Hydrol. Earth Syst. Sci. Discuss., 8, C6185–C6190, 2012
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Hydrology and Earth System Sciences Discussions

HESSD

8, C6185–C6190, 2012

Interactive Comment

Interactive comment on "Implications of deep drainage through saline clay for groundwater recharge and sustainable cropping in a semi-arid catchment, Australia" *by* W. A. Timms et al.

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Received and published: 28 February 2012

Referee: The paper objective: you mentioned in page 10057, line 27 that the groundwater already known to be deep and saline, how do you justify the objective of your study?

Reply: Firstly, we thank the Referee for providing feedback and an opportunity to comment and improve our manuscript. This catchment is located in the north-eastern part of Australia's Murray-Darling Basin, with groundwater and river water users downstream. If additional salt were mobilised to the river system, or with increased groundwater, there may be implications for natural ecosystems, town water supplies and irrigated agriculture beyond the study area.

Referee: Page 10057, Lines 10-13: casting your objectives in this way gives the impression that there is indeed significant deep drainage. Please rephrase a sharper objective statement.

Reply: The main objective of this exploratory study was to determine if deep drainage under annual cropping might mobilize the many tonnes of salt stored in these soils, with potential consequences for downstream water users including natural ecosystems.

Referee: The "Methods" section should be re-organized and presented in a more logic and easy to-follow way: I think that the core subsection in this section is subsection 3.5 which should be focused on. The other efforts to collect and describe supportive data and information (i.e. sections 3.1 - 3.2 - 3.3 - 3.4) should be presented within its framework. Too many details in the "Methods" section are not needed and negatively affect the paper readability. For example describing the hydraulic conductivity measurements (pages 10059-10060) is long, complicated and can be summarized in a few sentences.

Reply: We have deleted the long description of hydraulic conductivity measurements, and some other minor method details, particularly where information is also presented in Figures and Tables (eg. groundwater level logging periods and locations). We have also clarified the difference between shallow soil cores (Section 3.1) and deep cores (Section 3.2). The methods section proceeded from shallow soils, to deep sediment, to groundwater, to rainfall, to deep drainage simulations, which we consider is a logical progression.

Referee: This section "Methods" is also missing a clear description of the time frames within which the authors conducted the different investigations, data collection and simulations. How did these activities overlap in time?

Reply: The timing of the study components, and field observations is recorded in the headings of Table 1, 2, 3 and Figures 7,8,9 and 10. However, no time was given for soil coring so this statement has been added in the methods: "In May, 2005, soil cores (0-5 m) were taken from adjacent continuously cropped and never cropped perennially vegetated sites at 2 locations."

Referee: In section 3.5, three methods were presented to estimate and simulate deep drainage: The first method was not successful, as you stated that SODICS software did not lend itself well to the calculation of deep drainage, so the question here why you present this method, please discuss. The second method gives a rough idea about the deep drainage; this method involves many reasons of uncertainty, please discuss this in the paper.

Reply: We presented the SODICS outcome because we consider future studies may be guided to the methods that were successful in this soil and climatic environment. Recording an unsuccessful result, is of itself, significant and should not be ignored.

The chloride front displacement (CFD) method gave results of the same order of magnitude as APSIM simulations: between 3.2 and 4.3 mm/year, somewhat lower than the 5.0 mm/year APSM for Denham for example. At the Sefton Park site, the CFD method gave results that were somewhat higher than APSIM simulations.

The CFD method of estimating recharge is used in situations where landuse has changed (Walker et al., 1991) The method relies on observations of the movement of a particular chloride pattern with depth which retains its shape during the leaching process (Crosbie et al. 2010). Unlike the steady-state mass balance methods, there is no need to estimate a chloride deposition rate, (one of the major unknowns when using steady-state chloride mass balance method) nor does it assume that piston flow is occurring. However, a control site is required, as was the approach in our study, where the vegetation and soil conditions are representative of those prior to the change in land use.

The CFD method assumes that the two Cl- peaks are of the same size and differ only in displacement down the profile. We maintain this assumption when the size of the Cl- peaks differ between cropped and control because we believe that the differences are due to natural variability in salt stores and not the change in land use. There is no evidence in our data that the peaks are consistently larger under either continuous cropping or native vegetation. CFD estimations rely on estimations of drainable water volume. Our calculations are probably slight under estimations of deep drainage as we have assumed no change in bulk density with wetting at depths >0.8 m.

Referee: The third method: how did you calibrate the APSIM model, and how much are you confident about the output of its simulation? In Page 10070, line 17 you mentioned that the model provided good simulations of actual grain yields? Is this enough for calibration? Besides, I do not think that the agreement is sufficiently good as presented in Fig.10.

Reply: We agree that grain yield data alone doesn't validate a model, however, we are confident in model outcomes having simulated ball park chloride profiles and grain yields. The testing of APSIM at different sites over the past two decades (See reference list following) has been incorporated into model development and calibration. There is a track record of successful (and cumulative) calibration for northern Basin farming system with respect to yield, chloride and soil water dynamics. Local parameterisation is based on soil properties. Water retention was estimated from BD and assumptions about LL15=native vegetation control and no shrink/swell with soil water change below 0.8 m.

References for basic testing on Northern farming systems with respect to yield and SW dynamics including the following.

Foale, M.A., Probert, M.E., Carberry, P.S., Lack, D., Yeates, S., Brimblecombe, D., R. Shaw, Crocker, M. Participatory research in dryland cropping systems - monitoring and simulation of soil water and nitrogen in farmers' paddocks in Central Queensland. Australian Journal of Experimental Agriculture 44, 321-331, 2004. (Testing of APSIM

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Dalal, R.C., Weston, E.J., Strong, W.M., Probert, M.E., Lehane, K.J., Cooper, J.E., King, A.J., Holmes, C.J.. Sustaining productivity of a Vertosol at Warra, Queensland, with fertilisers, no-tillage or legumes. 8. Effect of duration of lucerne ley on soil nitrogen and water, wheat yield and protein. Australian Journal of Experimental Agriculture 44, 1013-1024, 2004 (Soil Water and N Sims for cropping and pasture phases in SE Queensland clay soils)

Probert, M.E., Dimes, J.P., Keating, B.A., Dalal, R.C., Strong, W.M. APSIM's water and nitrogen modules and simulation of the dynamics of water and nitrogen in fallow systems. Agricultural Systems 56, 1-18, 1998. (Soil Water and N Sims for cropping in SE Queensland clay soils.)

References for basic testing on Cl movement under Northern farming systems:

Huth, N.I., Thorburn, P.J., Radford, B.J., Thornton, C.M. Impacts of fertilisers and legumes on N2O and CO2 emissions from soils in subtropical agricultural systems: A simulation study. Agriculture Ecosystems & Environment 136, 351-357, 2010. (Wheat/Sorghum systems in Cental Queensland including production, water balance and Cl leaching after clearing of Brigalow, in clay soils)

Poulton, P.L., Huth, N.I., Carberry, P.S. Use of simulation in assessing cropping system strategies for minimising salinity risk in brigalow landscapes. Australian Journal of Experimental Agriculture 45, 635-642, 2005. (Similar to one above - production and salt leaching after clearing - on farm study for clay soils)

Paydar, Z., Huth, N., Ringrose-Voase, A., Young, R., Bernardi, T., Keating, B., Cresswell, H. Deep drainage and land use systems. Model verification and systems comparison. Australian Journal of Agricultural Research 56, 995-1007, 2005. (Wheat/Sorghum/Pastures/Legume rotations including water balance etc .in Liverpool Plains NSW for clay soils)

Turpin, J.E., Huth, N., Keating, B.A., Thompson, J.P. Computer simulation of the effects of cropping rotations and fallow management on solute movement. Proceedings of the 8th Australian Agronomy Conference, Toowoomba, Queensland, Australia, 30 January-2 February, 1996., 558-561, 1996. (Hermitage long term tillage trial simulations and Cl leaching in clay soils.)

Additional References

Crosbie, R. S., Jolly, I. D., Leaney, F. W., Petheram, C., and Wohling, D. Review of Australian groundwater recharge studies, CSIRO Water for a Healthy Country National Research Flagship, Canberra, 79 pp, 2010.

Walker GR, Jolly ID, Cook PG (1991) A new chloride leaching approach to the estimation of diffuse recharge following a change in land use. J Hydrol 128 (1-4):49-67, 1991.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 10053, 2011.