

## ***Interactive comment on “Prioritization of water management under climate change and urbanization using multi-criteria decision making methods” by J.-S. Yang et al.***

**J.-S. Yang et al.**

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The subject of the paper is relevant for HESS and the special issue “Assessing the impact of climate change for adaptive water management in coastal regions”, it is well written and generally well organized, and the selection and application of methods appear to be sound. However, more emphasis should be put on describing the hydrological setting and relevant climate change impact issues. I have personally no experience with multi-criteria decision analysis or the applied models, but although the approach appears to be sound, I find that the description of the approach and the investigated

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setting need to be clarified and improved, significantly. It is necessary to improve the manuscript in several ways for readers to better understand why and how the study were conducted, the hydrological setting and how the methods were applied before final publication.

C1) There are many tables (11) and fewer figures (4) in the paper, - I suggest changing 3-5 tables to figures. This would make the paper easier and more interesting to read – see section on specific comments for concrete suggestions. Ans) We changed 5 tables (1, 2, 4, 6, and 10) to figures as reviewer proposed.

C2) Figures are generally of acceptable quality except for Fig. 2 - see next section on specific comments. Ans) We redraw fig. 2.

C3) To better understand and clarify the objectives of the study, the projected climate change and urbanization impacts and the investigated setting, further details and clarification on the following subjects are needed:

1) How are the target instream flow needs and BOD defined – what are the projected (“feared”) impacts of climate change and urbanization on instream flow and BOD, water resources and ecological status of relevant ecosystems? – please laborate further in general terms Ans) We added some sentences to explain how to get the target instream flow needs and BOD concentrations and to define target instream flow and BOD concentration as follows: The instream flow is the amount of water needed in a stream to adequately provide for downstream uses occurring within the stream channel and the target BOD conc. is the daily average determined by local governments. This study watershed covers some or all of the following uses that extend beyond the need for aquatic habitat, recreation, riparian vegetation and water quality. The target instream flow and BOD conc. for all sub-watersheds were collected from Lee and Chung (2007b) and Chung et al. (2011b); they were calculated by considering the stream flow seasonal variability and the fish habitat suitability at this step.

In the introduction, we added some sentences to explain the second question as fol-

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lows: Both urbanization, primarily through the construction of impervious cover, and climate change, mainly through extensive increase of temperature and severe variation of precipitation, progressively impacts the hydrologic, physical, and biological qualities of aquatic health. That is, urbanization increases annual storm water runoff, diminishes baseflow, degrades stream habitat conditions, deteriorates water quality, and reduces the diversity of aquatic insects, riparian plants, and fish (CWP, 2005). In case of climate change, the resulting impacts on instream flow, BOD conc., and ecological status of relevant ecosystems varies in different localities.

2) What is the actual use of groundwater collected by subway stations, how/why is it collected and how can it be used for mitigating negative effects of climate change and urbanization?). Ans) We added the relevant explanation as follows: The groundwater collected by subway (Alt 4) is transferring to the wastewater treatment plant through sanitary sewers. The groundwater quantity is relatively enough and the quality is very clean. Therefore, the groundwater should be transferred to the depleted streams for the target instream flow and BOD concentration. It can increase the numbers of days to satisfy the EIF due to the increase of instream flow.

3) The structure of the water supply systems in the investigated area (the ratio between the amounts of surface water and groundwater used for water supply) Ans) In the description of the study watershed, we added the relevant explanation as follows: The water supply systems in the study watershed are mainly surface water (approximately over 98%). But private groundwater supply systems are used, occasionally. It cannot be measured because it is illegal (Lee et al., 2008).

4) Threats to water supply and relevant ecosystems in and associated with the investigated watershed(s) – what are the main concerns? It appears to be both quantitative and chemical/ecological status, but this should be clarified further. If data are available for indicators of chemical status other than BOD such as e.g. nutrients please provide a table showing these even though they are not included in the analysis. Such data would be important for comparison with other related watershed studies. Information

on the major sources to and components of the BOD would also be relevant information to include. Ans) We didn't consider SS, N, and P since both central and local governments have no interest in other pollutant problems, now. However, it will definitely be necessary to consider N and P in near future. We added the relevant sentence in the article.

5) Additional information on results of downscaled GCMs should be presented and illustrated in section 4.2. Ans) We added a figure and some sentences as follows: The daily mean temperature and precipitation are calculated for the study watershed using CGCM3 model output from A1B and A2 emission scenarios for the future scenarios (2011-2100) and SDSM. Chung et al. (2011) showed the procedure and results for calibration and verification. From the Mann-Kendall test (2010-2100), it can be estimated that Seoul and Suwon weather stations have a strong tendency for increasing temperatures and precipitation as shown in Fig. 2. The ave. temperature at Seoul and Suwon stations would increase by 1.6°C and 2.0°C under A1B and 2.0°C and 2.4°C under A2 during the period 2010-2100, respectively. Especially, the summer temperature of Seoul (A2) would increase up to 4.2°C. The ave. precipitation at Seoul and Suwon stations are 1896.9 mm and 1679.5 mm under A1B and 2029.5 mm and 1803.6 mm under A2. Especially, the summer intensity of Seoul station increased severely from 845.9 mm to 1317.3 mm (A2) and the remaining seasons didn't show any extreme increases.

Fig. 2. Summary of forecasted temperature and precipitation results

Point 1 and 2 should probably be described in the introduction while point 3 and 4 should be included in the current section 3 describing the investigated watershed(s). However, I suggest moving section 3 up before the methodology descriptions in order to better understand the investigated system before presenting the different applied methods Ans) We revised all as reviewer proposed.

Tables: As mentioned under general comments I suggest to change 3-5 tables e.g.

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Table 1, 2, 4, 6 and 11 to figures. Ans) We changed five tables (1, 2, 4, 6, and 11) to figures.

Figures: Figure 2 must be improved as it is hard to see exactly where the study site(s) are located in South Korea and some text is very hard/impossible to read. Hence, the size of the map of South Korea with the location of the study site should be increased including the fonts of the geographical coordinates. Fonts in the maps of the different sub-watersheds and the scale bar should be increased in size especially for the DR watershed. Ans) We redraw fig. 2.

Figure 3. EIR below the figure should be changed to EIF. Ans) We revised it.

A figure in section 4.2 illustrating the downscaled projected changes of SRES scenario A1B and A2 would be helpful Ans) We added a figure to illustrate the downscaled projected changes of SRES scenario A1B and A2. You can see Fig. 2.

Comments to specific lines in manuscript: P9890, L15: Change “Since” to “As” Ans) We changed it as the reviewer indicated.

P9890, L15-17: It is unclear to me what a cost component above 0.127 is, and how the collected groundwater is used – this should be clarified (note! Also that another measure apparently is preferred in the conclusion) Ans) We changed “cost component” to “the cost component weighting value” for clarity. We added a specific description related to Alt 4 as follows: Since the groundwater level in the study watershed is fluctuated all year around, groundwater gets into subway station occasionally. Most subway stations forced the groundwater transferring to the wastewater treatment plant through sanitary sewers in usual. However, the groundwater quantity is relatively enough and the quality is very clean. Therefore, the groundwater should be transferred to the depleted streams for the target instream flow and BOD concentration through the pumping device and transfer system (Alt 4).

P9891, L21: change “Many research have studied: : :” to: “Many studies have investi-

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gated: : :” Ans) We changed it as the reviewer indicated.

P9893, L1-2: Change “target instreamflow requirements.” to “target instream flow needs.” and consider describing how this and the target BOD were defined Ans) We added them as the reviewer indicated. The instream flow is the amount of water needed in a stream to adequately provide for downstream uses occurring within the stream channel and the target BOD conc. is the daily average determined by local governments. This study watershed covers some or all of the following uses that extend beyond the need for aquatic habitat, recreation, riparian vegetation and water quality. The target instream flow and BOD conc. for all sub-watersheds were collected from Lee and Chung (2007b) and Chung et al. (2011b); they were calculated by considering the stream flow seasonal variability and the fish habitat suitability at this step.

P9894, L25: Change “measurers taken into.” to “measures taken to ...” Ans) We changed it as the reviewer indicated.

P9898, L15-17: Describe what the most important quality and quantity problems are and whether it is in relation to water supply or ecosystem needs Ans) We added the relevant explanations in the study watershed description section as follows: That is, since base flows of three watersheds are very small, it can be easily guessed that the instream flow would not be enough. Especially, DR shows the depleted stream during all dry periods (Oct. ~ April). That is, since average BOD concentrations of three study watershed are too high (over 10 mg/L), it is definitely necessary to develop some measures for the reduction of BOD concentration. As a result, fish of the study watershed have died frequently from rainfall events.

P9899, L9-17: Consider presenting the data from the different watersheds in a figure preferably also with additional quality data on e.g. nutrients if available Ans) We didn't use nutrients because it is not available.

P9900, L 11-20: It would be very helpful to show the projected climate change in a figure for easier overview Ans) We added Fig. 2 and a specific description in section

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3.3.

P9901, L2: Change (no more urbanization) to (no increase in urbanization) Ans) We changed it as the reviewer indicated.

P9901, L12-15: More details on the setup, results and performance of the HSPF model described in Chung et al. (2011b) are needed e.g. the RMSEs Ans) Since Nash-Sutcliffe coefficient is more objective than RMSE to flow rate in general, we added the values in the article as follows: In case of flow rate, Nash-Sutcliffe coefficients showed 0.67~0.81 for calibration and 0.62~0.72 for verification and in case of BOD concentration, RMSE showed 1.61 ~ 4.43 mg/L for calibration and 1.95~15.18 mg/L for verification.

P9907, L1: this is not in agreement with the abstract?? Ans) The abstract is wrong. We changed it as the reviewer indicated.

Please also note the supplement to this comment:

<http://www.hydrol-earth-syst-sci-discuss.net/8/C5931/2012/hessd-8-C5931-2012-supplement.zip>

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 9889, 2011.

**HSSD**

8, C5931–C5947, 2012

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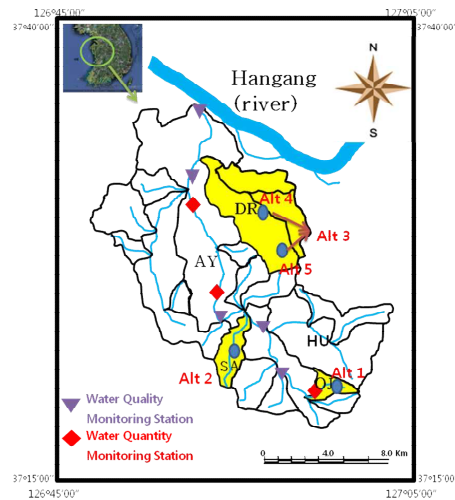


Fig. 1. Map of the study watershed

Fig. 1.



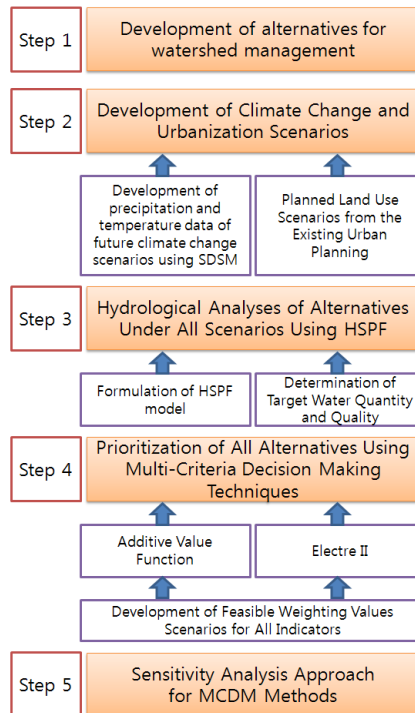


Fig. 2. Procedure of this stud

Fig. 2.

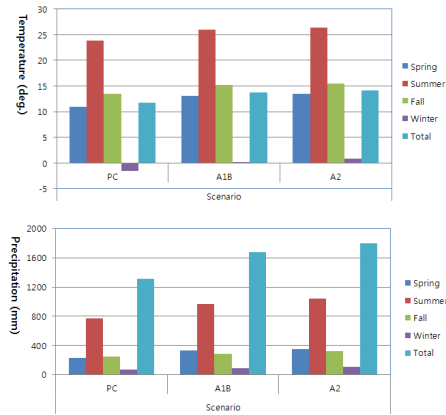


Fig. 3. Summary of forecasted temperature and precipitation results

Fig. 3.

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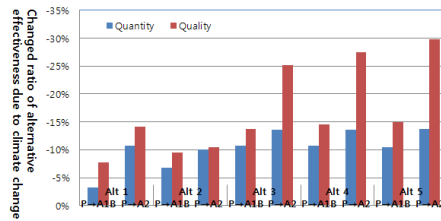


Fig. 4. Changed ratio of alternative effectiveness due to climate change

Fig. 4.

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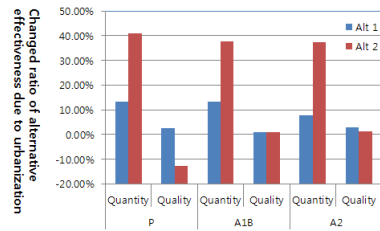


Fig. 5. Changed ratio of alternative effectiveness due to urbanization

Fig. 5.

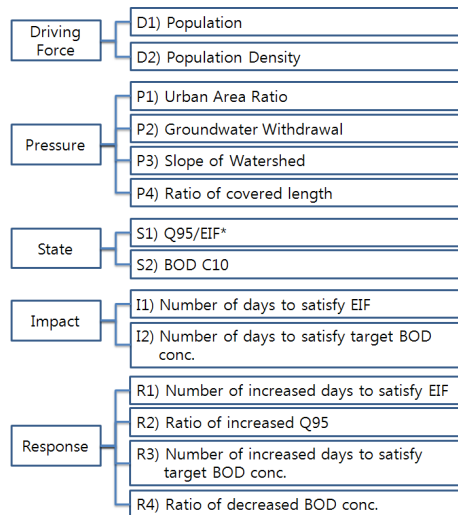
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\* EIF: Environmental Instream Flow

Fig. 6. Evaluation criteria based on DPSIR framework

Fig. 6.

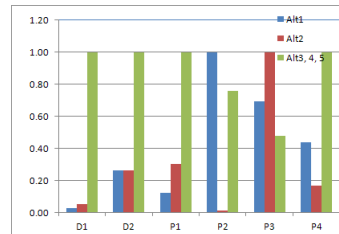


Fig. 7. Standardized values of driving force and pressure

Fig. 7.

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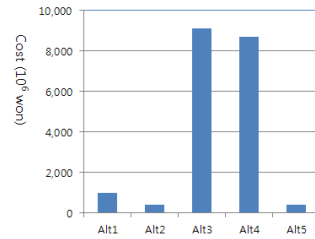


Fig. 8. Cost of all alternatives

Fig. 8.

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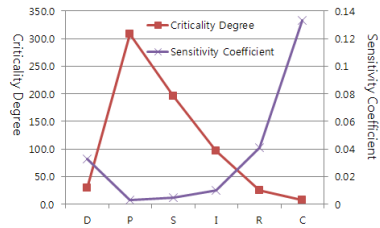


Fig. 9. Criticality degrees  $D_k$  and sensitivity coefficients  $sens(c_k)$  of the six criteria.

Fig. 9.

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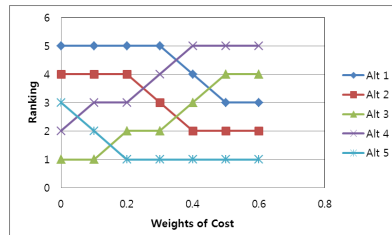


Fig. 10. Ranking trajectories of all alternatives to weights of cost

Fig. 10.

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