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ORIGINAL ARTICLE

# An Evaluation System for the Conservation of Geomorphological Assets: Landforms in South Korea

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**Abstract**
Landforms are spaces for human life, habitats for animals and plants, and areas that provide various ecological services. However, human development has undermined landform where it should be kept as an important human asset. In South Korea, to reduce this damage, a system was created to evaluate the conservation value of landforms, and either designate them as conservation areas or obtain permission for their development in advance. However, the general public, who demands the development of landforms continuously, have frequently questioned the subjectivity of the evaluation criteria used for the conservation of landforms. National Institute of Ecology (NIE) in South Korea was carried out a project which was to increase the reliability of these criteria by modifying the conservation evaluation system into a quantitative system. This paper aims to introduce the geomorphological survey as a part of the Investigation of National Environment (INE), and an improved evaluation system via the Delphi, the Analytic Hierarchy Process (AHP), on-site verification, etc. As a result of this quantitative evaluation using detailed scoring indicators, specific criteria, and weights for evaluation, there is a low correlation between the indicators, and this confirmed that each indicator was evaluated correctly. In addition, as the quantitative evaluation results and the experts' opinions generally coincided with the final evaluation grades and values, this indirectly confirmed that the experts who participated in the 4th INE agreed with the evaluation results. This research demonstrates a method that can be used to improve the objective assessment of landforms by experts' opinion surveys. Future research could use the assessment system developed in this research and apply it to other surveys or countries.

**Keywords** Investigation of national environment · Geomorphological survey · Evaluation for landform conservation · Quantitative evaluation

## Introduction

Assessments of geomorphological features are carried out to evaluate and mitigate the environmental effects of development or to designate areas with geomorphological and geological assets as conservation areas. One such evaluation is the environmental impact assessment (EIA), which has been adopted in many countries; the geomorphology in the EIA is concerned with natural disasters, in natural environments and landmark countries (Cavallin et al. 1994). Other assessments address conservation areas such as world heritage and geoparks (Eder 1999; Reis and Henriques 2009; Henriques and Brilha 2017), or geological heritage issues related to intrinsic, cultural and aesthetic, economic, research, educational, and functional values (Gray 2004). Although outstanding geomorphological assets and landscapes should be conserved, some are destroyed because they are developed before they can be converted into a conservation area.

The content of the evaluation of geomorphological features at the universal scale may differ in each country because the content reflects the national status and legal regulations. As a result, geological heritage areas are irregularly protected globally (Reis and Henriques 2009). National conserved areas are classified as protected areas (PA) and key biodiversity areas (KBAs) by IUCN, and natural world heritage sites (NWH), biosphere reserves (BR), and geoparks by UNESCO. The current guidelines from these organizations define the categories of protected areas and their characteristics (Dudley 2008; UNESCO 2013, 2015). The guidelines present several categories as global standards,

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and the review process is performed by advisory committee meetings and expert field inspections. Generally, the review process is conducted through qualitative evaluations, but in some protected areas such as KBAs and geoparks, the processes are conducted using quantitative methods according to global standard criteria (IUCN 2016) and self-evaluation forms (UNESCO 2014). Standard criteria for designating globally recognized conservation areas are broad and comparative because the criteria are universally applied. Generally, the review process is conducted through qualitative evaluations, but in some protected areas such as KBAs and geoparks, the processes are conducted using quantitative methods according to global standard criteria (IUCN 2016) and self-evaluation forms (UNESCO 2014). Standard criteria for designating globally recognized conservation areas are broad and comparative because the criteria are universally applied. Geodiversity is an element that composes natural diversity and means diversity of abiotic elements. It can be defined as geological heritage, geomorphological heritage, or palaeontological heritage, in reality. The major purpose of each heritage is geoconservation, which leads to the stages of inventory, evaluation, conservation, and monitoring (Brilha 2016). For the inventory and evaluation of geoheritages, it is important to clarify what their purpose is. This is because the evaluation method can be different depending on the purpose of the inventory (Brilha 2016). In the next step, an assessment frame can be developed by selecting an assessment indicators and elements appropriate for the purpose. An important element in the assessment frame is to select the elements and criteria for evaluation. Many research have introduced the criteria in each study; however, the criteria and parameters used in the methods are often unclear and ambiguous (Mucivuna et al. 2019).

In South Korea, there are two inventory projects related to geoheritage. One is geological heritage, and the geosite is discovered and evaluated, and the sites are designated as geopark. The primary purpose of geopark is to preserve geoheritage, but it is promoting geoheritage through application to the tourism industry. Another inventory is geomorphological heritage, and its final goal is to designate it as a conservation area to prevent damage to excellent geographic resources due to development. In evaluating the target site of geoheritage and geomorphological heritage, criteria for evaluating scientific values overlap. The evaluation methods of the two heritages share evaluation indicators such as representativeness, scarcity, diversity, reproducibility, specificity, and scale, but they have evaluation items appropriate for the purpose of each project. For example, the evaluation of geomorphical resources focuses on the scientific value to evaluate its intrinsic value and investigate its attributes. On the other hand, in the evaluation of geological resources, in addition to the scientific value, ancillary values such as accessibility, convenience, and protection facilities are also evaluated (Korea National Park Service [KNPS] 2014). Therefore, an assessment frame suitable for each purpose should be studied.

The Investigation of National Environment (INE) for the conservation of the natural environment has occurred every 5 years as required by article 30 of the National Environmental Conservation Act since 1987. The last investigation, which was the fourth investigation, was completed in 2018, and the fifth investigation began in 2019. One of the survey's goals is to investigate "the peculiarity of geomorphological features, geological features, and natural scenery" and evaluate the value for conservation (Ministry of Environment [MOE] 2010). The same act established the Ecological and Nature Map, which is generated by the survey results and has three graded zones and a separately managed zone. The three graded zones are based on the natural characteristics and value of topographic features. The separately managed zones are conserved areas pursuant to the provisions of another act. In addition, the map is utilized for comprehensive planning regarding the national environment, environmental impact assessments, and development plans.

The graded zones of the topographical features are evaluated by eight indicators that include representativeness, scarcity, specificity, reproduction, academic, and educational value. The evaluation used qualitative methods in the third investigation (Seo 2005; Yun and Shin 2015); however, the evaluation had several problems, including subjectivity and differences in the results between the investigators because of unclear and ambiguous criteria. Therefore, it suggested that a quantitative evaluation was necessary (Yun and Shin 2015). In 2015, the MOE and NIE carried out a joint project to improve the evaluation criteria with South Korean geomorphologists, and the developed evaluation was utilized in the 4th INE (Kang and Lee 2015).

The purposes of this research are to introduce a revised evaluation system for the conservation of topographical features in South Korea and to verify the effectiveness of the new system introduced in the 4th INE using the results of the INE performed by previous and developed systems. The aim is to also deliberate on the evaluation system's potential application to other surveys or countries with similar circumstances.

## Methods

### Data Collection

The 4th INE began in 2014, took 5 years, and ended in 2018. The INE is composed of various environmental sections, such as geomorphological, vegetation, flora, and fauna survey. Of them, the geomorphological component investigates approximately 10,000 geomorphological units by surveying 180 teams over 5 years. The geomorphological survey aims to search for new landforms distributed throughout the country, describe the characteristics of the landform according to the INE guidelines, and evaluate the value and conservation grades of the landform.

The geomorphological units are classified into five categories, mountain, stream, coastal, karst, and volcanic, to reflect the topography of South Korea. Two categories within the five categories are considered erosion/weathering and sedimentary landforms. Finally, the geomorphological units are divided into a total of 113 landform units. For example, mountainous sedimentary landforms are classified into patterned ground, block stream, block field, talus, and mountain wetlands. The surveyed terrain is recorded along with the terrains' name, location, boundary, evaluation result, description, and photographs.

The revised assessment system was conducted over 3 years, 2016–2018, and a total of 5635 terrains were surveyed. Of these, 2936 terrains were surveyed in the 3rd INE and re-examined in the 4th INE, along with 2699 newly surveyed terrains. In this research, the 2936 terrains' data were analyzed to discuss the improvement effects. Several parts of the data that could not be used to compare the results from the 3rd and 4th INE were removed, and subsequently, 2656, 92, and 94 s-, third-, and fourth-grade terrains, respectively, were used.

### Data Analysis

The re-evaluated terrains were analyzed to verify the effectiveness of the developed assessment system. For the statistical analysis, the third survey results, which consisted of high, medium, and low grades, were scored with a 3–2-1, and then compared with the fourth survey results. The paired *t*-test was used to confirm the statistical significance of the change in the third and fourth conservation grades, and SPSS 12.0 was used for this comparison. The paired *t*-test is an appropriate method as it verifies the average difference between two sets of data after data collection and before and after the experimental treatment of the same sample.

Previous research on the 3rd INE (Yun and Shin 2015) has analyzed the correlation between the evaluation indicators and demonstrated that the indicators could be duplicated because the definition of the indicators and criteria was not clear. Therefore, in order to analyze the independent variables among the evaluation indicators in the improved evaluation system, a correlation analysis between the evaluation indicators was conducted using the results from the 4th INE.

## Introduction of the Revised Evaluation System

### Previous Evaluation System

The South Korean geomorphological survey of the INE began with the second survey (1997). The survey was conducted by setting up a survey section within an index dividing South Korea into a regular grid, and the geomorphological units were then classified and evaluated by geomorphologists. No evaluation criteria were included in this process. From the third survey, the values of the geomorphological units were evaluated using the following eight indicators set by the MOE:

- Representativeness: highly assessed if the setting, processes, characteristics, and shapes of the geomorphological units are typically well represented.
- Scarcity: highly assessed if it demonstrates less frequent geomorphological units, such as dunes and wetlands in high elevation, fewer local occurrences, and relative scarcity according to regional characteristics.
- Specificity: highly assessed if it is associated with unusual natural phenomena (geyser, wind-holes, etc.).
- Impossibility of reproduction: highly assessed if there is a greater probability of change in the natural or artificial environment, and is less likely to be reshaped in the current environment.
- Academic and educational values: highly assessed if it is an object of research and natural education.
- Naturalness: highly assessed if it is well preserved in its natural state, and less artificial damage or changes are present.
- Diversity: highly assessed if the same units are distributed in clusters, or various units are formed in the same area.
- Scale: highly assessed if it is larger than most geomorphological units of its type.

The pre-evaluations divided the value of the geomorphological unit into "high, medium, and low" according to the above method, and a rating according to the number of high and medium grades. For example, if a unit received seven or more high grades, the value became grade I. Also, if it got five or six high grades, then the value became grade II.

However, the pre-evaluation system is problematic, as confusion may occur when assigning value according to the number of high and medium grades, and raising the grade according to the number of middle grade (Yun and Shin 2015). In order to solve this problem, Yun and Shin proposed a method of evaluating the scores without using high-medium–low. They suggested that detailed evaluation guidelines for each indicator should be prepared to avoid mistakes due to the unspecified definitions and criteria, and weight should be set in consideration of the relative importance of the indicator. Most importantly, they emphasized the need for discussion and consultation with geomorphologist in all of these processes.

## Method and Process for Developing the System

This research used the Delphi and AHP to develop the evaluation system for the conservation grade of geomorphological units. The Delphi method is an iterative process to collect and distill the anonymous judgments of experts using a series of data collection and analysis techniques interspersed with feedback (Skulmoski et al. 2007). The previous eight indicators posed problems for experts evaluating geomorphological assets subjectively because of broad and uncertain indicator definitions. Therefore, the first step toward revising the system was the creation of sub-items.

An expanded sub-item was selected based on the eight indicators set by the MOE (the initial item of Table 1). To select the best items among the expanded sub-items, questionnaire surveys were conducted twice with 31 geomorphology experts who had experience with the national environmental survey. Twenty-one surveyed experts responded.

In the first survey, the appropriateness of the initial items was ranked using a Likert-7-point scale with open/closed questions, and personal opinions on the items were also included. Expert responses were analyzed with statistical methods such as the mean, standard deviation, and content validity ratio (CVR), and then the initial item was revised with the statistical results and expert opinions. In the second questionnaire, the revised items and statistical analysis results were provided to the 21 experts, and the importance of each item was evaluated again in the same way. The second questionnaire responses were analyzed for increasing consensus, decreasing convergence, and increasing tendency with the first questionnaire responses. Finally, detailed evaluation indexes were extracted (Table 1, final item).

In the next step, the weighted values were calculated using the AHP because each item might have different weights to evaluate. AHP needs hierarchy for analyzing, the top-level set the evaluation of the geomorphological assets, and the intermediate level was eight indicators. The lowest level was 13 final items selected through the Delphi analysis.

When experts evaluate criteria, they weigh individual targets differently. Therefore, the second step analyzed the weight for each sub-item through the AHP analysis. The AHP is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive a priority scale (Saaty 2008). To make the pairwise comparisons, this study used a 1–9 scale (1: equally important; 3: slightly important; 5: essential or very important; 7: definitely important; and 9: absolutely important). The AHP survey selected 22 experts who participated in the Delphi survey and geomorphologists who had not participated in the Delphi survey but had taken part in the field survey. The AHP analysis was conducted by calculating pairwise comparison matrices as the geometric mean. For the final result, the consistency index (CI) was calculated and the logical consistency was evaluated. More detailed information on the above process can be found in Kang and Lee's (2015) previous study.

Verifying the ratings on-site is essential for these improved assessment criteria. For verification, we carried out field surveys with two or three experts on 50 geomorphological units in five categories (mountain, stream, coastal, karst, volcanic topography). If there were differences between the experts' results, they were revised through discussion.

## Developed Evaluation System

The improved assessment criteria are as follows (Appendix 1 and Table 2):

Eight indicators (scarcity, specificity, representativeness, academic educational value, naturalness, diversity, irreproducibility, scale) and 13 sub-items (frequency, pattern, differentiation, typicality, regional representativeness, academic value, educational value, conservation, landscape diversity, components, natural history, sensitivity, size) were established. The sub-items were divided into three scores, and evaluation criteria are presented in Appendix 1. In the field, the characteristics of the geomorphological unit are investigated according to the format of Appendices 2 and 3 , and the value of each indicator is evaluated based on the information. When the weight is reflected in this result, the topographic value grade is derived.

The weight for each sub-item is illustrated in Table 2.

The total score is obtained by summarizing the evaluation items, criteria, and weights as follows:

$$\text{Total score} = \sum_{i=1}^{n} I_i W_i \quad (1)$$

where I = score of evaluation item, W = weight of each item, and n = number of evaluation item.

The total score should determine its inclusion on the ecological and natural map. In this step, the score distribution for each grade was set by comparing the pre-assessment system, field verification results, and score distribution simulation using the results of 3rd INE. The total score from Eq. 1 was from 10 to 30 points, and grades I, II, III, and IV should be within 10–30 points. The previous evaluation system is an equal division method according to the number of high

**Table 1** The initial items and final items selected by experts' survey

| Index | Sub-index | Initial item | Final item |
|---|---|---|---|
| Representativeness | Regional representativeness | Protection area (natural monument, heritage, geopark, etc.) | Landmark for the local area (Natural monument, heritage, geopark, etc.) |
| | | Used for folktale or storytelling | |
| | | Reflect the geomorphological characteristics in the survey area | |
| | Typicality | Typicality of the geomorphological process and form | Typicality of the geomorphological process and form |
| | | Relationship between the process and form | |
| Scarcity | Frequency | Frequency in the whole country | Frequency in the whole country |
| | | Frequency in the index map | |
| | | Frequency in the administrative division | |
| | Pattern | Distribution pattern | Distribution pattern |
| Specificity | Differentiation | Specificity of the landform | Specificity of the landform, process, component materials |
| | | Specificity of the component materials of geomorphological unit | |
| | | Specificity of the geomorphological process | |
| | Natural phenomenon | Appearance of singular natural phenomenon | - |
| | | Unique habitat or specified species | |
| Impossibility of reproduction | Sensitivity | Easily changed by climate, processes, etc | Easily changed by climate, processes, etc |
| | | Unstable tectonic setting | |
| | Natural history | Relationship with paleoclimate or paleoenvironment | Relationship with paleoclimate or paleoenvironment |
| | | Duration of landform formation | |
| Academic and educational value | Academic value | Number of research reports, journals, books | Level of study area use |
| | | Level of study area use | |
| | | Contribution to related sciences | |
| | Educational value | Visiting for field study, educational tourism | Visiting for field study, educational tourism |
| | | Accessibility and view quality | |
| Naturalness | Conservation | Degree of damage of landform | Degree of damage of landform; designating conservation sites |
| | | Designating conservation sites | |
| | Distance from development | Residential area | |
| | | Distance from the development area | |
| Diversity | Components | Diversity of component factors in geomorphological unit | Diversity of component factors in geomorphological unit |
| | | Heterogenetic habitat | |
| | Landscape diversity | Heterogeneous landscape or geomorphological unit | Heterogeneous geomorphological unit |
| Scale | Size | Relative size among geomorphological unit | Relative size among geomorphological unit |
| | | Relative size in survey unit (index map, administrative division) | |

scores. If that method was applied by totaling the 3–2-1 scores, there would be 25 or more points for grade I, 20–24 for grade II, 15–19 for grade III, and 10–14 for grade IV. Therefore, the score between grades I and II is divided by 25 points. The score from the on-site verification had a distribution of 17.88–30 points for grade I, 14.1–25.12 points for

**Table 2** The weight of each sub-indicator analyzed by AHP

| | Index | Sub-index | Total relative importance |
|---|---|---|---|
| 1 | Scarcity | Frequency | 1.2 |
| | | Pattern | 1.2 |
| 2 | Specificity | Differentiation | 1.6 |
| 3 | Representativeness | Typicality | 0.9 |
| | | Regional representativeness | 0.6 |
| 4 | Academic and educational value | Academic value | 0.7 |
| | | Educational value | 0.6 |
| 5 | Naturalness | Conservation | 0.9 |
| 6 | Diversity | Landscape diversity | 0.5 |
| | | Components | 0.3 |
| 7 | Impossibility of reproduction | Natural history | 0.4 |
| | | Sensitivity | 0.4 |
| 8 | Scale | Size | 0.7 |

grade II, 14.74–25.26 points for grade III, and 10.35–18.56 points for grade IV. Figure 1 illustrates the distribution of the total scores according to the grade. The score distributions of grades I and IV are different, but there are overlapping segments in grades II and III. Therefore, the overlapping segment should be randomly classified between grades II and III.

A simulation result of the total score distribution is the normal distribution of median 20, with the first quartile (25%) at 18.3 and the third quartile (75%) at 21.7, and 50% of the total results are within 18.3–21.7 points. The most important aspect of the classification is the demarcation between grades I and II. This demarcation was set to 25 points, reflecting the numerical results such as 25 points in the equal division and 25.12 or more in the on-site verification results and the experts' opinions. Additionally, according to Eq. 2 below, y is more than 25 points for grade I, more than 20.8 and less than 25 for grade II, more than 15.2 and less than 20.8 for grade III, and less than 15.2 for grade IV.

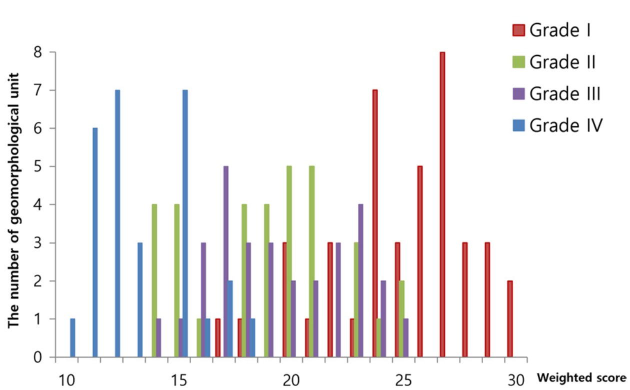


**Fig. 1** Distribution of weighted scores by grade

$$y = 3.6x \tag{2}$$

where x = total score from Eq. 1 and y = transformed score.

## Results

### Topography Survey on the 4th INE Survey

The 2842 geomorphological features reinvestigated were composed of 1023 stream landforms, 918 coastal landforms, 719 mountain landforms, 41 karst landforms, 112 volcanic landforms, and 29 others features. Figure 2 illustrates the distribution of the total score and weighted values of the 4th INE, which was completed using the improved assessment system. Figure 2a illustrates the distribution of the total scores between 13 and 38 points. The mode value is 28, and the next values are 30 and 32 points in order. When each item is multiplied by the weight, the distribution of the value changes, as illustrated in Fig. 2b. After weighting, the theoretical score distribution changes to 10–30 points, and the distribution of the surveyed values is confirmed to be a minimum of 10 and a maximum of 29.7. The mode was 22 points, which included 377 terrains. As the weight is applied, the graph moves to the left, and as the interval decreases, the frequency of the specific value increases.

The 4th INE total scores had 142 grade I, 1454 grade II, 927 grade III, and 319 grade IV landforms. Among them, 7 landforms were included in grade I and 39 landforms in grade II; 1.6% of the total landforms were upgraded from a lower grade by the expert opinions. Figure 3 illustrates the change of grade from the third survey. Approximately 52.6% of the landforms that were grade II in the 3rd INE remained unchanged. However, 42.5% of the landforms

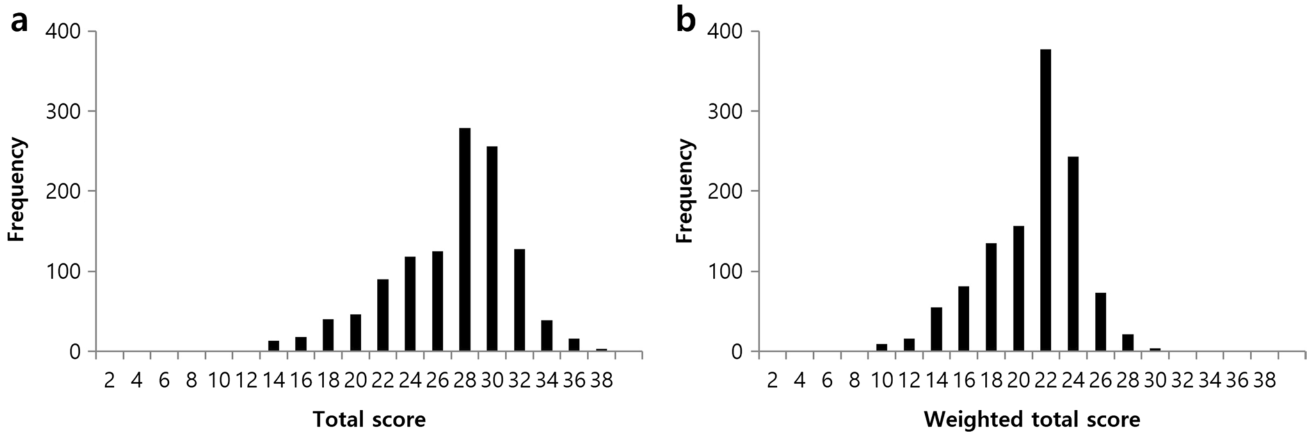


**Fig. 2** **a** Frequency of total scores from the 4th INE. **b** Frequency of weighted total scores from the 4th INE

were downgraded to grade III or IV. In the case of grade III, approximately 69.6% of the landforms remained the same grade, while 17.4% of the landforms decreased to grade IV, and 13% of the landforms were upgraded to grade I or II. For grade IV, 58.5% of landforms remained the same grade, while for the rest of the 41.5% landforms, 1.1% were upgraded to grade I, 10.6% were upgraded to grade II, and 29.8% were upgraded to grade III. Overall, 182 landforms were graded up, while 1145 landforms were downgraded. Nearly all of the upgraded landforms, 154, became grades I or II. On the other hand, 1129 landforms, which were grade II in the 3rd INE, became grades III or IV. Most of the grades for geomorphological conservation were downgraded.

Among the 182 upgraded landforms, coastal landforms were the highest rate, making up 47% of the total, followed by mountain and stream landforms. Stream landforms were downgraded at the highest rate of 42%, followed by coastal and mountain landforms at 29% and 27%, respectively (Fig. 4). Both coastal and river landforms experienced many grade changes in either direction.

## Average and Correlation Analyses of the Indicators

The averages of each sub-indicator of the 3rd and 4th INE were compared to verify the changes before and after the improved evaluation system. As a result, the average of each sub-indicator of the 4th survey decreased compared to the

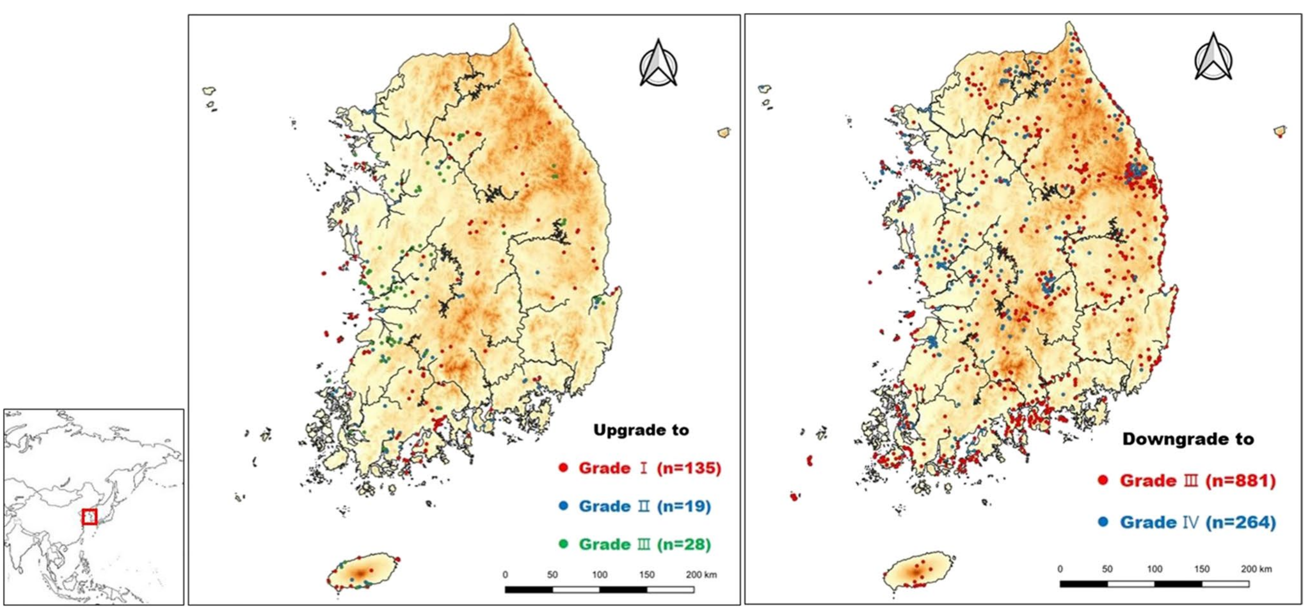


**Fig. 3** The number of upgrade and downgrade geomorphological features between 3rd and 4th INE surveys, and the distribution the features

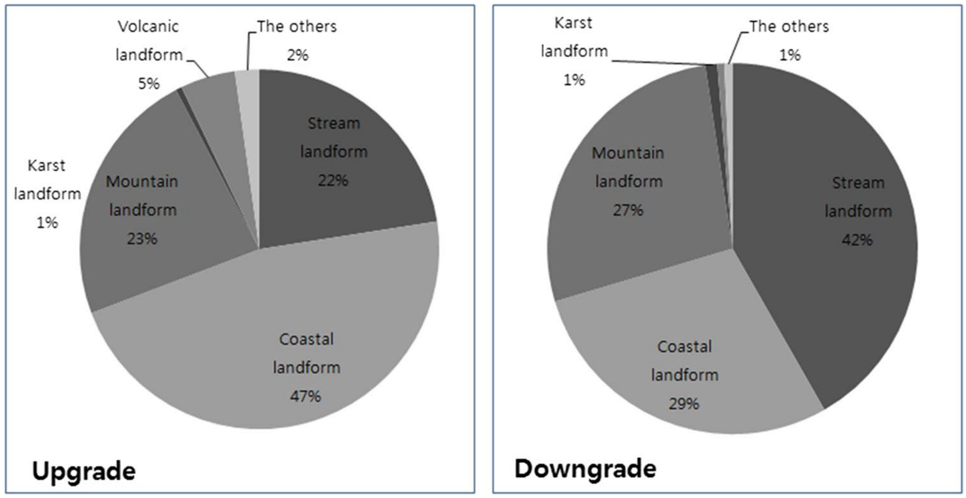


**Fig. 4** A percentage of upgrades and downgrades by landform types

3rd survey, and statistically significant changes were confirmed. This means that the re-evaluated landforms were generally downgraded compared to the previous assessment, as illustrated in the results in "Topography Survey on the 4th INE Survey." Table 3 illustrates the results of the paired sample *t*-test according to the divided groups, as upgrade or downgrade. When analyzing the changes in the average by group with upgraded landforms, the averages of

**Table 3** The results of the paired *t*-test for the upgrade and downgrade group

| Survey and sub-indicator | | Upgrade group | | | | Downgrade group | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | t | P | M | SD | t | P |
| 3rd | Representativeness | 2.7143 | 0.49941 | 9.178 | 0.000 | 2.8443 | 0.36993 | 72.543 | 0.000 |
| 4th | Regional representativeness | 2.1538 | 0.81996 | | | 1.3316 | 0.60884 | | |
| 3rd | Representativeness | 2.7143 | 0.49941 | −4.653 | 0.000 | 2.8443 | 0.36993 | 19.461 | 0.000 |
| 4th | Typicality | 2.9066 | 0.29180 | | | 2.3920 | 0.73230 | | |
| 3rd | Scarcity | 2.1374 | 0.70345 | −1.329 | 0.186 | 2.1802 | 0.55271 | 42.632 | 0.000 |
| 4th | Frequency | 2.3022 | 1.57392 | | | 1.2861 | 0.54359 | | |
| 3rd | Scarcity | 2.1374 | 0.70345 | −1.992 | 0.048 | 2.1802 | 0.55271 | 35.690 | 0.000 |
| 4th | Pattern | 2.2527 | 0.65803 | | | 1.3920 | 0.53134 | | |
| 3rd | Specificity | 2.1758 | 0.73722 | −7.178 | 0.000 | 2.2896 | 0.61586 | 41.256 | 0.000 |
| 4th | Differentiation | 2.5659 | 0.71568 | | | 1.3517 | 0.52153 | | |
| 3rd | Impossibility of reproduction | 2.5000 | 0.66274 | −5.733 | 0.000 | 2.6947 | 0.53954 | 13.334 | 0.000 |
| 4th | Sensitivity | 2.7802 | 0.44105 | | | 2.3648 | 0.69200 | | |
| 3rd | Impossibility of reproduction | 2.5000 | 0.66274 | −0.185 | 0.853 | 2.6947 | 0.53954 | 33.022 | 0.000 |
| 4th | Natural history | 2.5110 | 0.61956 | | | 1.9029 | 0.66315 | | |
| 3rd | Academic and educational value | 2.5690 | 0.56216 | 4.061 | 0.000 | 2.7690 | 0.44260 | 46.373 | 0.000 |
| 4th | Academic value | 2.3333 | 0.65696 | | | 1.6949 | 0.70544 | | |
| 3rd | Academic and educational value | 2.5690 | 0.56216 | 0.611 | 0.542 | 2.7690 | 0.44260 | 52.298 | 0.000 |
| 4th | Educational value | 2.5345 | 0.61434 | | | 1.6182 | 0.64847 | | |
| 3rd | Naturalness | 2.4121 | 0.72863 | −4.073 | 0.000 | 2.6340 | 0.56093 | 14.533 | 0.000 |
| 4th | Conservation | 2.6484 | 0.57332 | | | 2.2855 | 0.80584 | | |
| 3rd | Diversity | 2.2582 | 0.66008 | 2.467 | 0.015 | 2.5531 | 0.61722 | 37.245 | 0.000 |
| 4th | Components | 2.0934 | 0.82573 | | | 1.5593 | 0.66202 | | |
| 3rd | Diversity | 2.2582 | 0.66008 | −0.786 | 0.433 | 2.5531 | 0.61722 | 31.595 | 0.000 |
| 4th | Landscape diversity | 2.3077 | 0.69238 | | | 1.6857 | 0.73780 | | |
| 3rd | Scale | 2.2582 | 0.63447 | −4.310 | 0.000 | 2.3473 | 0.60869 | 15.903 | 0.000 |
| 4th | Size | 2.5220 | 0.66238 | | | 1.9493 | 0.82063 | | |

the typicality, frequency, pattern, differentiation, sensitivity, natural history, conservation, component diversity, and scale are higher than those of the 3rd survey. Among the indicators, there were statistically significant changes for differentiation, sensitivity, conservation, and scale. For regional representation and academic value, although the grade was raised, there was a significant decrease in the average. In the downgraded landform group, there was a significant decrease in all of the sub-indicators.

As a result of the correlation analysis of the sub-indicators, statistically significant correlations were analyzed in all of the items except the regional representative-sensitive and frequency-components, as illustrated in Table 4. The highest correlation was the academic-educational value, with a correlation of 0.560, and the frequency-pattern also showed a relatively high correlation of 0.404. The high correlation results are reasonable because landforms with high research value may be used academically to produce various research results. Frequency and pattern also have a high correlation because landforms concentrated or distributed in a specific pattern have a relatively low distribution frequency. However, in these two cases, the high correlation means that there is a possibility of a double evaluation in the system. The other indicators showed significant correlation coefficients, but most of them showed low correlations below 0.4.

## Discussion

### Implication of the Developed Assessment System

The improvement of the evaluation system has an impact on the internal and external aspects of the evaluation system. It is necessary to discuss whether the problems in the previous evaluation system have been solved in the revised assessment system. Externally, it is about whether the quantitative evaluation is necessary not only in Korea but also in other researches and regions.

As mentioned in the introduction, in the previous evaluation system, the evaluation was not accurately evaluated because the definition of the evaluation items was ambiguous. As a result, there was a problem that the correlation between several items was increased (Yun and Shin 2015). To solve this problem, the developed assessment system subdivided the items. As the results demonstrated, it is possible to confirm that the correlation between the indicators is lowered through increasing the independence of each indicator by defining detailed sub-indicators. In particular, experts who participated in the survey to develop this assessment system also participate in INE at the same time. Therefore, the participants understand the definition of each indicator. In addition, the weight of each item was calculated. The weight of

**Table 4** The result of correlation analysis between sub-indicators by Spearman's rho method

| Spearman's rho method | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1.000 | - | - | - | - | - | - | - | - | - | - | - | - |
| | 2 | $0.078^{**}$ | 1.000 | - | - | - | - | - | - | - | - | - | - | - |
| | 3 | $0.188^{**}$ | $0.048^{**}$ | 1.000 | - | - | - | - | - | - | - | - | - | - |
| | 4 | $0.147^{**}$ | $0.135^{**}$ | $0.404^{**}$ | 1.000 | - | - | - | - | - | - | - | - | - |
| | 5 | $0.210^{**}$ | $0.199^{**}$ | $0.191^{**}$ | $0.261^{**}$ | 1.000 | - | - | - | - | - | - | - | - |
| | 6 | 0.025 | $0.196^{**}$ | $0.160^{**}$ | $0.242^{**}$ | $0.215^{**}$ | 1.000 | - | - | - | - | - | - | - |
| | 7 | $0.099^{**}$ | $0.187^{**}$ | $0.164^{**}$ | $0.196^{**}$ | $0.202^{**}$ | $0.297^{**}$ | 1.000 | - | - | - | - | - | - |
| | 8 | $0.185^{**}$ | $0.227^{**}$ | $0.154^{**}$ | $0.122^{**}$ | $0.283^{**}$ | $0.178^{**}$ | $0.288^{**}$ | 1.000 | - | - | - | - | - |
| | 9 | $0.241^{**}$ | $0.278^{**}$ | $0.170^{**}$ | $0.129^{**}$ | $0.349^{**}$ | $0.169^{**}$ | $0.276^{**}$ | $0.560^{**}$ | 1.000 | - | - | - | - |
| | 10 | $-0.055^{**}$ | $0.233^{**}$ | $-0.040^{*}$ | $0.068^{**}$ | $0.239^{**}$ | $0.249^{**}$ | $0.096^{**}$ | $0.079^{**}$ | $0.148^{**}$ | 1.000 | - | - | - |
| | 11 | $0.059^{**}$ | $0.179^{**}$ | $0.056^{**}$ | $0.126^{**}$ | $0.329^{**}$ | $0.141^{**}$ | $0.126^{**}$ | $0.222^{**}$ | $0.248^{**}$ | $0.243^{**}$ | 1.000 | - | - |
| | 12 | $0.164^{**}$ | $0.151^{**}$ | 0.026 | $0.068^{**}$ | $0.249^{**}$ | $0.131^{**}$ | $0.107^{**}$ | $0.238^{**}$ | $0.279^{**}$ | $0.184^{**}$ | $0.364^{**}$ | 1.000 | - |
| | 13 | $0.066^{**}$ | $0.168^{**}$ | $0.087^{**}$ | $0.082^{**}$ | $0.136^{**}$ | $0.064^{**}$ | $0.041^{*}$ | $0.107^{**}$ | $0.148^{**}$ | $0.060^{**}$ | $0.143^{**}$ | $0.116^{**}$ | 1.000 |

$^{**}p<0.01$, $^{*}p<0.05$

1: regional representativeness; 2: typicality; 3: frequency; 4: pattern; 5: differentiation; 6: sensitivity; 7: natural history; 8: academic value; 9: educational value; 10: conservation; 11: components, 12: landscape diversity; 13: size the evaluation indicators changes its contribution to the results according to the importance of the evaluation indicators. According to the weighted results, scarcity, specificity, and representativeness were the most important factors in evaluating the conservation grade of the landform. This allocates a higher score to unique landforms than general spaces because the purpose of the geomorphological survey in South Korea is to preserve landforms. However, the weighted results are not permanent. As they should be recalculated periodically as the natural environment, perspectives, and academic issues change, the focal points of each expert in evaluating the landform can change.

The previous evaluation system was a method of judging the grade of terrains based on the opinion of experts according to the definition of evaluation indicators. This approach relies on the experts' knowledge and judgment, and it is inevitably affected by the subjectivity of the investigator; experts may assess different results for the same landforms. This subjectivity prompted researchers to consider whether scored criteria or universal assessment methods for evaluating conservation areas were necessary. Therefore, various methods have been proposed to improve the objective criteria and develop an absolute evaluation system (Sowińska-Świerkosz 2017). Many researchers have recently provided indicators for qualitative and quantitative assessments for natural and cultural heritage, landscapes, tourism sustainability, and ecosystem services. The revised assessment system of INE is also following the academic flow of references. Quantitative assessment system provides criteria for evaluation scores. Therefore, it is possible to reduce the deviation of assessment results among experts. In addition, the experts can provide evidence for evaluation results. Therefore, conflicts between stakeholders due to reliability issues are expected to decrease. However, the revised assessment system also needs to be supplemented. Several researches have demonstrated the trends in widely recognized social and economic indicators as well as evaluation indicators of spaces (Sowińska-Świerkosz 2017). However, the purpose of improving assessment system was to clarify a definition and subdivide the previous items. Therefore, items on social and economic influences are not sufficient. Almost items focus on the assessment of the status of the geomorphological assets except academic and education value. However, a geomorphological survey and assessment of the conservation value of the topography would benefit from the inclusion of social or economic indicators. This is a limitation of the current system, and it is considered a point to be improved further in the future. If this evaluation system is used with other surveys or in other countries, it may be possible to add social, economic, and policy indicators depending on the characteristics of the terrain and the purpose of the survey.

## Countermeasure for the Grade Changes

The comparison of the third and fourth survey results confirmed up- and downgrades in the landforms' conservation grades. The changes were caused by the natural changes of the landform, improvement of the detailed evaluation criteria and weighted scores, or a combination of both. For example, if the grade changed for mountain landforms, this does not change very much in the short term, and it can be classified as a change due to the improvement of the evaluation criteria. Some landforms were upgraded when the representativeness increased due to its designation as a protected area, geosite, or natural monument. On the other hand, the grade change in stream and coastal landforms can be understood by natural changes because these landforms can change in the short term. For example, sedimentary landforms such as tidal flats and coastal dunes have been verified as being upgraded by natural reconstruction resulting in increasing sediment volume and area over time. In this case, the scores of the preservation and the scale indicators increased, and at the same time, the academic and education values increased.

The lowered grades were found in many cases of terrain damaged by development. In South Korea, river projects were conducted between the third and fourth surveys, which resulted in a decrease in the naturalness of the streams or the simplification of various geomorphological units (Jeong 2009). In addition, coastal landforms still exposed to high development pressures (Kang et al. 2017). Therefore, these landforms were relatively lower grades due to direct damage by development or indirect changes by various facilities. In other case, the geomorphological units such as talus, tor, marine, and river terraces, which were frequently surveyed in the 3rd INE, were continuously distributed, so their grades were lowered due to their scale and scarcity scores.

The results of the INE by the MOE are used as references in other surveys, and when establishing environmental policies and plans. Depending on the grade, sites can be designated as an ecological landscape conservation area after a thorough, specific investigation has been conducted. In addition, the results reflected in the ecological and natural maps are mandatory for environmental impact assessments, and the surveyed data is shared with the geopark secretariat for geosite discovery in South Korea. Therefore, the high-grade landforms are designated as a conservation area or for conservation activities based on various systems, but if landform grades are lowered, the institutional basis for landform conservation is diminished, which may accelerate development. Fortunately, to prevent these problems, the INE and ecological and natural maps complement these problems at an upper level. Various conservation grades with vegetation and endangered species are marked on the map. The conservation value is recognized as a habitat for the animals and plants living there even if the landform itself or the landscape value is reduced. Therefore, if the survey system is used in other surveys, the value of the landform itself and other values such as social, economic, environmental, and ecological values are considered and evaluated together.

## Conclusions

This paper introduced an evaluation system and improvement process of the landform conservation evaluation performed as part of the topographic survey of South Korea's natural environment survey. In addition, the implications and applicability of the improved evaluation system were discussed through the application results of the 4th INE.

To improve the clarity and quantitative assessment of the landform evaluation system, the evaluation indicators, criteria, and weight of each indicator were set using the geomorphologists' survey. Although the indicators followed those from the previous assessment system, the definition of each indicator was clarified and the weights were set for each to arrive at the evaluation results for the INE. As the weighting is an index that reflects the experts' perception of the importance of geomorphological resources, it is meaningful as a topic for future geomorphological research. In addition, as the sub-indicators and weights are not permanent, they will be continuously improved to reflect the current situation in accordance with the objectives, and the sub-indicators and weights can be changed according to the topography of any country.

As a result of applying the improved evaluation system, the downtrend of the conservation grades was verified. The qualitative assessment evaluated as a relative high grades, while quantitative assessments are likely to be downgraded based upon the results from the 3rd and 4th INE. Geomorphological assets can be reduced with a strict quantitative evaluation; however, various values, including the ecological value as well as the value of the landform itself, can be combined and complemented. Downgrades can be considered positive as they reduce socio-economic losses in terms of reducing civil complaints and protecting private property rights.

Landforms are spaces where various stakeholders, including the people who live, use, and enjoy the space, are intertwined with the various animals and plants living in the space. As demonstrated, a single evaluation system does not meet the needs of these various stakeholders. Therefore, it is considered necessary to evaluate various aspects other than the evaluation of the scientific and spatial phenomena of the geomorphological assets (Table 5).

## Appendix 1

**Table 5** Criteria of revised evaluation system

| Index | Sub-index | Item | Valuation | | |
|---|---|---|---|---|---|
| | | | Criteria | Score | Weight |
| Representativeness | Regional Representativeness | Landmark for the local area (National monument, heritage, geopark, etc.) | (1) Geomorphological unit that is designated as a specific area (e.g., natural monument, scenic spot, geosite, etc.) | 3 | 0.6 |
| | | | (2) Geomorphological unit that is not designated as a specific area, but is expressed in topographic maps, sightseeing maps, signs | 2 | |
| | | | (3) Other than (1), (2) | 1 | |
| | Typicality | Typicality of geomorphological process and form | (1) Geomorphological unit that shows typicality of geomorphological process and form | 3 | 0.9 |
| | | | (2) Geomorphological unit that shows typicality of either geomorphological process or form | 2 | |
| | | | (3) Unknown cause and form of formation | 1 | |

**Table 5** (continued)

| Index | Sub-index | Item | Valuation: Criteria | Score | Weight |
|---|---|---|---|---|---|
| Scarcity | Frequency | Frequency in the whole country | (1) Geomorphological units are rarely distributed throughout the country | 3 | 1.2 |
| | | | (2) Geomorphological unit is rare in the survey map compared to the national distribution | 2 | |
| | | | (3) Universal distribution | 1 | |
| | Pattern | Distribution pattern | (1) Geomorphological unit that is concentrated or covered by the distribution characteristics of the tectonic, geology, and soil is localized to a specific region | 3 | 1.2 |
| | | | (2) Geomorphological unit such as (1) appears in several places | 2 | |
| | | | (3) Geomorphological unit distributes without any unique pattern | 1 | |
| Specificity | Differentiation | Specificity of landform, process, component materials | (1) Geomorphological unit that has a specificity of both geometry and constituent materials (geology, soil, etc.) | 3 | 1.6 |
| | | | (2) Geomorphological unit that has a specificity of either geometry or constituent materials (geology, soil, etc.) | 2 | |
| | | | (3) Other than (1), (2) | 1 | |
| Impossibility of reproduction | Sensitivity | Easily changed by climate, processes, etc | (1) Geomorphological unit can be rapidly removed due to external factors, and cannot be restored to natural (or artificial) processes | 3 | 0.4 |
| | | | (2) Geomorphological unit can be rapidly removed due to external factors but can be restored by natural (or artificial) factors | 2 | |
| | | | (3) Geomorphological unit with little impact from external factors | 1 | |
| | Natural History | Relationship with paleoclimate or paleoenvironment | (1) Geomorphological unit formed during the paleoclimate and serves as an indicator of the paleo-environment | 3 | 0.4 |
| | | | (2) Geomorphological unit that formed during the paleoclimate to the present | 2 | |
| | | | (3) Recently formed | 1 | |
| Academic and educational value | Academic value | Level of study area use | (1) Studies have been actively carried out, and academic results have been actively researched as a study subject or a case study area | 3 | 0.7 |
| | | | (2) Geomorphological unit that has the potential of geomorphological research | 2 | |
| | | | (3) Other than (1), (2) | 1 | |
| | Educational value | Visiting for field study, educational tourism | (1) Geomorphological unit frequently mentioned in texts, lectures, etc | 3 | 0.6 |
| | | | (2) Geomorphological unit that is likely to be used as an educational place | 2 | |
| | | | (3) Geomorphological unit that is unlikely to be used as an educational place | 1 | |
| Naturalness | Conservation | Degree of damage to geomorphology and designating conservation sites | (1) Geomorphological unit is set to a specific conservation area or is well preserved within the boundary without damage | 3 | 0.9 |
| | | | (2) 60% –80% of the area within the boundary of the geomorphological unit is preserved | 2 | |
| | | | (3) Less than 60% of the area within the boundary of the geomorphological unit is preserved | 1 | |

**Table 5** (continued)

| Index | Sub-index | Item | Valuation | | |
|---|---|---|---|---|---|
| | | | Criteria | Score | Weight |
| Diversity | Components | Diversity of component factors in geomorphological unit | (1) There are 5 to 6 components in the geomorphological unit that have various characteristics such as microforms, concave-convex, slope change, slope, geology, and soil | 3 | 0.3 |
| | | | (2) There are 3 to 4 components in the geomorphological unit that have various characteristics such as microforms, concave-convex, slope change, slope, geology, and soil | 2 | |
| | | | (3) There are 1 to 2 components in the geomorphological unit that have various characteristics such as microforms, concave-convex, slope change, slope, geology, and soil | 1 | |
| | Landscape diversity | Heterogeneous geomorphological unit | (1) There are more than 5 other geomorphological units distributed around the geomorphological unit | 3 | 0.5 |
| | | | (2) There are 3 to 4 other geomorphological units distributed around the geomorphological unit | 2 | |
| | | | (3) There are less than 2 other geomorphological units distributed around the geomorphological unit | 1 | |
| Scale | Size | Relative size among geomorphological units | (1) The measured long axis, short axis, and height are larger than average for geomorphological units | 3 | 0.7 |
| | | | (2) Any of the measured long axis, short axis, or remarks are larger than average for geomorphological units | 2 | |
| | | | (3) The measured long axis, short axis, and height are smaller than average for geomorphological units | 1 | |
| Notice | Points to the total score can be added by other items and content that are not considered in the above items but considered important by the judgment of experts. For example, when the terrain is related to unusual natural phenomena, and the identification of specific motifs and plants | | | | |

## Appendix 2 Geomorphological attributes information sheet

<table>
<tr><th colspan="4">Geomorphological Attributes Information</th></tr>
<tr><td>Survey Area<br>(Year<br>- Map Sheet Name)</td><td></td><td>Previous Survey<br>Information</td><td></td></tr>
<tr><td>Map Sheet Number</td><td></td><td>Grid Number<br>- Serial Number</td><td></td></tr>
<tr><td>Landform Unit<br>(Symbol)</td><td></td><td>Grade</td><td></td></tr>
<tr><td colspan="4">(Insert Photo)</td></tr>
<tr><td rowspan="2">Geomorphic<br>Process</td><td>Exogenous<br>Processes</td><td colspan="2">□ Weathering □ Mass Movement □ Biological Process<br>□ Erosion(River, Ground Water, Wave·current, Wind, Others)<br>□ Deposition(River, Ground Water, Wave·current, Wind, Others)<br>□ Others</td></tr>
<tr><td>Endogenous<br>Processes</td><td colspan="2">□ Tectonism □ Volcanism</td></tr>
<tr><td rowspan="5">Component<br>Material</td><td rowspan="2">Bed Rock</td><td>Geological Feature</td><td>Weathering Grade</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">Sediment</td><td>Grain Size</td><td>□ More than 256㎜ □ 64-256㎜ □ 2-64㎜<br>□ 0.0625-2㎜ □ Less than 0.0625㎜</td></tr>
<tr><td>Roundness</td><td>□ Angular □ Subangular □ Subrounded □ Rounded</td></tr>
<tr><td>Soil</td><td colspan="2">□ Absence □ Presence ( )</td></tr>
<tr><td>Landcover<br>State</td><td colspan="3">□ Vegetation(Forest, Grass) □ Barren(Beach, Riparian, Rocks)<br>□ Agricultural Land □ Water(River, Lake)<br>□ Wet Land(Inland Wetland, Riparian Vegetation, Coastal Wetland)<br>□ Used Area □ Others ( )</td></tr>
<tr><td rowspan="2">Disturbance<br>Factor</td><td>Natural factor</td><td colspan="2">□ Absence □ Presence ( )</td></tr>
<tr><td>Artificial factor</td><td colspan="2">□ Absence □ Presence ( )</td></tr>
<tr><td>Environmental<br>Monitoring</td><td colspan="3">Necessary, Unnecessary ( )</td></tr>
</table>

| | |
|---|---|
| **Site Description** | |
| **Notes** | |

## Appendix 3 Geomorphological evaluation sheet

Geomorphological Evaluation

| | | | |
|---|---|---|---|
| Survey Area (Year - Map Sheet Name) | | Previous Survey Information | |
| Map Sheet Number | | Grid Number - Serial Number | |
| Landform Unit (Symbol) | | | |

| Index | Sub-Index | Evaluation | | |
|---|---|---|---|---|
| | | Score | Description | Notes |
| Representativeness | Regional Representativeness | | | |
| | Typicality | | | |
| Scarcity | Frequency | | | |
| | Pattern | | | |
| Specificity | Differentiation | | | |
| Impossibility of Reproduction | Sensitivity | | | |
| | Natural History | | | |
| Academic and Educational Value | Academic Value | | | |
| | Educational Value | | | |
| Naturalness | Conservation | | | |
| Diversity | Components | | | |
| | Landscape Diversity | | | |
| Scale | Size | | | |
| Notice | (                ) | | | |

| | | | | | |
|---|---|---|---|---|---|
| Total Score | | Weighted Score | | Grade | |

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