is the definition of the research object “inhabitants”. In the survey process, combined with the statistics of the permanent population in the "Guiyang Statistical Yearbook 2019", the “inhabitants” involved in this study refer to the permanent inhabitants of Guiyang City, that is, the people who had lived in Guiyang City for 6 months or longer before the start of the survey (i.e., before September

30th, 2020) and who lived in Guiyang City throughout the survey. Other populations were not within the scope of the study.

### Questionnaire design

#### Design steps

To design the questionnaire, we proceeded as follows. The first step was to determine the conceptual framework and dimensions of “ecological literacy,” including ecological knowledge literacy, ecological awareness literacy, ecological ethics literacy, ecological emotional literacy, and ecological behavioral literacy as the first-level indicators of ecological literacy. An analytic hierarchy process in statistics requires that the indicators considered can be investigated and measured in actual situations; this required us to construct a series of decomposition content reflecting the force and influence of the elements, and to analyze the decomposition content. This content is described in detail (Xiao and Fan 2011). Therefore, within the scope of each first-level indicator, after discussions with five Chinese experts and scholars in the field of ecology, especially in the field of linguistic ecology, we formulated second-level indicators under the five first-level indicators of the concept of ecological literacy in this study (Table 1). The weight of each first-level indicator and second-level indicator was the same, and they were regarded as equally important. It

**Table 1** Second-level indicators of ecological literacy

First-level indicators	Second-level indicators
Ecological knowledge literacy (EKNL)	EKNL1-Ecosystem knowledge
	EKNL2-Knowledge of damage to the ecological environment
	EKNL3-Knowledge of the relationship between humans and nature
	EKNL4-Ecological and environmental protection knowledge
Ecological awareness literacy (EAWL)	EAWL1-Ecological environmental protection behavior subject consciousness
	EAWL2-Ecological environmental protection value awareness
	EAWL3-Awareness of the severity of current ecological and environmental problems
	EAWL4-Making judgments on the ecological environment damage encountered
Ecological ethics literacy (EETL)	EETL1-Correctly recognizing the relationship between humans and nature
	EETL2-The ethics and morality of protecting the ecological environment
	EETL3-Affirming the role of nature
	EETL4-Respecting and cherishing all living things
Ecological emotional literacy (EEML)	EEML1-Awe of the natural environment
	EEML2-Love for the natural environment
	EEML3-Sensitivity to natural environment protection
	EEML4-Ability to take responsibility for ecological and environmental issues
Ecological behavioral literacy (EBEL)	EBEL1-Daily practice of environmental protection
	EBEL2-Participation in environmental education activities
	EBEL3-Scientific environmental protection skills and methods
	EBEL4-Positive influence on the environmental protection behavior of others

means the number of second-level indicators in each dimension has to be equal. In a similar way, the number of survey questions in each second-level indicator has also to be equal. Taking into account the actual situation of the questionnaire survey, too many or too few survey questions may affect the effectiveness of the survey results. There are four second-level indicators under each first-level indicator finally. For this study, such a number (four second-level indicators with eight questions) not only guarantees the comprehensiveness of the survey contents, but also does not reduce the effectiveness of the participants' answers due to too many survey questions.

During the second step, we devised specific questions in the questionnaire under each second-level indicator. The topics were selected with reference to the "China Urban Public Environmental Awareness Questionnaire" developed by the Public Environmental Awareness Research Group of the State Environmental Protection Administration and the Public Environmental Awareness Research Group of the Chinese Academy of Social Sciences in 2005, and an effective survey developed by Pitman and Daniels (2016) of the University of South Australia on ecological literacy level assessment scale and questionnaire questions. At the same time, combined with China's ecologically advanced cities and current heated issues regarding the environment, as well as the specific situation in Guiyang City, the first draft of the research questionnaire was formed. Although part of the questionnaire design draws on preliminary research results, due to the quantitative assessment of the ecological literacy level, there is currently no unified assessment scale. Therefore, we designed most of the content in this step.

The third step was to revise and improve the first draft of the questionnaire to form the final version of the questionnaire. This step involved two statistical forecast stages. After the second forecast stage, we tested the reliability of the questionnaire within an acceptable range before proceeding to the actual measurement stage. Subsequently, the forecast respondents' opinions and suggestions on the content of the questionnaire were collected, and the content of the questionnaire was carefully analyzed and improved. Finally, after issuing the questionnaire and collecting responses during the actual measurement phase, we examined the total reliability of the questionnaire in detail, as well as the validity of the scale, to ensure the authentic validity of the survey data for data analysis.

### Topic structure

The final version of the questionnaire contained 60 survey questions. Of these, there were 40 questions on ecological literacy. In what follows, we focus on discussing this part. The ecological literacy survey was designed to assess the level of ecological literacy of the inhabitants in Guiyang City, and the scores needed to be measured quantitatively. The measurement part of the ecological literacy level score of this study was

designed in the form of a five-point Likert scale (five-point scoring). There were 40 survey questions, and each question had five options (Appendix). The options were sorted in ascending or descending order. This could better distinguish the nuances of the respondent's ecological literacy level and thus produce more accurate measurement results. The minimum score that a respondent could get in this part was 40 points, and the maximum score was 200 points. Specifically, there were five topics: ecological knowledge, ecological awareness, ecological ethics, ecological emotion, and ecological behavior. Each topic included eight sub-topics to examine the corresponding second-level indicators of ecological literacy.

### Reliability and validity

The reliability of the questionnaire, that is, whether the results of the questionnaire were internally consistent, was evaluated by Cronbach's Alpha reliability coefficient. Normally, a Cronbach's Alpha above 0.70 ( $\alpha \geq 0.70$ ) indicates that the questionnaire has a certain degree of credibility (Cortina 1993; Gleim and Gliem 2003), and the higher the value, the more reliable the data results, and the greater the confidence. But if the Cronbach's Alpha is between 0.60 and 0.70 ( $0.60 \leq \alpha < 0.70$ ), the result of reliability is also acceptable to the study (Zhou 2017: 44). Two reliability tests were carried out in this study. The reliability of 97 samples in the prediction phase was tested, and the Cronbach's Alpha was 0.872 (overall ecological literacy level). Then, we tested all 494 samples used for the analysis. The Cronbach's Alpha was 0.888 (overall ecological literacy level), and the reliability coefficients of all five dimensions were also above 0.60. Its internal consistency (the questionnaire) was thus within an acceptable range, indicating high credibility suitable for further statistical analysis of data.

The validity of a questionnaire mainly refers to the degree of validity of the questionnaire measurement results. The higher the validity of the questionnaire, the closer the collected data are to the actual purpose of the survey. Generally, the validity of a questionnaire includes content validity and structural validity (Chai 2010). Specifically, the content validity of a questionnaire is combined with expert judgments, and structural validity refers to the construction validity, which mainly detects the structure of a questionnaire by the factors of the Estimate, CR, and AVE. The evaluation criteria for these factors were set as Estimate above 0.45, CR above 0.60, AVE above 0.36 (Wu 2010, 2013; Wan et al. 2015). Because the dimensions of our questionnaire are discussed in detail in the previous sections, that is, because the dimensions of the questionnaire are known, the structural validity of the questionnaire was evaluated by confirmatory factor analysis using AMOS 23.0 software, to ensure that the questionnaire had explanatory power. After testing this, the content validity and structural validity (Estimate: 0.67; CR: 0.95; AVE:

0.49) of our questionnaire were found to be within the acceptable range.

## Data collection

We adopted a combination of network distribution and paper distribution; network distribution was the main method, and paper distribution was supplementary. Online distribution involved a questionnaire network platform, with the questionnaire sent and received by e-mail; paper distribution involved using centralized fixed-point distribution and mailing. We combined the total permanent population of Guiyang City and the population of each district (city, county) in the survey area and decided to use the 10 districts (cities, counties) of Guiyang City as a benchmark, with random stratification according to a ratio of 1:10,000 sampling.

Therefore, at least 494 copies of the questionnaire needed to be distributed during the survey process of this study. The survey of participants was completely based on the principle of voluntary participation, and the survey results were anonymous. However, a minimum of 494 questionnaires were needed to guarantee the validity. In order to ensure that the minimum effective sample size drawn met the needs of the survey, we increased the number of questionnaire surveys by 10% on the basis of the minimum sample size. Thus, we needed to distribute at least  $494 \times (1 + 10\%) = 543.4$  (take 544) questionnaires. Hopkins et al. (1990) pointed out in related research that subjects who fill out questionnaires faster do not necessarily answer interview questions better, and the evaluation process should not consider speed. Thus, the speed of answering has a negligible relationship with the understanding of knowledge. Therefore, we did not have strict requirements on the answering speed of the questionnaire, although it usually took about 10–15 min to complete. The duration of the entire survey was about 6 weeks in October and November of 2020.

In this study, a total of 600 questionnaires were distributed and 591 were collected, of which 539 were valid questionnaires. Then, in accordance with the above-mentioned standard of 494 samples and the number of samples drawn in each administrative region, questionnaires that exceeded the sample size were randomly eliminated. Thus, 494 valid questionnaires were summarized, numbered, and entered into a Microsoft Excel table one-by-one.

## Data analysis

We analyzed the collected data using SPSS 25.0. To do so, we analyzed the overall ecological literacy level of the inhabitants in Guiyang City. The data from this part were mainly obtained from the score statistics of the 40 questions in the questionnaire, including the normality test of the questionnaire, descriptive statistics of the overall level analysis, and descriptive

statistical analysis and correlation analysis of the five dimensions of ecological literacy. Then, we conducted descriptive statistical analysis and a brief analysis of the second-level indicators in the five dimensions of ecological knowledge literacy, ecological awareness literacy, ecological ethics literacy, ecological emotional literacy, and ecological behavioral literacy. This was done to understand the ecological literacy of the inhabitants of Guiyang at a micro-level so that we could propose targeted strategies to improve the level of ecological literacy.

## Results and discussion

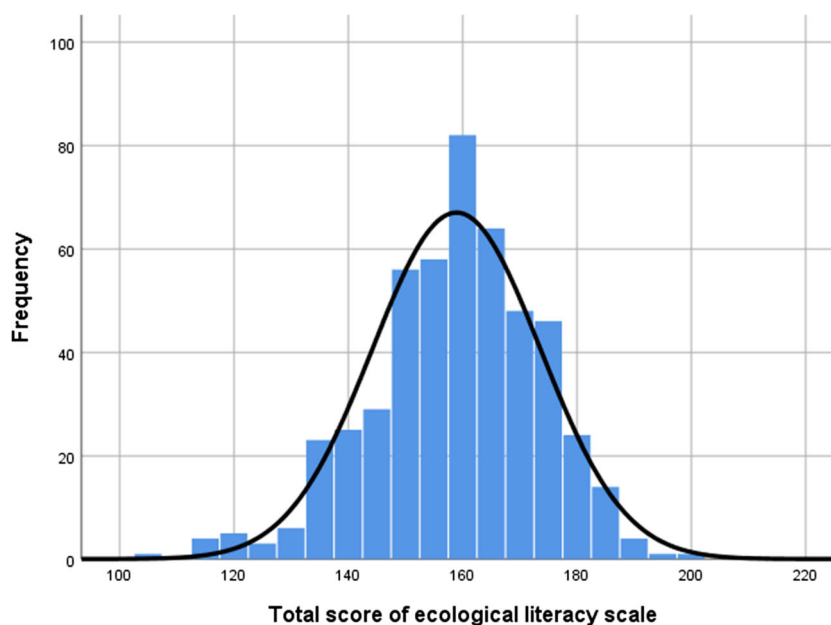
### Overall ecological literacy level

The overall ecological literacy level of the participants is the total score from the 40 questions in the questionnaire. The descriptive statistics of SPSS 25.0 show that the total ecological literacy measurement scores of the 494 Guiyang inhabitants surveyed were normally distributed on the whole. The average score was 158.91 points ( $158.91 \pm 14.693$ , 79.46%), with a minimum of 105 points, and a maximum of 199 points (Figure 3). From the score rate of the scale here, it can be seen that the overall ecological literacy level of the inhabitants of Guiyang City was relatively good. The average score rate of the questionnaire was close to 80%, which was at the middle and upper levels.

In the descriptive statistical analysis of the five first-level indicators of the ecological literacy level of Guiyang inhabitants, we found that there were developments in the internal structure of the five dimensions of ecological knowledge literacy, ecological awareness literacy, ecological ethics literacy, ecological emotional literacy, and ecological behavioral literacy. For the problem of imbalance, there were big differences between different dimensions (Table 2), but the overall average score rate was higher. Each dimension consisted of eight scale questions. That is, the range of scores that the respondent could obtain was [8, 40] in each dimension.

From Table 2, it can be seen that, among the ecological literacy levels of Guiyang inhabitants, the level of ecological ethics literacy was the highest ( $36.41 \pm 4.010$ ), and their average scoring rate reached 91.03%; the level of ecological emotional literacy was slightly lower than that of ecological ethics ( $35.35 \pm 3.758$ ), and ecological awareness literacy was lower ( $33.21 \pm 3.918$ ). The average scores of the interviewees were relatively low in terms of ecological knowledge literacy ( $29.11 \pm 5.191$ ) and ecological behavioral literacy ( $24.83 \pm 4.775$ ), but their average score rates were still higher than 60% (72.78% and 62.08%, respectively). The average score of these two dimensions was significantly lower than that of the other three dimensions, but from a macro point of view, the levels of these two

**Fig. 3** Total score histogram of ecological literacy in Guiyang City



dimensions were still within a good range. This showed that the inhabitants of Guiyang City had a high level of ecological literacy, especially in terms of ecological ethics, ecological emotion, and ecological awareness. However, there is room for improvement in the possessing of ecological knowledge and the ability and level of implementing ecological literacy in specific actions.

Subsequently, we conducted a bi-variate correlation analysis of the relationship among each dimension of ecological literacy (Table 3), with the purpose of exploring the correlation between each dimension and the other four dimensions. Owing to the uneven levels of all five dimensions of ecological literacy, the correlation analysis between each two dimensions can help to improve a certain specific dimension level, relying on whether they are related, whether the relationship is positive or negative, and the strength of the correlation with other dimensions. Based on a variety of statistical data, the overall situation was coordinated, and solutions were proposed in many aspects.

Table 3 shows that there was no direct correlation between ecological ethics literacy and ecological behavioral literacy ( $P$

$= 0.500 > 0.05$ ). There was a significant correlation between the other four dimensions ( $P < 0.05$ ), and it was a significant correlation at the 0.01 level. A closer look at the Pearson's correlation coefficients shows that they were all positive numbers, so that all dimensions with correlation were positive correlations. First, the correlation coefficient between ecological ethics literacy and ecological emotional literacy was the largest ( $R = 0.617^{**}$ ,  $0.6 < R \leq 0.8$ ), indicating that there was a significant positive and strong correlation between ecological ethics literacy and ecological emotional literacy. Second, the correlation coefficient between ecological awareness literacy and ecological ethics literacy ( $R = 0.597^{**}$ ,  $0.4 < R \leq 0.6$ ), and between ecological awareness literacy and ecological emotional literacy ( $R = 0.514^{**}$ ,  $0.4 < R \leq 0.6$ ) was only lower than the correlation coefficient between ecological ethics literacy and ecological emotional literacy. In particular, the correlation coefficient between ecological awareness literacy and ecological ethics literacy was very close to 0.6. Therefore, ecological awareness literacy and ecological ethics literacy had a significant moderate correlation, and ecological awareness literacy and ecological emotional literacy had a significant moderate correlation, too. Third, there was a significant positively weak correlation between each dimension of ecological literacy. The correlation coefficient ( $0.2 < R \leq 0.4$ ) from high to low was as follows: ecological emotional literacy and ecological behavioral literacy ( $R = 0.365^{**}$ ), ecological knowledge literacy and ecological behavioral literacy ( $R = 0.338^{**}$ ), ecological knowledge literacy and ecological emotional literacy ( $R = 0.296^{**}$ ), ecological knowledge literacy and ecological awareness literacy ( $R = 0.288^{**}$ ), and ecological knowledge literacy and ecological ethics literacy ( $R = 0.209^{**}$ ). Finally, there was a significant but very low positive correlation between a group of dimensions ( $0 \leq R \leq 0.2$ ), namely, the correlation coefficient

**Table 2** Descriptive statistical analysis of five dimensions of the ecological literacy levels of Guiyang inhabitants

	Mean	Standard deviation	Minimum	Maximum
EKNL	29.11	5.191	8	40
EAWL	33.21	3.918	18	40
EETL	36.41	4.010	18	40
EEML	35.35	3.758	22	40
EBEL	24.83	4.775	12	40



**Table 3** Correlation analysis of the five dimensions of ecological literacy levels of Guiyang inhabitants

		EKNL	EAWL	EETL	EEML	EBEL
<b>EKNL</b>	Pearson’s correlation coefficient	1	.288**	.209**	.296**	.338**
	Sig. (two-tailed)		.000	.000	.000	.000
<b>EAWL</b>	Pearson’s correlation coefficient	.288**	1	.597**	.514**	.138**
	Sig. (two-tailed)	.000		.000	.000	.002
<b>EETL</b>	Pearson’s correlation coefficient	.209**	.597**	1	.617**	.030
	Sig. (two-tailed)	.000	.000		.000	.500
<b>EEML</b>	Pearson’s correlation coefficient	.296**	.514**	.617**	1	.365**
	Sig. (two-tailed)	.000	.000	.000		.000
<b>EBEL</b>	Pearson’s correlation coefficient	.338**	.138**	.030	.365**	1
	Sig. (two-tailed)	.000	.002	.500	.000	

Note: The number of cases is 494

"\*\*" means it is at the 0.01 level (two-tailed) and that the correlation is significant

between ecological awareness literacy and ecological behavioral literacy ( $R = 0.138^{**}$ ).

During the development of ecologically advanced cities, we should focus on acquiring ecological theory and the practice of ecological actions for the ecological literacy level of the inhabitants of Guiyang City. From the correlation coefficients related to the two dimensions of ecological knowledge literacy and ecological behavioral literacy in Table 3, it can be seen that the coefficients related to them in the five dimensions are in the range of weak to very low correlation. This implies that, in the process of improving ecological knowledge literacy and ecological behavioral literacy, while taking other dimensions into account to improve both literacy indirectly, we must consciously focus on themselves. The inhabitants, who have strong ecological awareness and social responsibility, are able to strengthen their ecological knowledge, so that they can improve their ecological knowledge level. Finally, they can transform their strong ecological knowledge and ecological awareness into practice, and practice ecological literacy in their actions. Moreover, they can influence other inhabitants to become more ecologically literate.

### Specific analysis of the five dimensions

#### Ecological knowledge literacy level

Among the four factors of the second-level indicators of ecological knowledge literacy, the range of scores that respondents could obtain in the two questions set by each factor was [2, 10]. The inhabitants of Guiyang City scored highest for “knowledge of the relationship between humans and nature” ( $7.98 \pm 1.481$ ). For “ecological and environmental protection knowledge” ( $7.13 \pm 1.471$ ) and “knowledge of damage to the ecological environment” ( $7.12 \pm 1.659$ ), the difference between the average scores obtained was relatively small. Both were lower than

the score for “knowledge of the relationship between humans and nature”. The average score of “ecosystem knowledge” of Guiyang inhabitants ( $6.89 \pm 1.700$ ) was above 60%, indicating that Guiyang inhabitants still have a good grasp of “ecosystem knowledge”. The average score of “ecosystem knowledge” was the only factor in the second-level indicators of ecological knowledge literacy that had a score lower than 70%.

It can be seen from Table 4 that the inhabitants of Guiyang City had a higher ability and better grasp of the four factors of the second-level indicators of ecological knowledge literacy, especially in “knowledge of the relationship between humans and nature”. This indicated that the participants attach great importance to all aspects of ecological knowledge. However, Guiyang inhabitants still had certain weaknesses in their grasp of “ecosystem knowledge”. This was because ecosystem knowledge is professional theoretical knowledge of ecology, and it was rare for Guiyang inhabitants to study or work in the field of ecology. It is difficult for them to acquire ecological knowledge. But in fact, the processes, functions, and components of the ecosystem, as well as the collection of processes that contribute to the planet, are all included in the broader concept of nature (Maller et al. 2006; Pitman and Daniels 2020). Therefore, ecosystem knowledge was very important for everyone. We must pay special attention to the concepts and connotations of sustainable development and ecosystem

**Table 4** Descriptive statistical analysis of second-level indicators of ecological knowledge literacy of Guiyang inhabitants

	Mean	Standard deviation	Minimum	Maximum
<b>EKNL1</b>	6.89	1.700	2	10
<b>EKNL2</b>	7.12	1.659	2	10
<b>EKNL3</b>	7.98	1.481	2	10
<b>EKNL4</b>	7.13	1.471	2	10

services to promote the sustainable development of human society (Zhao et al. 2020). In the process of cultivating and improving the level of ecological knowledge literacy, it was necessary to pay attention to this aspect of ecological knowledge in order to promote the overall ecological knowledge literacy of Guiyang inhabitants.

### Ecological awareness literacy level

Among the eight questions considered for ecological awareness literacy, the range of scores that the inhabitants of Guiyang City could obtain in the two questions of each second-level indicator was [2, 10]. The respondents scored higher on average in this part than for the ecological knowledge literacy part. Only the average score rate ( $7.21 \pm 1.571$ ) of the second-level indicator of “awareness of the severity of current ecological and environmental problems” was below 80%. The average score of “ecological environmental protection value consciousness” was the highest ( $9.11 \pm 1.254$ ). Meanwhile, the participants’ understanding was relatively good in terms of “making judgments on the ecological environmental damage encountered” ( $8.88 \pm 1.385$ ) and “ecological environmental protection behavior subject consciousness” ( $8.01 \pm 1.456$ ).

The descriptive statistical analysis results of the second-level indicators of ecological awareness literacy in Table 5 showed that the level of ecological awareness literacy of Guiyang inhabitants is relatively good, and most inhabitants realize the value of ecological environmental protection. At the same time, many inhabitants could make effective judgments when encountering eco-environmental damage. This was due to the correlation between ecological awareness literacy and ecological ethics literacy ( $0.597^{**}$ ), and ecological emotional literacy ( $0.514^{**}$ ). This was affected and restricted by ecological ethics literacy and ecological emotional literacy. However, ecological awareness is basically formed by good ecological education among the inhabitants of Guiyang; only education can truly change people’s consciousness (Huang and Zhao 2019). If the ecological awareness of the inhabitants of Guiyang City is to be improved, the focus should be on two aspects: “ecological environmental protection behavior subject consciousness” and “awareness of the severity of current

ecological and environmental problems”. In particular, the index of “awareness of the severity of current ecological and environmental problems” still needs to be taken seriously. We have to allow more inhabitants to work hard to maintain the surrounding living environment on the basis of being aware of the severity of the current ecological problems through further publicity and education. The construction of ecological civilization in Guiyang City was relatively good, but there were still certain ecological problems. Our process of consciously maintaining or optimizing the ecological environment of Guiyang City can nurture and drive other urban inhabitants to realize the seriousness of ecological problems and jointly seek solutions.

### Ecological ethics literacy level

The consideration of the ecological ethics level of Guiyang inhabitants comprised eight questions, and the fluctuation range of each second-level indicator in scores was [2, 10] theoretically. The average score of the four factors of ecological ethics literacy was relatively high, and the score ratio was above 85%. The score ratios for “affirming the role of nature” ( $9.38 \pm 1.092$ ) and “respecting and cherishing all living things” ( $9.36 \pm 1.073$ ) reached more than 90%, and the difference in the scores between the two was small. In contrast, the average scores of “the ethics and morality of protecting the ecological environment” ( $8.89 \pm 1.422$ ) and “correctly recognizing the relationship between humans and nature” ( $8.78 \pm 1.417$ ) were low but still higher than many other second-level indicators factors.

Table 6 shows that the status of the ecological ethics of the inhabitants of Guiyang City was relatively good in general. Among the four factors, the minimum score for “affirming the role of nature” was 3 points, and the minimum score for the other three factors was 4 points. The maximum scores for these factors were all full marks. From this perspective, the inhabitants of Guiyang City had a high level of ecological ethics, mainly influenced by the development of ecological ethics in China. In China, ecological ethics and environmental ethics are used in parallel, and their development has gone through three research stages: the 1970s was the incubation stage, the 1980s was the exploratory stage, and the 1990s was

**Table 5** Descriptive statistical analysis of second-level indicators of ecological awareness literacy of Guiyang inhabitants

	Mean	Standard deviation	Minimum	Maximum
EAWL1	8.01	1.456	3	10
EAWL2	9.11	1.254	3	10
EAWL3	7.21	1.571	3	10
EAWL4	8.88	1.385	2	10

**Table 6** Descriptive statistical analysis of second-level indicators of ecological ethics literacy of Guiyang inhabitants

	Mean	Standard deviation	Minimum	Maximum
EETL1	8.78	1.417	4	10
EETL2	8.89	1.422	4	10
EETL3	9.38	1.092	3	10
EETL4	9.36	1.073	4	10

the birth and rapid growth stage (Yu et al. 2019). However, Chinese traditional culture contains a wealth of environmental ethics, such as the principle of “one yin and one yang is the Tao” in Yi-ology, the ethical wisdom of the “innateness of all things” and “the harmony between humans and nature” in Confucianism, the ethical ideas of “Tao to follow nature” and “rule by doing nothing” in Taoism, and the Buddhist ethical concept that “all beings are equal” (Yu et al. 2019). In this study, the penetration of these ecological ethics gradually formed the ecological ethics literacy of Guiyang inhabitants. If the level of ecological ethics continues to improve, the focus should be on the improvement of “the ethics and morality of protecting the ecological environment” and “correctly recognizing the relationship between humans and nature”. For individuals, the formation of ecological ethics and moral concepts is a long process. One way to improve this is to integrate ecological education with ecological knowledge, so that people can systematically master the theory of ecological ethics and clearly understand the relationship between humans and nature for guiding practice. This includes adhering to the “universal symbiosis” in deep ecology and maximizing the “symbiosis phenomenon” (Naess 1989; Huang and Zhao 2019). But from the macro-level of ecological literacy, people can focus on other relatively low levels of ecological literacy on the basis of maintaining the level of ecological ethics literacy to ensure that the overall level of ecological literacy is steadily improved.

**Ecological emotional literacy level**

The consideration of the level of ecological emotional literacy is also reflected by the eight questions under the four second-level indicators. The range of scores that respondents could obtain in each indicator was [2, 10] theoretically. The average score ( $9.43 \pm 0.980$ ) for “awe of the natural environment” of the respondents in ecological emotional literacy was the highest average score among the 40 questions in the entire scale, and the standard deviation fluctuated little. The score ratio was close to 95%. At the same time, this item was the only element among all scale questions that had a minimum of 5 points. The average score level of the other three factors was above 80%, in order from high to low: “love for the natural

environment” ( $9.17 \pm 1.154$ ), “ability to take responsibility for ecological and environmental issues” ( $8.66 \pm 1.282$ ), and “sensitivity to natural environment protection” ( $8.09 \pm 1.349$ ).

Through the descriptive statistical analysis in Table 7, we relied on the questionnaire data of the second-level indicators of Guiyang inhabitants’ ecological emotional literacy to further demonstrate the respondents’ ecological literacy levels in this dimension. The overall level of this part is still high, due to the good natural environment in Guiyang City. As stated in Sect. 2.3, Guiyang’s forest coverage rate was 39.19%, with beautiful mountains and clear waters. There are many natural landscapes for inhabitants to experience, e.g., Huaxi National Urban Wetland Park, Hongfeng Lake Scenic Area, Nanjiang Grand Canyon, and Qianling Mountain Park. When discussing the development of the ecological literacy of children in forest parks, some researchers point out that training children in forest parks will allow them to use all their senses to observe and acquire meaningful situations in the natural world. They will get sense of belonging and become ecologically literate (Hammarsten et al. 2018). Therefore, among the inhabitants of Guiyang City, children will stimulate ecological emotion under the guidance of their parents and teachers, while adults will generate ecological emotions based on their own experiences and perception of nature. Over time, they will subconsciously develop respect and love for nature. However, they have been living in areas with a good ecological environment and are facing fewer ecological problems, making the inhabitants relatively insensitive to natural environmental protection issues. Therefore, they might not take the initiative to be responsible for environmental problems; this needs to be improved. Guiyang inhabitants can improve their ecological emotional literacy level in two aspects: “sensitivity to natural environment protection” and “ability to take responsibility for ecological and environmental issues”. This important improvement process can be achieved by outdoor education, especially in terms of the judgment and perception of current environmental problems, which will increase the sensitivity to the natural environment. Responsibility training in education can enable the inhabitants to develop a sense of social responsibility that emerges spontaneously. But objectively speaking, the lowest score of the participants on these two factors was 4 points, and the highest score was 10 points, indicating that the participants were basically qualified in the mastery of these two factors and have a good emotional state regarding ecological problems. In the process of optimizing the overall level of ecological literacy, it is also possible to temporarily focus on other dimensions.

**Table 7** Descriptive statistical analysis of second-level indicators of ecological emotional literacy of Guiyang inhabitants

	Mean	Standard deviation	Minimum	Maximum
EEML1	9.43	0.980	5	10
EEML2	9.17	1.154	3	10
EEML3	8.09	1.349	4	10
EEML4	8.66	1.282	4	10

**Ecological behavioral literacy level**

Among the four second-level indicators of Guiyang inhabitants’ ecological behavioral literacy, each indicator was examined by two scale questions, and the fluctuation range of the

score was [2, 10]. The average scores of the second-level indicators of ecological behavioral literacy were low. Only the average score rate ( $8.59 \pm 1.392$ ) of “daily practice of environmental protection” was above 80%. The lowest score of the respondents was 4 points, and the highest score was 10 points. These are roughly equivalent to the scores of multiple second-level indicators in other dimensions. However, the average score rate of the other three factors of ecological behavioral literacy was low. The average score of “scientific environmental protection skills and methods” was the lowest ( $4.68 \pm 1.741$ ). This indicated that many Guiyang inhabitants had less of a grasp of environmental protection skills and methods. They do not know how to protect the surrounding ecological environment in daily work, study, and life. Although the average scores of the other two items were higher than that for “scientific environmental protection skills and methods,” the average score ratio did not reach 60%. The average scores of these two differed only slightly, with “positive influence on the environmental protection behavior of others” at  $5.88 \pm 1.801$  and “participation in environmental education activities” at  $5.68 \pm 1.699$ .

The statistical analysis in Table 8 shows that Guiyang inhabitants generally scored low in terms of ecological behavioral literacy, and there was a lot of room for improvement. This was mainly due to the fact that there were still many inhabitants who have not implemented their ecological theoretical knowledge and ecological ideology into actual action. The ultimate goal of ecological literacy is to enable inhabitants with ecological theoretical knowledge and ecological ideology to take action on environmental problems. Ecological behavioral literacy is an important part of the process of maintaining or improving the level of ecological literacy of the inhabitants in Guiyang City. At the level of environmental protection skills and methods, it is necessary to adopt a variety of ways to promote scientific skills in order to achieve ecological behavioral literacy. The factor with the lowest average score in this part is gradually improving; at the same time, the inhabitants of Guiyang City should be actively involved in environmental education activities, and efforts should be made to actively influence the surrounding inhabitants through the practice and supervision of their own ecological environmental protection behavior. For the purposes of this

study, only by integrating ecological knowledge, ecological awareness, ecological ethics, and ecological emotion into ecological behavior can the multiple indicators of the level of ecological behavioral literacy be effectively improved.

## Conclusions

We used the concepts of linguistic ecology to conduct quantitative research on five aspects of ecological literacy: knowledge, awareness, ethics, emotion, and behavior. These aspects provided valid assessment criteria for assessing ecological literacy, and they can serve as a new direction for ecological research and development. Our study was an exploration of interdisciplinary research, combining ecology with linguistics. We found that the participants in our case study differed considerably in their level of ecological literacy among these five aspects. Thus, we propose the following three targeted solutions.

First, we must pay attention to the content and development of ecological education, including classroom education and outdoor education. This will affect the level of ecological literacy in different ways, and it is one of the most effective ways to cultivate ecological literacy. Ecological education will have the most direct impact on the level of ecological knowledge, involving various aspects of ecological knowledge, such as ecological professional knowledge, ecological ethics knowledge, and ecological and biological knowledge in nature.

Second, we should encourage the inhabitants of Guiyang City to actively devote themselves to appreciating local natural scenery, strengthening outdoor activities, and feeling the charm of nature. On the basis of receiving ecological education, the relevant departments need to increase outdoor activities. This will enhance physical fitness, while allowing inhabitants to appreciate nature. By getting closer to nature, we can better recognize the seriousness of ecological problems.

Finally, we must take action to express everything related to ecology through our own behavior, to achieve the goal of improving ecological literacy. After recognizing ecological problems, solutions need to be implemented in action. The best way to achieve effective ecological behavior is by adopting the above solutions. Regular environmental education activities are needed, and they should be guided by professionals with a high level of ecological literacy who practice ecological behavior.

In future research, we will conduct a comparative study of the different types and characteristics of the inhabitants of Guiyang City in terms of ecological literacy (i.e., socio-demographic characteristics), and we will explore more detailed suggestions to improve ecological literacy, to better understand the inherent differences in the inhabitants of ecologically advanced cities such as Guiyang City. This will help us

**Table 8** Descriptive statistical analysis of second-level indicators of ecological behavioral literacy of Guiyang inhabitants

	Mean	Standard deviation	Minimum	Maximum
EBEL1	8.59	1.392	4	10
EBEL2	5.68	1.699	2	10
EBEL3	4.68	1.741	2	10
EBEL4	5.88	1.801	2	10

to promote and cultivate ecological literacy according to specific characteristics of the inhabitants by proposing effective cultivation methods. The results of the current study can provide some meaningful points, which can help to improve the overall level of ecological literacy in China, and they can be used as a reference for the investigation and cultivation of ecological literacy in other countries and regions.

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**Data availability** The datasets and materials used and/or analyzed during the current study are available from the corresponding authors on reasonable request.

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