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Hydrology and Earth System Sciences Discussions

Interactive comment on "A daily salt balance model for representing stream salinity generation process following land use change" *by* M. A. Bari and K. R. J. Smettem

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1. General comments

Referee Comments: The authors present a salinity generating model component coupled to a daily water balance model and demonstrate successful application on two experimental catchments showing the effects of forest clearing. The model seems to be a reasonable approach to simulate salinity generation processes. However, the presentation is partly confusing and important information are missing. I can see further improvement of the paper regarding a more comprehensive review of field data and preceding work and adding further aspects to the general discussion to answer open questions and to put the paper into a more general context. As forest clearing is the only land use change considered, the title may be misleading and should be modified.

The presentation of the study catchments, the hydrological characteristics and the stream salinity generation processes is a bit confusing, as data are not presented in context and distributed over several sections. A systematic structure would greatly improve this part. A characterization of the study areas should be followed by a presentation of hydrological characteristics and processes. Based on these information, the stream salinity generation processes can be explained. Figures of observed data may be introduced to illustrate the salinity generation process, such as annual discharges, groundwater levels, stream salinity and salt loads. Is it possible to give a figure comparing runoff components and salt sources of the two catchments and before and after clearing?

Author Response: The title of the paper is modified as suggested by both the reviewers and now reflects specifically the effects of forest clearing for pasture development.

The description of the two experimental catchments (Section 2) is now elaborated. Section 3 of the paper is now restructured to reflect streamflow and salinity generation process better. A table (Table 1) with different flow components and storage contents are now added and described in Section 3.3. Annual streamflow and groundwater level changes are presented in the monthly and daily papers relevant to water balance model, and therefore not repeated in this paper. Observed and predicted stream salt loads from both the catchments are now presented in Fig. 3. Table 1 presents the sources of flow and salt components of two catchments.

Referee Comments: The water balance module was presented in a previous paper (“A daily water balance model for representing streamflow generation process following land use change”) and is only shortly reviewed assuming that this part is known to the reader. A more substantial overview of the water balance model in a separate section would increase comprehensibility for the reader. It should give an idea of the processes and storages are considered, the spatial organization of the model (how is subcatchment heterogeneity (esp. different land use types) considered) and the main parameters controlling the water balance model (relation land use!).

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Author Response: The description of the water balance model has now been elaborated (Section 4). How the stores are connected and fluxes between them are described in detail. How the model handles subcatchment heterogeneity – particularly land use – is described in the calibration section (Section 5).

Referee Comments: To understand how the model takes into account land use change, information is required on how land use is considered within the model and interferes with salt transport processes. It seems to me that i) increase of groundwater table and ii) release of salt from the unsaturated zone to the groundwater result from an increased recharge flux after clearing, which does not become clear in the description of the salinity generation process. Taking into account the preceding paper on the daily water balance model, interception storage and LAI seem to be the only parameters controlling recharge and being related to land use types? It also remains unclear, how different land use types within a catchment are considered in the model (or in other words: how is land use heterogeneity considered in the model). Are there other land use changes, which could be relevant for salinity generation in addition to forest clearing?

Author Response: The salinity generation process is now described in detail in Section 3. A new table (Table 3) shows different components of the water balance. How the model handles subcatchment heterogeneity – particularly land use – is described in the calibration section (Section 5). In the model, forests or pastures are represented by LAI, relative rooting depth and volumes. The salt and water balance model was used as a ‘building block’ for developing a basin-scale operational model, and has been used for predicting other land use management options such as logging, forest fire and reforestation. It is discussed in General Discussion section (Section 7) in detail.

Referee Comments: The salt balance model has only two parameters C and Cu controlling salt release from one store to another. It would be important to discus if these parameters relate to observable catchment properties and could be (at least theoreti-

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cally) determined a priori. If the model should be used as elementary unit of a regional model, regionalization or a priori definition of model parameters will be essential. Are these parameters constant or change in time depending on land use or soil moisture? Dry store, wet store and subsurface store are serially connected, therefore I would expect close interrelation of these parameters. Equifinality might be a problem. Are the calibrated parameters physically meaningful?

Author Response: Initial indicative values of these two parameters could be obtained from the salt content of the Dry and Wet Stores and the salinity of the shallow (2-3 m deep) bores. This is elaborated in Section 5 – Calibration and data requirements. Once calibrated these two parameter values remained unchanged over time. In the basin-scale operational model where this salt and water balance model was used as a ‘building block’ calibrated values of these two parameters remain unchanged across the basin. We have not yet tested equifinality phenomena of the model but endeavour to do so in future. These two parameters have some physical meaning and represent transport and mixing processes – convection, advection, dispersion, diffusion and dilution.

Referee Comments: As the water balance model and the salt balance model have been derived using a downward modelling approach, the transferability of the models to other catchments and landscapes might also be of further interest. Are model assumptions and model structure valid representations in the study catchments from the authors process knowledge? Is the model approach specific for the study areas or can it be considered a general model of dry land salinity generation?

Author Response: The basin scale model – developed using this model as building block – has now been applied to many catchments in Western Australia and one catchment in the State of Victoria (Australia). The basin scale model has been used for predicting other land use management options such as logging, forest fire and reforestation. It is now discussed in General Discussion section (Section 7) in detail. Applications to date demonstrate that the basin scale model is relatively easy to

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calibrate and can be considered a general model for representing salinity generation process, at least for Australia.

Referee Comments: The authors mention related models (DRCM and LASCAM, Tuteja 2003, WEC-C). As far as I understood, WEC-C is a fully distributed process model well suited to handle salinity problems, whereas the others are simple models that need further improvement. What are the limitations of these models and what is the benefit of the new approach?

Author Response: There are two problems of the existing models – (i) conceptual models have large number of parameters, inaccurate representation of processes and are hard to calibrate, (ii) the distributed models are applicable to experimental catchment scale only. The present model endeavours to represent salinity generation process better. A ‘downward approach’ was followed so that the model required minimal calibration. Presented in Introduction section (Section 1).

Referee Comments: The coupled model shall be used as an elementary unit in developing a regional-scale catchment model. It would be necessary to discus the suitability of the model and to give a short outlook on the intended regional model. Especially questions of model parameterization and transferability of the modelling approach could be addressed here.

Author Response: The basin scale model – developed using this salt and water balance model as building block – has now been applied to many catchments in Western Australia and one catchment in the State of Victoria (Australia). The basin scale model has been used for predicting other land use management options such as logging, forest fire and reforestation. It is discussed in General Discussion section (Section 7) in detail.

2. Specific comments

Referee Comments: Title: The land use changes indicated in the title refer to clearing of

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forests only. I would therefore suggest to rename the paper (“following clearing of forests” or similar).

Author Response: The title of the paper is modified as suggested.

Referee Comments: P1150, 22f: Even if your paper mainly confines on model description and a first application, your principal objective should have a more general focus (for example: improve existing modelling approaches, built a regional model, etc). “coupling and testing of a salinity component” can then be a specific aspect within this general framework.

Author Response: Done as suggested.

Referee Comments: P1150, 1151: Study catchments - You should give more detailed information on the study areas in this section. For example, you give average evaporation, but no precipitation data for comparison. Can you shortly give further information on morphology and subsurface properties (soils, geology) to assist understanding of the hydrologic system? What is the climatic regime of the area? Especially rainfall and runoff characteristics may be interesting with respect to salinity generation. It is also unclear, which rainfall and evapotranspiratioon values relate to which catchment. Do both catchments extend over the high and low rainfall zone or is one located in the high rainfall zone and the other in the low rainfall zone? If the later is the case, can these catchments still be compared with each other?

Author Response: Description of the experimental catchments (Section 2) is elaborated and a new figure (Fig. 2) added.

Referee Comments: p11152, 1152: The salinity generation is closely connected to water dynamics of the catchment. I would suggest giving a concise overview of the hydrology of the catchment first. The stream salinity generation processes should be explained in a second step. Figures of observed data may be introduced to illustrate the salinity generation process, such as annual discharges, groundwater levels, stream

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salinity and salt loads. Is it possible to give a figure comparing runoff components and salt sources of the two catchments and before and after clearing?

Author Response: Section 3 of the paper is now restructured to reflect streamflow and salinity generation process better. A table (Table 1) with different flow components and storage contents are now added and described in Section 3.3. Annual streamflow and groundwater level changes are presented in the monthly and daily papers relevant to water balance model, and therefore not repeated in this paper. Observed and predicted stream salt loads from both the catchments are now presented in Fig. 3. Table 1 presents the sources of flow and salt components of two catchments.

Referee Comments: p1152, 24: In which way did the flow generation process change? If you point it out here, you should be more specific.

Author Response: Section 3.3 is rewritten and reorganised. A new table (Table 1) show how the storage and different flow components changed.

Referee Comments: p1153: You refer to the daily water balance model only shortly. In my opinion, a more comprehensive outline of the water balance model is required here. The paper should be understandable independent of the previous paper.

Author Response: Description of the water balance model is elaborated.

Referee Comments: p1159: You state that salinity generating factors in West Australia “are different from other parts of the world” and cite literature stating both similarities and differences to salinity generation in North America. This seems to be contradictory and the differences or similarities should be highlighted more closely.

Author Response: The text is modified and reorganised as suggested by the other reviewer.

Referee Comments: p1161, 1162: Why do you give a performance measure for monthly data and not also for daily data? A good performance of daily data does not necessarily constitute good performance on monthly or annual data (e.g. in case

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of systematic errors) and a low performance of daily data may result in a correct calculation of monthly loads. Therefore model performance should be considered on a daily time step as well as for aggregated periods. Both aspects should be confirmed by quantitative measures.

Author Response: The performance of the model on daily time step is now incorporated in Section 6.2.1. A new table (Table 2) shows the model performance.

Referee Comments: p1164, 9f: Poor model performance of daily salinity during the low flow period was not pointed out in the results section. If you discuss it here, you should first introduce the problem by appropriate simulation results.

Author Response: Done as suggested.

Referee Comments: Figure2: The scatter plot compares paired salt discharges from both catchment. It does not highlight causal relations (increase after clearing in relation to reference catchment). A comparison of data from the pre-treatment and transition period is difficult as salt discharges increase80-fold. I would therefore suggest to present the data as time series and plot both series in a log scale.

Author Response: Done as suggested.

3. Technical corrections

Referee Comments: Structure of the paper: 1. The salinity generation process (Section 3) should include a short characterization of hydrological processes. The model description (Section 4) should include an extended overview on the water balance model. 2. Section6 should confine to model application and model results. The General discusion6.3 should be a separate section7. You don’t really need a summary, but you should draw meaningful conclusions at the end of your discussion.

Author Response: Sections 3 and 4 are elaborated. Discussion section is separated as section 7. We would like to keep the summary and conclusion section unchanged.

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Interactive Comment

Referee Comments: p1151/1152: In the low rainfall zone the groundwater table lies far below the stream channel and streamflow is substantially generated by shallow interflow (p1151, 15f). How can groundwater then discharge salts to the stream (p1152, 12f)? Although groundwater tables rise after clearing, it remains unclear at this point, if they rise up to discharge into the stream system. This is more closely explained later in the paragraph (p1152, 17f), but the relevant information is missing at this point. You should change the order of the relevant information or, as indicated above, characterize hydrological changes in advance.

Author Response: Sections 3.1 and 3.3 are reorganised and rewritten as suggested.

Referee Comments: p1154, 12f: we introduced a lumped parameter[(Cu)] to represent these processes.

Author Response: Done

Referee Comments: P1158, 1159: . and then the other parameters associated with the salt balance. [The first five years] The salt balance model has two parameters . - I recommend to first describe the model parameters and then to define the data periods used for calibration. The topic started by the first two sentences of chapter five is disrupted by directly switching to the time periods and picking up model parameters later again -rearrange this section as follows: . …and then the other parameters associated with the salt balance. The salt balance model has two parameters……The first five years…...

Author Response: Done as suggested.

Referee Comments: p1161, 2f: Streamflow, salinity and salt load matched [the observed data] reasonably well for both catchments

Author Response: Done.

Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 1147, 2005.