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Interactive Comment

Interactive comment on "Modeling suspended sediment sources and transport in the Ishikari River Basin, Japan using SPARROW" *by* W. Duan et al.

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Response to reviewers Please find our responses to the reviewer comments below:

Reviewers' comments:

Anonymous Referee #1 This paper shows an example of the application of the statistical SPARROW model to the Ishikari River basin. As a result, the modeled result is likely reasonable to the observed annual sediment load as shown by Fig. 6. However, the Ishikari River basin is located in the subarctic region with high snow depth in winter. It should be noted that: i) The Ishikari River basin has a long period of low flow and sediment load in December to mid-March with high snowfall. For this period, sediment load is very low except for the temporary snowmelt at positive degree air temperature. ii) High flow and sediment load are observed in the snowmelt season of mid-March to May and in heavy rainfalls in May - late November. Thus, (1) the sediment load estimated by the SPARROW model should focus only on the snowmelt and/or rainfall river runoffs. Otherwise, the authors should explain such a natural condition as the background of the river basin to the readers, and apply the SPARROW model to river runoffs for the limited period. (2) If the "developing land" produces the high sediment yield even in winter, they have to state why and how the high sediment yield is produced. The authors had better explain the sedimentary situation of the developing land in detail. (3) The explanation of data sets utilized in the model is not enough: How and when were the sediment load data acquired at the 31 gauging stations? (4) If many data are missing, is there some criterion for the limit of the application of SPARROW? (5) Actual evapotranspiration from the river basin is never explained in the text. The effective rainfall in the rainfall season is one of important parameters to produce river runoffs and sediment load. The authors should utilize the MET data at many weather stations in the river basin for the modelling. Response: These comments include 5 sub-questions. The explanations are given one by one as follows:

Sub-question 1: The sediment load estimated by the SPARROW model should focus only on the snowmelt and/or rainfall river runoffs. Otherwise, the authors should explain such a natural condition as the background of the river basin to the readers, and apply the SPARROW model to river runoffs for the limited period. Original manuscript: —- Revised manuscript: Section 2.4, Lines 106 to 108; Section 2.4, Lines 254 to 258 Response: The SPARROW model is a watershed modeling technique for relating water-quality measurements made at a network of monitoring stations to attributes of the watersheds containing the stations, land-to-water delivery rates, and in-stream processing rates, the core of which consists of a nonlinear regression equation. The calibration of the equation requires long-term averaging and load adjustments for changes in flow and sources, and therefore existing SPARROW models can only show simulated changes in mean-annual water-quality loads despite the fact that extreme loads are what is most important, especially if they occur close together in time. It is one of the limitations of the steady state "assumption" in existing SPARROW modeling and many researchers, ourselves included, are trying to develop dynamic SPARROW modeling to deal with these problems. We did not only focus on sediment loads produced in the snowmelt season and rainfall season, but considered the annual water flow and sediment loads at the monitoring stations from 1985 to 2010 in this study. We agree that our description was vague and we have added explanation in the Study Area and Model calibration and application sections.

Sub-question 2: If the "developing land" produces the high sediment yield even in winter, they have to state why and how the high sediment yield is produced. The authors had better explain the sedimentary situation of the developing land in detail. Original manuscript: —- Revised manuscript: Section 2.4, Lines 254 to 258; Section 3.1, Lines 304 to 308 Response: Our results indicate that the largest intrinsic sediment yield is associated with developing land (around 1006.27 kg/km2/yr), which is a mean-annual estimation from 1985 to 2010 (not only for one season). We did not focus only on the sediments in winter. Land development, including removing cover and developing cuts and fills, can increase potential erosion and sediment hazards on-site by changing water conveyance routes, soil compaction (both planned and unplanned), longer slopes and more and faster stormwater runoff. We have added some discussion about why and how the high sediment yield is produced in developing land.

Sub-question 3: The explanation of data sets utilized in the model is not enough: How and when were the sediment load data acquired at the 31 gauging stations? Original manuscript: Section 2.3 Revised manuscript: Section 2.3, lines 187 to 253 Response: Section 2.3 shows how the input data were obtained, in which Section 2.3.2 explains how and when the sediment load data at 31 gauging stations were acquired. We have checked and further improved this part. The following has been added to the text: "Suspended sediment concentration and daily flow data are collected to calculate the long-term (from 1985 to 2010) mean SS flux at every monitoring station. Thirty-one monitoring stations were chosen for model calibration in this study (Fig. 1). SS concentration and daily flow data were collected at each site for the period from 1985 to 2010 by the National Land with Water Information (http://www1.river.go.jp/) monitoring network (Fig. 3). However, some streamflow gaging stations have short periods of record or missing flow values but do not over 10% of the time periods. A streamflow record extension method called the Maintenance of Variance-Extension type 3 (MOVE.3) (Vogel and Stedinger, 1985) is employed to estimate missing flow values or to extend the record at a short-record station on the basis of daily streamflow values recorded at nearby, hydrologically similar index stations. On this basis, the FORTRAN Load Estimator (LOADEST), which uses time-series streamflow data and constituent concentrations to calibrate a regression model that describes constituent loads in terms of various functions of streamflow and time, is applied to estimate SS loads. The output regression model equations take the following general form (Runkel et al., 2004): lnâĄą(L_i)=a+blnQ+clnQˆ2+dsin(2πdtime)+ecos(2πdtime)+fdtime+gãĂŰdtimeãĂŮˆ2+ε (4) where L_i is the calculated load for sample i; Q is stream discharge; dtime is time, in decimal years from the beginning of the calibration period; ε is error; and a,b,c,d,e,f,g are the fitted parameters in the multiple regression model. The number of parameters may be different at different stations, depending on the lowest Akaike Information Criterion (AIC) values (for details please see Duan et al., 2013). AIC=2k-2lnâĄą(L) (5) where k is the number of parameters in the statistical model, and L is the maximized value of the likelihood function for the estimated model. The mean annual load is normalized to the 2006 base year at the 31 monitoring stations to address the problem of incompatibility in periods of record by using normalizing or detrending methods (for detailed process please see Schwarz et al., 2006)."

Sub-question 4: If many data are missing, is there some criterion for the limit of the application of SPARROW? Original manuscript: —- Revised manuscript: —- Response: It is generally the case for SPARROW model, as for any model with statistically estimated

HESSD
11, C6474–C6483, 2015

parameters, that model accuracy (bias and precision) and complexity (number of statistically significant or sensitive parameters) are dependent on the “information content” of the water-resources data used in the model calibrations. There are some criterion for the time and space scales required to develop SPARROW data sets and accurate models. First, a sufficiently large number of water-quality monitoring stations are required. Second, the amount of spatial variability in the stream monitoring data and explanatory factors should reflect as broad and representative a range of watershed conditions as possible. So, based on the experience from applications of SPARROW (Schwarz et al., 2006), some practical criterion can be summarized as follows. The stream fluxes, watershed data on pollutant sources, and watershed properties affecting contaminant transport vary over at least one order of magnitude. In addition, Stream water-quality records should be at least 5 years in length (at least 24-30 observations) and preferably include long-term continuous (i.e., daily) measures of streamflow, although the records may contain some gaps.

Sub-question 5: Actual evapotranspiration from the river basin is never explained in the text. The effective rainfall in the rainfall season is one of important parameters to produce river runoffs and sediment load. The authors should utilize the MET data at many weather stations in the river basin for the modelling. Original manuscript: —- Revised manuscript: Section 2.3.4, lines 246 to 253 Response: Climatic and landscape characteristics considered candidates for SS-transport predictors include climate, topography and soil. In this study slope, soil permeability, and precipitation are used to evaluate the influences of “land-to-water” delivery terms. So we did not use the effective rainfall, but use the total precipitation including snow and rainfall. Section 2.3.4 shows how and when the MET data were used to calculate the precipitation distribution in the Ishikari River basin (see following explanation).

Mean annual precipitation data, representing the 20-year (1990-2010) average, were obtained from daily precipitation data at 161 weather stations (see Fig. S1) in Hokkaido from 1990 to 2010. We first interpolated the mean annual precipitation over Hokkaido using a conventional kriging technique on the basis of 161 stations, and then clipped the mean annual precipitation distribution for the Ishikari River basin.

Fig. S1 Rain gauge station distributions used in this study We have added some explanations about why and how the MET data were used to obtain the precipitation distribution.

Anonymous Referee #2

This is an interesting study and the topic is very relevant for the journal. Overall the paper is well written. I have few suggestions to improve the quality of the manuscript.

Major comments: Question 1: As far as I understand, the model was only calibrated but no validation was carried out. It is important for the readers to see how well the model performs for the data set not used in model calibration. Therefore, instead of using the all the SS data (1985 to 2010) for calibration, I suggest to split the data for calibration and validation. Original manuscript: —- Revised manuscript: —- Response: Yes, usually the application of the hydrological modeling should contain calibration and validation processes. Here, like many applications of the SPARROW model, we typically calibrated our SPARROW models using all of the available data for an area. We then used various Bootstrapping techniques to help put confidence limits on all of our predictions. This approach puts different weights on each of the observations and then compares the coefficient values and compares our predictions from each of the "new" models. So we did not have the validation process for the following reasons. SPARROW is a statistical model that predicts mean annual nutrient loads for a “base” year, suggesting the effects of spatial variations in mean climatic (precipitation, temperature) and streamflow conditions. It gives more accurate estimates of the long-term mean annual load than can be obtained using the individual sediment measurements alone. It is critical to obtain stream sediment loads for calibrating the SPARROW model that are representative of the long-term mean hydrologic and water-quality conditions at each monitoring station. In this study, the mean annual loads from 1985 to 2010 were normalized to the 2006 base year at the 31 monitoring stations, which were used to statistically calibrate the SPARROW model. Then the calibrated model was used to predict the mean-annual sediment loads from 1985 to 2010, which enhances the capability of the spatial model to estimate the major sediment sources, including land uses and human activities, and natural processes that affect the long-term supply, transport, and fate of sediments in the Ishikari River basin.

Question 2: The results shown in Fig 6 seem to me are averages for the time period used (1985–2010). Can the model be used to predict the sediment load on annual basis? If 'yes', it will be more interesting to see the results on annul time-series. Original manuscript: —- Revised manuscript: —- Response: Unfortunately this model cannot evaluate trends (annul time-series) in actual sediment loads or determine whether the sediment conditions are getting worse or better by simulating the sediment loads on annul time-series. The existing SPARROW model were just widely applied to evaluate the long-term mean hydrologic and water-quality conditions because the calibration of the model requires long-term averaging and load adjustments for changes in flow and sources. Here, our study focused on improving understanding of the major sediment sources, including land uses and stream channels that contribute sediments to the Ishikari Bay; to quantify the total and incremental sediments loads in different sub-basin. However, many researchers including us are trying to develop a dynamic SPARROW modeling to deal with these problems.

Question 3: In general the uncertainly in prediction of basin wide sediment load is high. The prediction uncertainty was not discussed in the paper. I would suggest strengthening the paper by adding discussion on uncertainty and/or sensitivity of the regressed parameters to the model prediction. Original manuscript: —- Revised manuscript: Section 3.3, lines 375 to 388 Response: Uncertainty is always present in hydrological models such as SPARROW. According to the review's suggestion, we have added Section 3.3 (Uncertainty analysis). "Uncertainty always exists in hydrological models such as SPARROW and therefore cannot imperfect reflect of reality. The sources of uncertainty in this study include: 1) resolution of the geospatial data; 2) quality of the sediment loads used to calibrate the model; and 3) limitations of the modeling approach in representing the environmental processes accurately (Alexander et al., 2007). First, the hydrologic network was derived from a 50 m digital elevation model (DEM), which potentially deviates from the actual stream network, causing the discrepancy of stream reach and sub-basin characteristics such as stream length, local and total drainage area. This will lead to spatial uncertainty, although that uncertainty is generally reflected in the SPARROW model errors after the calibration process (Alexander et al., 2007). Another cause of uncertainty is suitability of using SS grab samples at the 31 monitoring sites for model calibration to reflect the normal conditions in-stream. Also, the SS loads at some monitoring stations were estimated using the MOVE.3 and LOADEST techniques (Runkel et al., 2004; Duan et al., 2013), which also have some uncertainties."

Minor comments: Question 1: P11038, L1-3: I suggest to rewrite the sentence as " . . .that control the fate and transport suspended sediment (SS) in rivers, because high . . .". Original manuscript: P11038, L1-3 Revised manuscript: Section Abstract, Lines 10 to 12 Response: Done

Question 2: P11039, L14: I would use "similarly" instead of "meanwhile". Original manuscript: P11039, L14 Revised manuscript: Section 1 Introduction, Line 46 Response: Done

Question 3: P11038, L17: I would not refer to just one dam (TRG). Better to be deleted. Original manuscript: P11038, L17 Revised manuscript: Section 1 Introduction, Line 48 Response: Done

Question 4: Fig 8 and 9: It is not clear what is incremental? Should be explained. Original manuscript: Figs. 8 and 9 Revised manuscript: Section 3.2 Model application, Lines 350 to 353 Response: The total yields (load per area) represent the amount of sediment including upstream load and local catchment load contributed to each stream reach, and the incremental yields represent the amount of sediment generated locally independent of upstream supply, and contributed to each stream reach, normalized by the local catchment area (see following explanation).

Fig. S2 Schematic illustration of a reach network for five incremental watersheds (Total Load at X = L1+L2+L3+L4+L5, Incremental Load at X = L5 only). We are very sorry for our vague expression. So, this has been clarified in the text.

Anonymous Referee #3 This paper demonstrates an application of the SPARROW suspended solid water quality model to the Ishikari River Basin in Japan. The paper is well written and easy to read. I have a few comments and questions: Question 1: Line 14, P. 11038: I believe the unit of the mean annual SS flux should be (kg yr − 1). Original manuscript: Line 14, P. 11038 Revised manuscript: Section Abstract, Line 21 Response: Done.

Question 2: Line 6, P. 11049: Same comment as above. Also, are you sure the unit of MSE is kg km − 2 yr − 1? Original manuscript: Line 6, P. 11049 Revised manuscript: Section 3.1 Model calibration, lines 281 to 282 Response: We have modified the unit.

Question 3: P. 11060: The calibration results in Table 2 look strange. For Forest Land, I don't understand why the P value can be 0.011 given that parameter estimate and standard error are 75.554 and 123.79, respectively. The parameter estimate is statistically insignificant (t = 75.554/123.79 = 0.61) and is inconsistent with the P value. Why is that? There are several other parameters which have similar problems. Original manuscript: P. 11060 Revised manuscript: Table 2 Response: In this study, the measures of statistical significance were based on statistical evaluations of the t statistics (ratio of the coefficient value to its standard error) and the p-value was used to identify statistically significant model coefficients. The t statistics are asymptotically distributed as a standard Normal Distribution. The statistical significance (alpha=0.05) of the coefficients for each of the SS source terms (which were constrained to be positive) were determined by using a one-sided t-test, and the significance of the coefficients for each of the land- to- water delivery terms (which were allowed to be positive or negative, reflecting either enhanced or attenuated delivery, respectively) and the variables representing SS loss in free-flowing streams and impoundments were determined by using a two-sided t-test. Here, I did not update the table. We have checked and modified them.

Question 4: I suggest that the authors go over the paper carefully to make sure everything is correct. Original manuscript: —- Revised manuscript: Please see the revised paper. Response: We have carefully checked and improved the manuscript according to the Reviewer's comments and suggestions.

We have improved the manuscript according to the Reviewer's comments and suggestions. These changes do not influence the content or form of the paper. We did not list all of the changes here. Other changes are marked in red in the revised paper. We hope that the correction will meet with approval.

Special thanks to you for your very helpful comments.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/11/C6474/2015/hessd-11-C6474-2015-supplement.zip

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