Hydrol. Earth Syst. Sci. Discuss., 3, S1616–S1623, 2006
www.hydrol-earth-syst-sci-discuss.net/3/S1616/2006/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Modeling and analysis of collective management of water resources" *by* A. Tilmant et al.

A. Tilmant et al.

Received and published: 6 December 2006

The authors would like to thank reviewer 1 for his thorough and meticulous review. We hope this note together with the updated manuscript will clarify the issues raised by the reviewer.

Anonymous Referee 1

Received and published: 27 October 2006

This paper presents a model for the participatory (collective) management of a multi-purpose reservoir, using stochastic dynamic programming, combined with fuzzy sets, as well as Analytic Hierarchy Process for the prioritization (relative importance) of the objectives. Although the subject and the application are interesting, the paper could

greatly improve by giving more details about the weight extraction, as well as by using a different fuzzy aggregator for the objectives.

Reviewer evaluation for specific questions: 1) Does the paper address relevant scientific questions within the scope of HESS? Yes

2) Does the paper present novel concepts, ideas, tools, or data? No. From the mathematics/modelling/tools point of view there is nothing new. The concept again is not new. In fact there is another application/case study of the concept published by the same authors in a previous paper (Reference mentioned in the paper: Tilmant et al 2002b). The only relatively "new" addition/element is the introduction of the Analytic Hierarchy Process (AHP) (Saaty, 1980) (a well-known, established and old technique for prioritization) for extracting the relative weights for the objectives. However there are several comments about it: (a) AHP is very old technique. There exist a significant number of published papers about it and its variations/advantages/disadvantages. Apart from the general (26 years old) Saaty book, no other recent reference is given.

The section 3 dealing with AHP has been revised: more background information about AHP and MAHP are now given, including their advantages and disadvantages. Additional and more recent references concerning the use of AHP/MAHP in water resources management are also given.

(b) The authors chose to apply only the most simple 1-9 arithmetic scale for extracting weights, although there exist other scales (e.g. exponential or fuzzy), which could be used alternatively, in order to establish the robustness/sensitivity of the proposed weights/model. Moreover the eigenvalue technique (Equation 4) is not the only one in literature for extracting weights. What about the other existing methods (e.g. logarithmic least squares)? There is strong evidence in literature that they are sometimes better. Have the authors used them and compared results?

The authors have not used exponential nor fuzzy scales to extract the weights. AHP was used here to generate a first set of weights which were then validated (adjusted)

HESSD

3, S1616–S1623, 2006

by the three experts based on their knowledge of the hydro system. Consequently, testing different scales was not a priority in this work.

(c) The data (coefficients aij) for matrix A (Equation 4) are not given. The reader does not even know the preference levels assigned by the decision makers. Also there is no mention of any consistency check, referring to the "participatory" choices - a standard feature in all AHP models, establishing the validity of the procedure. What was the consistency index of matrix A for extracting the weights presented in Table 3? What were the linguistic preferences of the decision makers?

The information used to generate the matrix A is now given in section 5 and the corresponding consistency ratio is 0.016

(d) Moreover, it is not clear whether there have been one or multiple decision makers, as far as weight estimation is concerned. In the case of a single decision maker, a single weight vector (like the one presented in Table 3) is enough. However, should there be multiple decision makers, the authors should make clear how they obtained a single weight vector, because there exist various techniques in literature for extracting a single weight vector from multiple decision makers.

Three experts reached a consensus on a single weight vector, which was obtained from the 'empirical' adjustment of the weight vector obtained from AHP. This 'empirical' approach was made possible because the number of experts and objectives was limited. In case of more complex systems, more sophisticated approaches should be implemented to handle multiple weight vectors obtained from multiple stakeholders. This issue is now mentioned in the text and references are given for readers who are dealing with such situation.

(e) Consequently the lack of data/evidence/clarity about the AHP/Saaty process makes the weights presented in Table 3 insignificant. The reader may well assume that they have been arbitrarily chosen by the authors, unless more details are given. Apart from the comments about the Saaty AHP process for extracting weights, there are also ad-

HESSD

3, S1616–S1623, 2006

ditional comments about the membership functions and grades, mentioned in sections 2 and 3: There is nothing (mathematically) new about the fuzzy aggregation operators described in these sections. In fact they are the three simplest aggregation operators in literature: The min operator is the fuzzy intersection, the max is the fuzzy union and the p=1 is the weighted arithmetic mean of multiple fuzzy sets, as described in any fuzzy logic book. The “social” dimension (egalitarian, totalitarian, utilitarian) assigned by the authors to these three widely known and applied operators is interesting, but there are some comments about the “utilitarian” aggregation operator (weighted arithmetic mean) used: The authors applied the simplest numerical form for aggregation, namely the weighted arithmetic mean. However, other interesting “utilitarian” aggregators do exist. For instance the weighted geometric mean (p=0) (Equation 10), is theoretically the “median” of all existing aggregators (it lies “mid-way” between all operators). Sometimes it gives better results for fuzzy multiobjective optimisation. If the intention of the authors was to compare results between two extremes (min and max) and a well balanced “utilitarian” (or compromise) approach, mathematically their choice should be the p=0 operator (not the p=1 they used here, which is (mathematically and socially) more tolerant and biased towards the max operator). Mathematically the results (and conclusions) from Table 5 should be greatly improved and more (generally) valid, if Equation 10 (weighted geometric mean) had been used for the application, instead of the weighted arithmetic mean. The point has been discussed in literature (e.g. Klir G.J and Folger T.A. ,1988, Fuzzy sets, uncertainty and information, Prentice-Hall, Englewood Cliffs, N.J.)

The traditional weighted sum was adopted here because it was felt to be more intuitive by the three experts familiar with the system. We agree that, theoretically, more balanced results should be obtained with the weighted geometric mean. This is now stated in the text but the ultimate choice must be in line with the understanding and expectation of the decision-makers/stakeholders.

3) Are substantial conclusions reached? No. The authors discuss only the output

HESSD

3, S1616–S1623, 2006

Interactive Comment

of a single case study. The results presented in Table 5 are more or less obvious and expected, while there is no substantial discussion about sensitivity analysis and/or general conclusions as to the method or the application.

4) Are the scientific methods and assumptions valid and clearly outlined? The stochastic model is relatively clearly described. However there are several points about the weight vector, which are not clearly/adequately described and should be reconsidered. (Please refer to question 2 for details)

5) Are the results sufficient to support the interpretations and conclusions? No, results/data about the weight vector are missing (Please see question 2). The results in Table 5 should be more valid if another fuzzy aggregator had been used (Please see question 2) and the fuzzy sets for satisfaction are missing (Please see question 13).

See above

6) Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? No. There is no way for another person to reproduce/verify the results, because data are not explicitly given. Although the space of the paper is limited, the authors could make up for the lack of space by referring to a detailed report/publication (or even website), which should be available/accessible on request to any interested person. Apart from that, details about the preferences leading to the weight vector and the fuzzy membership grades should be included in this paper.

Papers on reservoir operation rarely provide detailed information on the case study for obvious confidentiality reasons. Historic flow data can be found here : http://www.seas.ucla.edu/chpr/chile/7321002.html. The main characteristics of the system are now listed in Table 4. Further information about Colbun company can be found here: www.colbun.cl. The annual report provides the latest information concerning the performance of Colbun hydropower plants.

HESSD

3, S1616–S1623, 2006

7) Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Proper credit to related work is given, although it could improve by adding references about the weight vector. However their new/original contribution is not clear (Please see question 2 for details).

8) Does the title clearly reflect the contents of the paper? Yes.

9) Does the abstract provide a concise and complete summary? Yes.

10) Is the overall presentation well structured and clear? Comments about the structure and the contents are given in question 2.

11) Is the language fluent and precise? Yes in general. However there are a few (minor) language/typo comments: Line 5, page 2709: “the management of a water resources system”, instead of “the management of a eater resource system”

Done

Line 16, page 2710: “and O a fuzzy relation related to constraint C”, instead of “and O a fuzzy relation related to the constraint C”.

Done

Line 10, page 2711: “More specifically, the membership grade 956; translates water user satisfaction” , instead of “More specifically, the membership grade 956; translate water user satisfaction” .

Done

Line 13, page 2711: “In the [0, 1] interval”, instead of “In the]0, 1[interval”.

Partially acceptable solutions are in the open interval. Partially acceptable AND fully acceptable solutions are in the closed interval.

Line 6, page 2717: “gt the system operational benefit during period t”, instead of “gt the benefit of system operation during period t”.

HESSD

3, S1616–S1623, 2006

Done

Line 26, page 2717: “are determined by a variant of SDP”, instead of “are determined from a variant of SDP”.

Done

Line 16, page 2721: “the “88-00” period”, instead of “the “88-”00 period”.

Done

12) Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Symbols: The symbol for weights is not clear. In Equations 4 and 5 the symbol w (latin letter w) is used, while later in the paper in Equations 13, 14, 16 and Tables 3 and 4 the greek letter omega is used. Obviously one of the two should change.

The symbols are now identical (omega)

Abbreviations: Line 14, page 2718: The abbreviation FSDP is used for the first time, without explanation. Explanation follows in the next paragraph. Explanation for FSDP should be in line 14.

The explanation is now given in the paragraph before eq 13.

Units/ Numerical data:

(a) Line 15, page 2719: “imposes a lower limit on the storage level therefore reducing the usable storage capacity by as much as 30

(b) Line 6, page 6: The exact numerical data for initial storage (1449hm3) is given, although it is useless for the reader, since no other data are given and the results cannot be reproduced. Moreover no qualitative definition is given, which might be useful for the reader: (e.g. Was the reservoir initially nearly full or nearly empty?) It is sufficient to mention that all simulations had the same initial conditions for storage,

HESSD

3, S1616–S1623, 2006

adding potentially a qualitative definition for the initial conditions.

Table 4 now lists the main characteristics of the system such as max storage capacity, max release, avg inflow, etc.

13) Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

Table 1 is trivial (it exists in any elementary book/introduction about Analytic Hierarchy Process) and can be omitted. It is sufficient to mention in the text that the Saaty arithmetic scale 1-9 is used.

Done

The fuzzy sets defining satisfaction for the various objectives should be added to the paper.

We cannot give all membership functions as most of them vary from month to month. However, we now give an example of two membership functions, one for hydropower, one for irrigation.

14) Are the number and quality of references appropriate? Yes, in general, apart from the weight vector extraction (Please see question 2 for details).

Section 3 has been revised and more recent references are now provided.

15) Is the amount and quality of supplementary material appropriate? Please see Question 13 General conclusion: This paper could be greatly improved if the section about the relative weights was revised and the weighted geometric mean (instead of the weighted arithmetic mean) was used for the application of the model.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 3, 2707, 2006.