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Hydrology and Earth System Sciences Discussions

HESSD

8, C5913–C5930, 2012

Interactive Comment

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

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General comments In this paper, multi-criteria decision making techniques are used to evaluate five different alternative management strategies concerning their effectiveness to guarantee environmental flow under climate change and urbanization conditions. Although I find the topic interesting, in the current form, the paper is hard to follow. A clear formulation of the problem is missing and the work is based on number of (hydrological) methods which are not explained in the paper. The authors also did not account for the uncertainty related to climate change projections and the hydrological modeling.

Specific comments C1) I found some parts of the manuscript hard to follow. For example, I miss a clear formulation of the management problem. What is the specific problem in the catchment and how would the suggested measures contribute to a solution. Related to that, I would suggest to put the catchment description in front of the methodology section. Ans) We moved the catchment description in front of the methodology section and added the following sentences to explain the specific problems in the study watershed as follows: This study was applied to the Anyangcheon watershed which has suffered from potential streamflow depletion and possible water quality deterioration (Chung and Lee, 2009). Therefore, some local governments had strong political wills to restore the distorted hydrological cycle through some suggested measures as follows: redevelopment of the existing reservoir, reuse of treated waste water effluent, use of groundwater poured into subway stations and construction of a small waste water treatment plant. Four kinds of alternatives are intended to secure the abundant instream flow and induce water quality enhancement.

Also we added a clear formulation of the management problem in the section 4.1 as follows: The small reservoir in OJ was built for the agricultural uses about fifty years ago. Now, it, however, is not used anymore for that reason because the agricultural area has been substituted by the urban. Therefore, the reservoir should be redeveloped for the target instream flow (Alt 1). 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).

C2) Your work is based on the modeling results presented in Chung et al. 2011. To enable the reader following your study without thoroughly reading the complete Chung et al. paper, I would suggest including a short description of the hydrological model and the downscaling method in your methodology section. Related to that I would also strongly recommend to clearly separate between the results you produced yourself and results you got from Chung et al. 2011. You shouldn't present the results of Chung et al. 2011in your result section. Ans) We added some sentences to explain your questions as follows: 3.2 Hydrologic model This study modified Chung et al. (2011)'s HSPF model to estimate flow rate and BOD loads in the Anyangcheon watershed. HSPF requires physical (topographic and land use) and climate data and stream flow and water quality data are required for calibration and validation. Therefore, a 1:25000 digital elevation model (DEM) and landuse map of the year 2000 of the study watershed were used as physical data. Also, climate data (daily precipitation, temperature, ave. wind speed, ave. humidity, and ave. solar radiation data) of Suwon and Seoul weather stations operated by Korean Meteorological Administration (KMA) were introduced to the climate data input of HSPF since the study watershed is located between two stations. Stream water quantity and quality data were obtained from Lee (2007) and Ministry of Environment of Korea. This study used the validated HSPF model of Chung et al. (2011) which had showed the results of sensitivity analysis and results of calibration and validation. 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.

3.3 Downscaling method 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 senarios (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 1.6âĎČ and 2.0âĎČ under A1B and 2.0âĎČ and 2.4âĎČ under A2 during the period 2010-2100, respectively. Especially, the summer temperature of Seoul (A2) would increase up to 4.2âĎČ. 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.

C3) Being a natural science-oriented hydrologist and quite a novice concerning the multicriteria decision making problem, I would find it very convenient to have a bit more comprehensive introduction into the multi-criteria decision making topic. For example by introducing terms like the payoff matrix shortly. Section 4.1 What is the rationale behind the proposed alternative watershed management strategies? Why did you choose them and what is the benefit regarding the management problem. I would rather put them into the methodology section, as they are not a result of an analysis you presented in the manuscript. It would be also interesting to know, what you mean by using groundwater which is collected in the subway (how is it collected, where is it stored and pumped etc.; are the cost for pumping included in the cost estimates presented in Table 6). Ans) We added the concept of payoff matrix as follows: This study used the concept of payoff matrix which consisted of rows and columns. Each row represents one action that the decision maker might or might not freely choose to perform and each column represents a possible state of nature. At the time the decision must be made the decision maker assumes that one of the columns represents the actual decision situation, but the decision maker does not know which column is the correct one. The cell of the matrix represent payoffs that the decision maker would receive if the decision maker chose the action represented by a particular row and the actual state of nature were the one represented by a particular columns.

Also, we added a rationale behind the watershed management strategies as follows: The small reservoir in OJ was built for the agricultural uses about fifty years ago. Now, it, however, is not used anymore for that reason because the agricultural area has been substituted by the urban. Therefore, the reservoir should be redeveloped for the target instream flow (Alt 1). 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). This study considered the cost of the pumping device and transfer system.

C4) I have some serious reservations how climate change is handled. The climate change scenarios presented, are based on the downscaled outputs of just one global climate model. It is widely known that especially the precipitation outputs of global climate models are highly uncertain. Different climate models usually produce different precipitation trends. While one model expects decreasing precipitation other models may project increasing precipitation amounts. There is also the uncertainty connected to the intra-annual distribution of precipitation which can be quite different among several climate models. Additionally, recent studies have shown that also the downscaling method can contribute significantly to the uncertainty envelope. Related to the latter, I'm also missing a description of the downscaling method (not the name of the software, but the approach used in the software). I would recommend analyzing the results of other climate models. At least, a discussion about the uncertainties should be included in the manuscript. Stating clearly, this is just one among several possible future climate change projections. Ans) This study focused on the decision making procedure development considering climate change and urbanization. Therefore, we included just one GCM model for the clarity. In addition, it will take lots of days to use more general circulation models. Please understand our limitations. We added the reason in the article.

C5) Usually Rainfall-Runoff models are subject to large parameter uncertainty. As the performance of the model is not reported in the manuscript, I had a look in the Chung et al. paper. Although the model efficiency was reasonable, I had the impression that especially during the recessions, significant deviations are present. As you focus on discharge during dry periods, this might be of importance. Therefore, it would be interesting to know not only the standard Nash-Sutcliffe efficiency but also the logarithmic one, which gives more emphasis on the low flows. Ans) We calculated the logarithmic Nash-Sutcliffe coefficient in our article. But there is no big difference between two numbers (0.67∼0.81 and 0.62∼0.76). Therefore, we didn't add the relevant description in the article.

C6) P9903, l.19-25 and Table 7 It would be interesting to know, which random values were assigned. I find it very surprising that although random numbers were chosen, no change (compared to the other scenarios) can be recognized concerning the prioritization. Can you comment on this? How to do explain, that you get quite serious different results for AVF and Electre II (e.g. for alternative 4)? Which method would you trust more? Ans) We added the following sentence to solve the reviewer's question. The rankings in Table 7 mean not the fixed values but the most plausible (e.g. the most frequent at all cases).

Also, we added the following question to answer the reason why quite different results for AVF and ELECTRE II come out.

As shown in Sections 3.5 and 3.6, Electre II and AVF prioritize all alternatives with totally different algorithms. We, therefore, cannot select one method to be more trustful. If you want to determine all ranking with comparatively exact weighting values, AVF will be more convenient. Otherwise, Electre II which can show the outranking priorities will be more effective.

C7) Figure 3 I did not fully understand why you introduced driving force and pressure as evaluation criteria. While I understand that it would be beneficial to reduce P2 (groundwater withdrawal), I do not see how you can judge the others. For example how do you score things like the slope? What is meant by ratio of covered length? Ans) The explanations on Fig. 3 were shown in Chung and Lee (2009). So we added some detail sentences as follows: As shown in section 3.4, since driving force and pressure components should include the socioeconomic factors and anthropogenic activities, population (D1) and population density (D2) were selected for driving force and urban area ratio (P1), groundwater withdrawal (P2), slope of watershed (P3), and ratio of covered stream length (P4) were included to pressure component. P1 can affect both water quantity and quality directly and P2 and P3 have positive tendency with stream flow quantity during the dry period. P4 can decrease water quality due to intervention of sunlight and inflow of untreated wastewater. All values of Driving force ( ), and Pressure ( ) for five alternatives were collected and aggregated from statistical data and GIS analyses, as shown in Table 4. In addition, since state and impact components are related to the resulting environmental conditions and environmental consequences resulting from these conditions, 95-percentile flow (Q95) over environmental instream flow (EIF) (S1) and 10-percentile BOD concentration (C10, S2) which resulted from HSPF simulation were selected in state and numbers of days to satisfy EIF (I1) and target BOD concentration (I2) were included to impact. Finally, since the response should reflect the effectiveness of measures taken to improve the environmental state, four criteria which are numbers of increased days to satisfy EIF (R1) and target BOD concentration (R3) and ratios of increased Q95 (R2) and decreased BOD C10 (R4) were chosen. All values of State ( ), Impact ( ) and Response ( ) were derived by analyzing the simulation results of HSPF, as shown in Table 5. Since the cost ( ) must be considered for sustainable management, all costs were estimated, as shown in Table 6.

Technical corrections In your conclusions you state, that Alt 5 is found to be the most preferred one, which would be the construction of a small treatment plant in DR. However, in the abstract you state that the use of groundwater collected by the subway would be the preferred alternative. Ans) That is our mistake. We changed it.

P9903, l.6: insert “selected” after “Fourteen criteria are . . . ” Ans) We changed it as the reviewer indicated.

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P9904, l.22: correct to 0.6 Ans) We changed it as the reviewer indicated.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/8/C5913/2012/hessd-8-C5913-2012-supplement.zip

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

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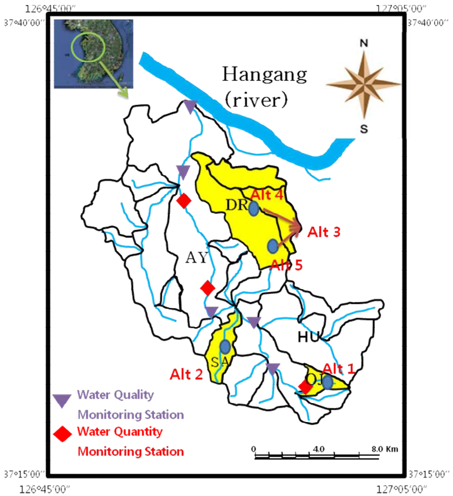

Fig. 1. Map of the study watershed

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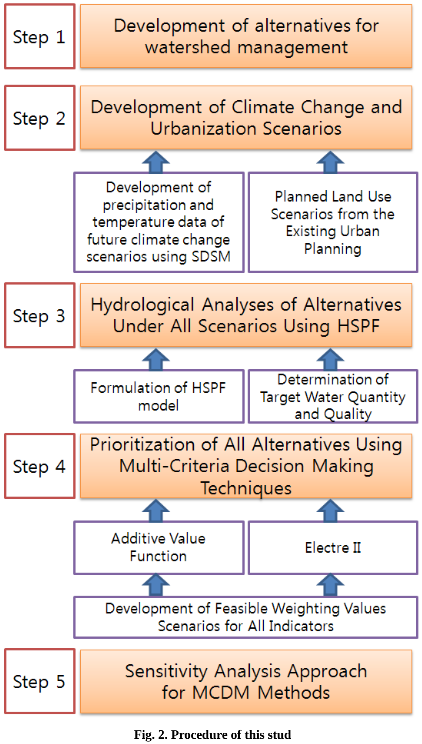

Fig. 2. Procedure of this study

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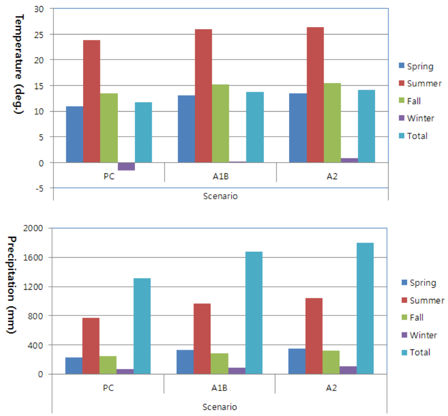

Fig. 3. Summary of forecasted temperature and precipitation results

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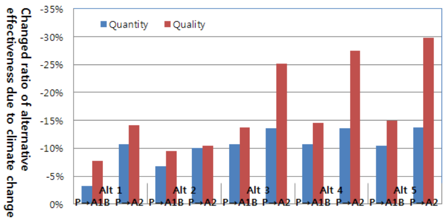

Fig. 4. Changed ratio of alternative effectiveness due to climate change

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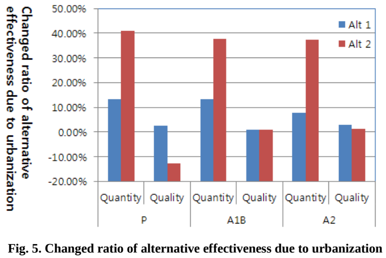

Fig. 5. Changed ratio of alternative effectiveness due to urbanization

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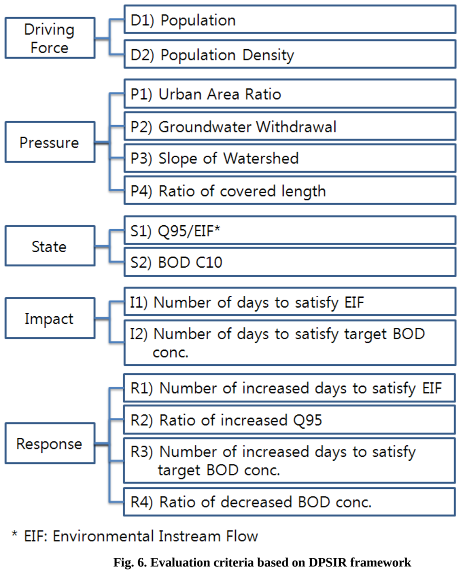

Fig. 6. Evaluation criteria based on DPSIR framework

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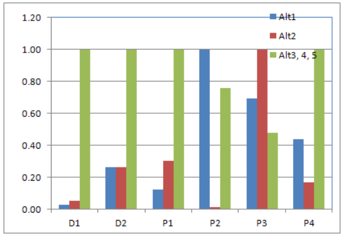

Fig. 7. Standardized values of driving force and pressure

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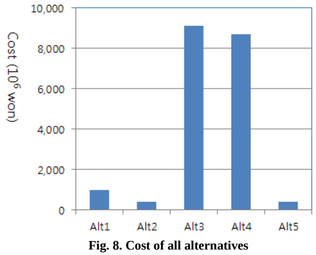

Fig. 8. Cost of all alternatives

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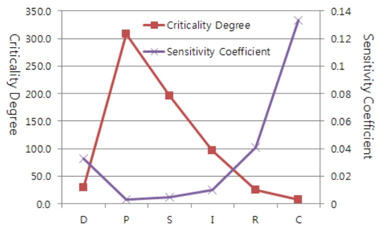

Fig. 9. Criticality degrees $D_k^{'}$ and sensitivity coefficients $sens(c_k)$ of the six criteria.

Fig. 9. degrees and sensitivity coefficients of the six criteria.

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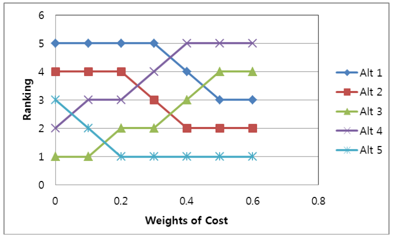

Fig. 10. Ranking trajectories of all alternatives to weights of cost

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