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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Framework to prioritize watersheds for diffuse pollution management in Korea: application of multicriteria analysis using the Delphi method" *by* G. Lee et al.

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Dear Prof. Jose Manuel Antón

We thank for your valuable and very scrupulous comments. I tried to sincerely response to all of your comments as explained below. I have corrected the title number and equation 9 that you have pointed out in page 9 and 8, respectively. I was embarrassed to that mistake. In order to help readers understand, I have included few figures to present the collected data. Since this study used 26 estimation criteria for 814 subbasins that covering the whole country, showing details about data used for estimation and computation procedures in the paper is difficult. In our future study, we will develop

a policy for the management of nonpoint pollution source after selecting priority regions for management. Monitoring will be required for this future study. The purpose of this study is to provide scientific information for the selection of regions where a policy of nonpoint source can be applied. Even though many efforts have been carried out by Department of Environment in Korea for reducing the emissions of pollution source, there are still difficulties in management of industries such as livestock industry that are the main pollution source due to their close relationship with individual income and regional economy. So far, therefore, local governments prioritize regions where technical assistance for the management of nonpoint source is requested. However, this method can not control the regions that really need management. Therefore, this study is trying to provide procedures to achieve water quality goal based on characteristics of regions by monitoring the application of policy scenarios for improvement of water quality in the example areas selected from priority regions. Thank you very much for your consideration.

Best regards, Gyumin Lee

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2019-152/nhess-2019-152-AC1-supplement.pdf

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When values of each evaluation item for 814 small watersheds were determined, some data items were not measured or missed. As for the water quality data, if there is a water quality observatory in a watershed, the data were obtained from it, and if there is no such observatory and thus no measurement was available, data from an adjacent watershed or lake were analyzed and utilized. As for flow rate, if a small watershed consists of a single basin, the measurement of flow rate is attributable to the watershed. On the other hand, if there is another upstream small watershed, the measurement cannot indicate the characteristic of a single small watershed. In order to improve this problem, the flow rate, rainfall, and areas of the upstream basin and small watershed were used to calculate a specific discharge and determine the flow rate of each small watershed.

$$Q_2 = \frac{P_2}{P_1}\frac{A_2}{A_1}Q_1 \quad (9)$$

where, Q is flow rate, P is rainfall and A is the basin area at the calculation point of flow rate. The subscript 1 means the reference point, and the subscript 2 indicates the calculation point of flow rate.

Since many small watersheds including estuaries do not have any measurement even at the level of middle watersheds, such watersheds were left unmeasured and a low score was given without using data of adjacent small watersheds. In addition, if necessary, flow rate data of a dam were also utilized to represent runoff characteristics of small watersheds.

Collected data were spatially distributed as Fig.3.

(2) Standardization of evaluation items

Because each dataset for evaluation items has different units and properties, standardization is required to use datasets for evaluation. The re-scaling method was adopted in the standardization process. The overall range of data was normalized to assign values between 0 and 1, as described in the equation (10).

$$X_i = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (10)$$

where, X_i is the i-th standardized value, x_i is the i-th data value, x_{max} is the maximum value, and x_{min} is the minimum value. However, in case the data collected are used to standardize evaluation items without modification, the standardized scores are often either biased or equalized in their range and distribution according to characteristics and types of data. Accordingly, since it seemed to be unreasonable to apply the above equation with no modification, the data collected were prioritized and the consequential order of priority was scored before the equation was used for standardization.

3.4 Assessing Vulnerability

The vulnerability of every small watershed to diffuse pollution was evaluated by using data and weights for each factor, and the vulnerable areas were determined based on this assessment (Fig. 4). In addition, the small watersheds were prioritized again in each of 4 large watersheds, and top 30 small watersheds are illustrated in Fig. 5. This was because the pollution source management and relevant policies were organized based on the large watersheds. Both ranking and ratio methods were applied to calculate weights.

Fig. 1.

C3

Among top 50 small watersheds in the order of priority in each large watershed, main rivers and small watersheds, which required diffuse pollution source management, were derived in each river system.

Han River basin has 3 priority control target river: down stream of Namhan River, Mid-down stream of Han River and Anseong stream. Geum River basin has 4 priority control target river: mid stream of Geum River, Dongjin River, Mankyeng River and Sapgyo stream.

Youngsan River basin has 2 priority control target river: Youngsan River and Sumjin River. Most vulnerable area of Nakdong River basin is in main stream of Nakdong River.

The evaluation results were analyzed in terms of effects of each evaluation factor. It turned out that if a large number of livestock are reared and much fertilizer is used in a basin, the land area is wide and the public water has much soil and high SS concentration, such a watershed needs to be preferentially managed.

4 Conclusion

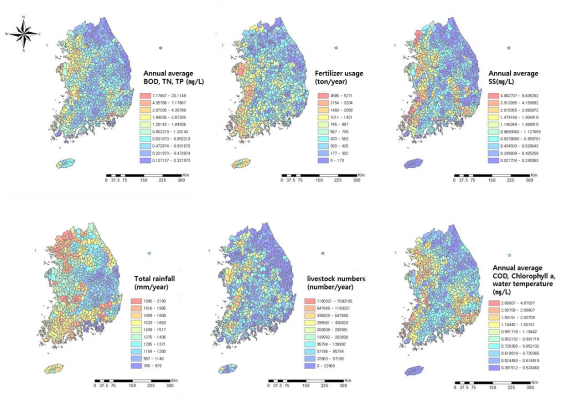
There are little studies to assess watersheds in respect of the diffuse pollution management in Korea. This study has suggested a scientific analysis method for selecting priority areas in the current diffuse pollution management system. As various uncertain factors are included in assessing vulnerable areas to diffuse pollution sources, such factors need to be quantified and analyzed objectively and scientifically. The Delphi method was used to determine the vulnerability evaluation items, which included basin characteristics, pollution source and water quality, and weights for diffuse pollution, on the basis of expert opinions. Criteria and sub-criteria were allocated into three groups of pollution source, hydrologic process, and receiving water. Based on the weights and evaluation items thus obtained, data of each item were applied, and the vulnerability to diffuse pollution was assessed by the TOPSIS method. The proposed evaluation process will promote efficient policy implementation and set a foundation for scientific/clear diffuse pollution management.

In addition, this study attempted a small watershed-based analysis for more selective/intensive policy enforcement. However, it was difficult to standardize quantitatively each evaluation item, which was needed to determine management areas, at the level of small watershed. Accordingly, a runoff model needs to be applied to improve the estimations for unmeasured areas. A vulnerability assessment system for diffuse pollution is also to be established in order to promote efficient policy enforcement. Such system should update relevant data and enable cyclic reevaluation.

Finally, this study has not reflected the current diffuse pollution management policy in the list of evaluation items. It was because the effect of the policy could not be accurately quantified. A further study will solve this problem and include the current policy in assessment.

Fig. 2.

C4



5 **Figure 3: Sample of collected data sets.**

Fig. 3.