

Protecting environmental flows through enhanced water licensing and water markets

T. Erfani, O. Binions and J.J. Harou

Referee #1

***Referee:** This manuscript addresses an interesting topic related to the impacts of institutional change to water allocation approaches in the UK. At the heart of this manuscript is an analysis of the differences between an allocation policy with rights/licenses subject to a constant minimum flow constraint, and one in which the quantity that the license entitles the owner to “scales” as streamflow declines. Results suggest that the scaled approach protects environmental flows more effectively, but at the sacrifice of some economic benefits.*

I found the paper to be interesting, and the modeling approach sound, but kept asking what the nature of the contribution might be. The results are useful (i.e. scaled approach improves environmental flows), in particular to the basin in question, but surely the outcome could have been largely predicted before the analysis was undertaken. Is identifying the magnitude of the effect alone enough to constitute a novel addition to the literature? I’m not sure. The fact that this manuscript appears to be the third of three papers in a similar vein also gives rise to questions about what differentiates this work from the earlier submissions (both in review). It would be nice to see the authors take a bit more time to make an academic case for the novelty of the work. Presuming that the authors can provide a reasonable rationale, this work is likely to be interesting to some portion of the HESS readership.

Authors’ response:

The authors thank Referee #1 for their comments and we appreciate this opportunity to further specify the paper’s research contribution, both here and in the manuscript. First we will explain how this paper relates to the two related 2013, 2014 Erfani et al. papers (now published in Water Resources Research) by the same authors, and secondly we describe further the paper’s academic and water management contribution.

1. Erfani et al. (2013) described a modification of a conventional network flow optimisation model formulation that enables such a model to track transactions in water resource networks. Erfani et al. (2014) used the innovative optimisation formulation published in 2013 to propose a generic optimisation-driven simulation model of a water market that can incorporate transaction costs, i.e., the cost incurred when water users interact in a water resource system with market transactions. This model was applied to the Ouse basin, comparing results with and without a market.

2. In this paper we modify the generic simulation model of Erfani (2014) to represent new water management and allocation policies being considered in England: a replacement of static minimum environmental flows and a new water rights regime. These policy initiatives are currently being assessed by DEFRA (environment ministry) in England, and decision makers wanted to know how these

proposed changes would function under a water market which is also being considered as a future policy option to encourage.

The first academic contribution of this paper involves adding two components to a state-of-the-art generalised agent simulation model of water markets: (a) dynamic environmental flows and (b) water license scaling. Dynamic environmental flows are designed to replace static minimum flows. The objective is to leave a larger proportion of flow for the environment when flows are high, and a smaller one when conditions are dry. The model implements a dynamic environmental flow regime following Klaar et al. (2014) and applies this to the case-study basin. Water license scaling involves replacing fixed volumetric allocations with a shares-based water allocation system (similar to the water rights used in Australia). The paper formulates a shares-based constraint (section 2.3) and embeds it into the generalised water market optimisation model of Erfani et al. (2014).

The second academic contribution of the paper is the case-study application, its results and their discussion. The paper is a result of a real policy investigation funded by water utilities and government and is relevant in the UK and beyond because several countries and regions globally are considering adopting higher performing water rights and environmental protection regimes.

The application of the model illustrates how spot market water trading could manifest under current and proposed regulatory environments. The application demonstrates not only that the proposed new system is better able to protect the environmental flows, but also a) how a water market would function under the two water allocation systems; and b) how the new licensing system re-distributes water allowances between the users. In addition to the magnitude of the effect on the environmental flows, the paper provides insights under both systems into: 1) possible trading partners and volumes traded; 2) the potential economic benefits to the region; 3) how benefits are distributed amongst the different sectors.

To better specify the nature of the research contribution, we have edited the end of the introduction, the new text is as follows:

“This paper extends the generic water market simulation model proposed by Erfani et al. (2014) to assess possible outcomes of water trading under a share-based licensing system where allocations (water rights) are updated according to current flow conditions and dynamically updated environmental flows (EA, 2013; Young and McColl, 2005). The new model is applied to a case-study basin in Eastern England. The performance of the proposed licensing system is compared to the currently used licensing system which uses static minimum environmental flows and volumetric licenses. The current system allocates fixed water volumes whilst the proposed system scales licensed volumes weekly proportionally to each abstractors’ shares depending on flow conditions.”

Based on the above, we believe this paper is a state-of-the-art research contribution in water markets and associated water management policy design. We’ve presented this work at several UK water management meetings and international academic conferences; in both cases the work, because of the modelling and its implications, has received a positive response and led to interesting discussions on future water management.

Referee: *With regard to specific questions, most of mine revolve around the role of Public Water Supplies (PWSs) in this work. Do I understand correctly that PWS usage (read: urban) comprises 95% of basin demand? If so, does that make this problem less interesting in general?*

Authors' response: PWS abstraction in the case-study basin constitute 95% of total yearly historical abstractions. However, PWS water abstracted is not all used within the basin (the largest proportion is stored in the reservoir also feeds surrounding population centres). Generally the UK has higher relative PWS consumption than many other countries using or considering water markets. In many areas with markets, market activity is somewhat predictable: farmers sell to cities during dry spells. In this case, because of the high volume of high-value usage (PWS, energy cooling) in the basin, results are different than in many water market studies; we see this as strength of the case-study. In particular, the study allows investigating for example how reservoirs could be used in markets and how large well-funded actors could potentially interact with a multitude of smaller actors (e.g. farmers) with lower valued water uses, in a context where there is high value placed on environmental quality. This is an interesting topic for the future, bringing up human-environment interaction issues relevant to precisely the special issue to which this paper was submitted. This topic also brings up human equity issues of general interest to water managers and water market specialists.

Referee: In most water scarce regions the transfers move irrigation-to-urban uses, but here it is urban-to-power. In the regions I am familiar with, an urban supplier would never transfer water to another user under conditions of scarcity out of concern (however unjustified) that the urban supplier might "run out" of water.

Authors' response: Thank you, this is of course a good and fair point. The paper does consider concerns over selling water that a public water supply company would certainly have. This concern is reflected in a trading rule described on last paragraph of Section 3.3.1. The PWS has 2 surface water sources, one being the reservoir. When a drought alert is activated (when the reservoir is some % below the target storage), PWS stops selling water. The percentage can be changed to investigate different levels of conservatism by PWS managers. We used 50% as an example. This is perhaps on the low side, but we wanted to investigate how a relatively active market would work, so we chose this number. Further studies could complete a large sensitivity analysis, where the behaviours of different agents could be varied systematically to assess impacts on other sectors.

Referee: In this case, it appears that the PWSs enjoy some sort of favored status under drought, however, and are not subject to reductions in their supply. If true, is that the reason that they feel comfortable in selling water to energy producers during drought (i.e. they have so much that it doesn't matter). And, if that is the case, it would seem that the PWSs are set up to collect substantial economic rents from this arrangement. Some more discussion of this would assist in an understanding of Figures 5 & 6. This point might also have bearing on the transferability of the results to other water scarce regions, especially if the magnitude of the economic losses imposed by a move to scalable allocations in the point of the paper (this value is likely to be substantially higher than in the more common scenario involving irrigator-to-urban transfers in a market where urban users receive no such protection).

Authors' response: Thank you for this interesting comment. We have added text to the discussion section (see below) about Figures 5 and 6 to respond to the comment above.

Under the current licensing system, both of the PWS licenses are not restricted by 'hands-off flow' (HoF) rules (please see Section 4.2) although they still have maximum weekly and yearly allowances. The PWS Intake abstracts the amount demanded, and sells the rest to other users (mostly the Power station). As noted in the previous response, the PWS agent only sells water if the reservoir is sufficiently

full. Regulators are definitely concerned about rent seeking behaviour of privatised water companies. Under license scaling, as modelled, PWS loses its priority status (because the lack of HoF conditions on the PWS license is replaced by severe restrictions imposed on all abstractors by the new environment flows regime). This means reservoir storage reduces rapidly and PWS is unable to sell water from end of April. In fact, in the shares-based system, PWS has to buy allocations from other users in June-September, so the irrigator-to-urban transfers are presented. A variety of other attitudes to trading could be represented in the model, but we consider this more behavioural work is beyond the scope of this paper.

The following text was added at the beginning of results section 4.3:

“Figure 5 shows that because of PWS’s lack of HoF conditions, they are able to sell water to the energy sector throughout the year. Under the proposed system as modelled (Figure 6), where sectors are on equal footing, these rents are not available and PWS stops selling water at the end of April, at which point the energy sector begins buying from farmers (with higher transaction costs due to the larger number of transactions involved).”

Referee #2

Referee: *Main part of the method adopted in this manuscript is very similar to the one used in another paper published by the authors (Erfani et al., 2014, Water Research). I would suggest the author try to revise their manuscript greatly and specify the main innovations compared with their previous works.*

Authors' response:

Thank you for this comment. We have included here a response that was also provided to the other referee to specify the exact nature of the academic research contribution.

The authors thank Referee #2 for their comments and we appreciate this opportunity to further specify the paper's research contribution, both here and in the manuscript. First we will explain how this paper relates to the two related 2013, 2014 Erfani et al. papers (now published in Water Resources Research) by the same authors, and secondly we describe further the paper's academic and water management contribution.

1. Erfani et al. (2013) described a modification of a conventional network flow optimisation model formulation that enables such a model to track transactions in water resource networks. Erfani et al. (2014) used the innovative optimisation formulation published in 2013 to propose a generic optimisation-driven simulation model of a water market that can incorporate transaction costs, i.e., the cost incurred when water users interact in a water resource system with market transactions. This model was applied to the Ouse basin, comparing results with and without a market.

2. In this paper we modify the generic simulation model of Erfani (2014) to represent new water management and allocation policies being considered in England: a replacement of static minimum environmental flows and a new water rights regime. These policy initiatives are currently being assessed by DEFRA (environment ministry) in England, and decision makers wanted to know how these proposed changes would function under a water market which is also being considered as a future policy option to encourage.

The first academic contribution of this paper involves adding two components to a state-of-the-art generalised agent simulation model of water markets: (a) dynamic environmental flows and (b) water license scaling. Dynamic environmental flows are designed to replace static minimum flows. The objective is to leave a larger proportion of flow for the environment when flows are high, and a smaller one when conditions are dry. The model implements a dynamic environmental flow regime following Klaar et al. (2014) and applies this to the case-study basin. Water license scaling involves replacing fixed volumetric allocations with a shares-based water allocation system (similar to the water rights used in Australia). The paper formulates a shares-based constraint (section 2.3) and embeds it into the generalised water market optimisation model of Erfani et al. (2014).

The second academic contribution of the paper is the case-study application, its results and their discussion. The paper is a result of a real policy investigation funded by water utilities and government and is relevant in the UK and beyond because several countries and regions globally are considering adopting higher performing water rights and environmental protection regimes.

The application of the model illustrates how spot market water trading could manifest under current and proposed regulatory environments. The application demonstrates not only that the proposed new

system is better able to protect the environmental flows, but also a) how a water market would function under the two water allocation systems; and b) how the new licensing system re-distributes water allowances between the users. In addition to the magnitude of the effect on the environmental flows, the paper provides insights under both systems into: 1) possible trading partners and volumes traded; 2) the potential economic benefits to the region; 3) how benefits are distributed amongst the different sectors.

To better specify the nature of the research contribution, we have edited the end of the introduction, the new text is as follows:

“This paper extends the generic water market simulation model proposed by Erfani et al. (2014) to assess possible outcomes of water trading under a share-based licensing system where allocations (water rights) are updated according to current flow conditions and dynamically updated environmental flows (EA, 2013; Young and McColl, 2005). The new model is applied to a case-study basin in Eastern England. The performance of the proposed licensing system is compared to the currently used licensing system which uses static minimum environmental flows and volumetric licenses. The current system allocates fixed water volumes whilst the proposed system scales licensed volumes weekly proportionally to each abstractors’ shares depending on flow conditions.”

Based on the above, we believe this paper is a state-of-the-art research contribution in water markets and associated water management policy design. We’ve presented this work at several UK water management meetings and international academic conferences; in both cases the work, because of the modelling and its implications, has received a positive response and led to interesting discussions on future water management.

Referee:

Detailed comments for authors:

- 1. In 2.1, the core model is similar with the author’s previous paper. The further extended models, described in the sections 2.2 and 2.3, are regarded as two more constraints compared with the authors’ previous work,*

Authors’ response: As detailed in the previous author response, this paper builds on the Erfani et al. (2014) paper. The equations presented in sections 2.2 and 2.3 are new. Also, the way in which the shares system is modelled is new and distinct from Erfani et al. (2014). Firstly, the river basin is broken down into sub-catchments delineated by gauging stations. Each sub-catchment’s abstraction volumes are determined as a percentage of the environmental flow. Secondly, within each sub-catchment, each water abstraction license is translated into a share of the available resource.

These model extensions radically change results of the model and enable a relevant comparative study of proposed changes to the English water allocation and management system. The strength of the paper is the way the model was extended to address two pertinent policy questions, and the in-depth way this policy question is addressed (hydrological, allocation, and economic impacts of new regulations). The policy question: how pro-environment regulation would impact water users when paired with a water market, is very much inline with the HESS special issue to which this paper was submitted.

Referee:

2. *In 2.2 and 3.4, more explanation and comparison of MinFlowj with other similar research should be added.*

Authors' response:

Thank you for this comment. Dynamic environmental flows are now being considered in many regions. This is not our invention; we follow the English 'EFI' (Environmental Indicator) approach which has been adopted by England's Environment agency. In response to the request we have now added, in addition to the explanations on EFI in section 3.1, the following reference to section 3.4 which will further clarify the background behind the EFI dynamic flow approach:

"Please see Klaar et al. (2014) for further information on the EFI approach."

Klaar, M. J., Dunbar, M. J., Warren, M., and Soley, R.: Developing hydroecological models to inform environmental flow standards: a case study from England, *Wiley Interdisciplinary Reviews: Water*, 1, 207-217, 10.1002/wat2.1012, 2014.

Referee:

3. *The case study in the section 3.2 is the same with the one in section 3 of the authors' previous work (Erfani et al., 2014).*

Authors' response: Thank you for this comment. We have given a short review of the case-study basin so that readers don't have to download other papers to understand this paper. Although the case study river basin is the same, the abstraction regulation setting is different: the 2014 paper concerns only the current existing regulation framework. The proposed paper represents a very different "shares-based" licensing system with dynamic environmental flows and compares this to the current system. There are several series of papers in the literature that have been published on a single basin. This is only the second paper published on the Ouse basin and we think this valuable data-rich case-study will support further studies (e.g. we're now working on a paper about how investment in small reservoirs by farmers is encouraged or discouraged by water markets and water management policy innovations).

Referee:

4. *The relationship among "junction", "gauge", "node", "junction node", and "river" should be explained in details (e.g., with the employment of a figure).*

Authors' response:

Thank you for this comment. We have now added the following text in section 2.1 to further specify what is meant by these terms.

"The river network is modelled as a network of nodes (e.g. demands, storage reservoirs, junctions where flow links converge or diverge) and conveyance links (e.g. river 'reaches', i.e., segments) and water balance is ensured at each junction or storage node (see e.g. Loucks et al., 1981; Loucks and Van Beek, 2005)."

Because we already have many figures (8 in addition to tables), we prefer not to include a figure on this as these are standard terms used to refer to water resource network models. We have included a reference where readers unfamiliar with these terms can get more information.