

“Sharing water and benefits in transboundary river basins” by D. Arjoon et al.

The authors would like to thank the reviewer for his/her interesting and constructive comments. Our responses and the proposed changes/corrections are detailed below.

Referee #1

General Comments:

- 1.1 The paper considers an institutional arrangement to distribute welfare in a river basin by maximizing the economic benefits of water use and then sharing these benefits using a (game theoretic?) method developed through stakeholder involvement. The methodology was applied to the Eastern Nile River basin.

RESPONSE: In Section 2.4, we describe a method of sharing the economic benefits which “should be determined in collaboration with the water users. Properties that define fairness, as determined through negotiations with the water users, are then translated into a sharing rule using an axiomatic approach.” This description of the sharing method is left intentionally very general, since this will be different for each river basin. How the benefits will be shared depends entirely on the definition of fairness that results from negotiations with the water users. Benefits could be shared proportionally or using an egalitarian method or some other form of sharing could be used. We have further clarified this in the first paragraph of Section 2.4 by adding the following statement: “*How the benefits are shared depends entirely on this definition as agreed to by water users. For example, a simple proportional sharing method may satisfy the properties of equity defined by the users, or an egalitarian method, or some other form of sharing may be required.*”

In our case study, using the Eastern Nile River Basin (Section 3), the method used is not game theoretic; we abstract from any stability/equilibrium analysis. We do not investigate the possibility that one or more of the water users could be better off on their own. Instead, we propose a mechanism whereby overall benefits would be maximized as a result of full cooperation and then shared according to a key perceived as fair by the different water users. In other words, the proposed institutional arrangement makes sure that (1) the size of the pie is the largest and (2) the pie is shared in an equitable manner between the participants.

- 1.2 The paper makes an interesting contribution to the body of knowledge surrounding calculating the benefits of transboundary water sharing. However, there are several shortcomings that should be addressed before the paper can be published in the journal. First the Methodology section of the paper is incomplete and needs to be improved as suggested in the specific comments below, mainly that the axiomatic process that implements the bankruptcy game should be introduced and explained in the methodology section. Otherwise, the main potential contribution of the paper is without a methodological basis and is completely ad hoc depending on the site being studied. Second, the method was not actually applied using real stakeholders but it is applied to the widely studied Eastern Nile Basin. The authors need to acknowledge the history of water use in this basin and how the benefits sharing indicated in the results of the paper differ from recent or projected use of water in the basin.

RESPONSE:

1. We agree that the last part of the methodology section might look ad hoc. This is because the benefit sharing mechanism is meant to be flexible since it will depend on the specific conditions of the basin being studied. Section 2.4 has been changed to make this more clear. It now states: *“At this point in the methodology, the RBA has collected an amount of money, referred to as the estate (E), that can be shared among the water use agents. Using an axiomatic approach, a method of sharing this estate should be determined. The aim of the axiomatic approach is to find and capture the notion of fairness that water users could agree upon. The approach then sets out axioms (properties) that fairness should or should not satisfy. Finally, these properties are translated into a sharing rule that quantifies the particular definition of fairness. How the benefits are shared depends entirely on this definition as agreed to by water users. For example, a simple proportional sharing method may satisfy the properties of equity defined by the users, or an egalitarian method, or some other form of sharing may be required. Since each river basin will have a different definition of fairness (depending on conditions in the basin and the outcome of negotiations with the water users), each river basin will likely have its own unique sharing rule.”*
2. A brief history of water sharing agreements in the Nile River Basin is given in Section 3.1 of the paper. The purpose of the presented methodology is an alternative to these types of agreements on international river basins, which are often perceived as zero-sum games and can lead to distrust and tension between riparian countries, as is the case in the Nile River Basin. What we present is an entirely different perspective that may help to avoid the pitfalls and limitations of current agreements. For example, with respect to the Nile Basin, the current agreement driving water allocation legally constrains Sudan to 18.5 bcm of water use. Sudan has land resources to expand irrigation and use much more water than this (Allan et al 2013), but is limited due to the agreement. As well, uncertainty with respect to changing climate and the possibility of increased evaporation, uncertain hydrology and sea level rise could create an imbalance in water demand and supply in the basin (Whittington, 2014). A rise in sea level would result in the loss of agricultural land in the Nile Delta and, subsequently, a large portion of Egypt's historic water use would no longer be required (Whittington, 2014). We have added a sentence to the last paragraph in the introduction (Section 1) which states *“The institutional arrangement described in this paper should encourage full cooperation between water users because it is intended as a replacement for traditional types of agreements on international river basins, which can lead to distrust and tension between riparian countries. What we present is an entirely different perspective that may help to avoid the pitfalls and limitations of current agreements.”*

It is difficult to compare the results of the case study with current water use in the basin. The presented case study is highly hypothetical and is not consistent with the actual, current allocation scheme. In the case study, we assume complete cooperation, there is expanded irrigation in the basin and the Grand Ethiopian Renaissance Dam is online. This represents a possible long-term future scenario in the basin and the results reflect this. We have added a paragraph to the end of the results (Section 4) to clarify this: *“Finally, it should be noted that we make no attempt to compare the results of the case study with current water use in the basin. While the presented case study is hypothetical and is not consistent with the actual, current situation, it represents a possible long-term future scenario in the basin and the results reflect these assumptions. In the case study, we assume complete cooperation, there is expanded irrigation in the basin and the Grand Ethiopian Renaissance Dam is online.”*

Specific Comments:

- 1.3 P.1-L.20: “There is a consensus among water professionals that the cooperative management of shared river basins should provide opportunities to increase the scope and scale of benefits” The authors have provided a single reference to justify this assertion. A broader consensus needs to be demonstrated before this statement can be accepted.

RESPONSE: More references have been added. “There is a consensus among water professionals that the cooperative management of shared river basins should provide opportunities to increase the scope and scale of benefits (Phillips et al., 2006; Grey and Sadoff, 2007; Leb, 2015), stepping beyond the volumetric allocation of water that reduces negotiations between riparians to a zero-sum game.”

- 1.4 P.2-L.10: “water is allocated to maximize the net benefits from water use over the whole basin (economically efficient allocation).” Not all of these papers take the economist’s position that one can simply maximize the benefits of water use in a basin and many of them recognize the political and administrative boundaries present in their case study basins and how those boundaries affect (restrict) the allocation of water in the basins.

RESPONSE: We agree that not all of these papers take the position that the benefits of water use can simply be maximized without recognizing the various constraints within the cases studied. We have changed the wording in the 3rd paragraph of the introduction to make this clearer. The sentence now reads “The traditional approach to estimating the economic benefits of cooperation relies on hydro-economic modelling (Arjoon et al., 2014; Jeuland et al., 2014; Tilmant and Kinzelbach, 2012; Teasley and McKinney, 2011; Whittington et al., 2005). These studies present various implementation strategies representing various levels of cooperation, but all show that there are significant economic benefits to be had through basin-wide cooperation.”

- 1.5 P.3-L.30: “pseudo-market approach, a river basin authority (RBA) plays the role of water system operator, identifying economically efficient allocation policies which are then imposed on the agents (water users). The agents are charged for water, payments are redistributed to ensure equitability among the users.” “the RBA collects information that is required to assess the demand curves, or at least the productivity of all users in the system, once at the beginning of each year.” How realistic is this? In many parts of the world, this information is considered confidential. “. . .based on the bid information, the demand curve can be inferred using the residual imputation method. . .” This seems much more realistic that requiring users to give up their business information.

RESPONSE: The authors believe that in the future, it will be realistic to get some of this information. Currently, market prices, either national or international, can be observed and transportation costs can be estimated, allowing for an approximation of the mark-up that may accrue to farmers, for example. We stress that this paper describes a system in which it is assumed that there is cooperation over the whole basin. This means that water users have agreed to bid for water and to supply the information that is necessary to make the methodology work. It is up to the RBA to check that the information is reliable. Increasingly, river basins are being monitored and the information required is becoming available (for example, current hydromet projects in the Senegal River Basin). The system may not seem realistic at this point,

but, in the long-term, exchange of information will increase the availability of data over river basins. This increase in information exchange is in keeping with the obligation to cooperate and exchange information that is outlined in the UN Convention on the Law of the Non-navigational Uses of International Watercourses.

We have added a paragraph to the conclusions Section 5 (second to last paragraph) to discuss the constraint of available/reliable data. This paragraph reads: *“Another constraint is the availability of reliable data. Some information such as market prices, either national or international, can be observed and transportation costs can be estimated, allowing for an approximation of the mark-up that may accrue to farmers, for example. This paper describes a system in which it is assumed that there is cooperation over the whole basin and that water users have agreed to bid for water and to supply the information that is necessary to make the methodology work. Increasingly, the information required is becoming available through the use of remote sensing and monitoring of river basins.”*

- 1.6 P.4-L. 15: “techniques such as remote sensing can be applied to validate land classification and cropping areas” Do the authors utilize these methods in this paper?

RESPONSE: It is up to the RBA to check that the information given by water users is reliable. Remote sensing is one of the techniques available to validate information such as land classification and cropping areas. We have updated paragraph 2 in Section 2.1 to more clearly state this. This paragraph now states: *“In order to control the declarations of agents in the agricultural sector, the RBA can use techniques such as remote sensing to validate land classification and cropping areas (Gallego et al., 2014; El-Kawy et al., 2011; Rozenstein and Karnieli, 2011).”*

We do not use these methods in the present case study.

- 1.7 P.4-L.30: “allocation decisions are identified by matching demand with supply in a cost effective way, i.e. by giving priority of access to users with the highest productivity” It is not clear what the authors mean by “cost effective” way and this should be more clearly defined. Giving water to its highest valued use may be cost effective, but that depends on how you define “cost effective”. Please clarify. As mentioned previously, this allocation method depends on the benevolent water manager having the authority to allocate the water in such a manner and in the real world this ignores any water rights or transboundary agreements that may exist in the basin. I think the authors should point out this limitation and discuss its implications in detail later in the paper.

RESPONSE:

1. The authors have changed the term “cost-effective” to “cost-efficient” implying least cost, or maximum productivity.
2. The allocation method departs from traditional (physical) allocation mechanisms based on water rights and relies instead on a bidding process whereby all water users are granted equal access to the resource. Productive use and allocation decisions are separated. The benevolent water manager is a non-profit, regulated organization that acts as a third party operator of the water resources system. In other words, it does not directly put water to productive use for its own benefit. Instead, it coordinates allocation decisions throughout the system based on the offers provided by eligible water users, and tries to achieve allocative

efficiency by ensuring that the good or service is consumed by those who value it most highly. The benevolent water manager, then, is the operator of an auction-based market. We agree that this is a highly hypothetical scenario but technological changes (e.g. availability of massive remote sensing data) combined with the need to achieve greater efficiency due to external pressures (population growth, climate change) might trigger major regulatory reforms in the water sector. This was seen in the energy sector in the late XXth century where, before 1970, energy generation was widely believed to be part of a natural monopoly. Technological developments such as cheap gas-fired power plants, combined with costly and inefficient investments made by the monopolies, suggested that competition was needed and led to the introduction of deregulated electricity markets. This manuscript must be seen as a prospective analysis. We are concerned with a future situation that does not currently exist and we look at how the institutional arrangement would perform under these conditions.

- 1.8 P.4-L.30: "...power companies are considered non-rival water users since a unit of water released through one dam can be used downstream by another dam. . ." This may or may not be the case. In the case of the Syr Darya basin in Central Asia, this is certainly NOT the case since electricity production is in high demand in the winter when there is no irrigation water demand and hydropower releases in winter are lost to summer irrigation use. In the Eastern Nile, where the authors apply their model, the Grand Ethiopian Renaissance Dam may or may not be operated in a manner that allows the non-rival use of the water for power. The authors need to make this clear and explain the limitations of their assumptions.

RESPONSE: Thank you for this insight. We are in agreement. We have changed the text in this section to reflect this. The first paragraph in Section 2.2 now includes the following statement: *"For example, water flowing through a dam may be considered a non-rival water use since a unit of water released through one dam can be used downstream by another dam. In rival water use, units are consumed and are no longer available to other water users (for example, water lost to irrigation or water held in a reservoir during a period when it is required downstream for irrigation)."*

- 1.9 P.6-L.5: "...Non-consumptive users buy inflow from the RBA, at the marginal value at the user site, and then sells the outflow downstream, back to the RBA, at the marginal value of water at the downstream site. . ." Why not just say that the users pay the difference between marginal value at the user site and the marginal value of water at the downstream site?

RESPONSE: This sentence now reads *"Non-consumptive users buy inflow from the RBA at a price equal to the difference between the marginal value of water at the user site and the marginal value of water at the downstream site (Fig. 3)."*

- 1.10 P.7-L.5: The Methodology section of the paper is incomplete since it does not indicate any method of determining the "transfer payments". The idea is stated that the "fairness" of the payments will be determined through an "axiomatic process" involving the stakeholders, but no methodology is mentioned for how this procedure is carried out. Some description of a method should be given here, since this is the main contribution of the paper (the other components are well known and reported in the literature previously). Otherwise, the main potential contribution of the paper is without a methodological basis and is completely ad hoc depending

on the site being studied. Section 3.5 presents much of the methodology (bankruptcy game theory) and should be moved back to Section 2 and the main aspects presented as general methodology.

RESPONSE: We have updated the first paragraph in Section 2.4 to further describe the method of transfer payments. We have added the following: *“How the benefits are shared depends entirely on this definition as agreed to by water users. For example, a simple proportional sharing method may satisfy the properties of equity defined by the users, or an egalitarian method, or some other form of sharing may be required.”*

Please see the response to comments 1.1 and 1.2 for further details.

- 1.11 P.13-L.5: “. . .for this study, the properties for this rule were not developed with stakeholder input as this was beyond the scope of this research project” So the method was not actually applied using real stakeholders. This fact needs to be pointed out in the abstract as it substantially weakens the impact of the paper. In addition, the authors do not acknowledge the history of water use in this river basin and the massive efforts that have been made to develop lasting and fair transboundary water sharing agreements in the basin. How do these historic efforts differ from the water allocation and benefits sharing indicated in the results of the authors’ model? This should be explained and discussed in some detail, since this could be a major contribution of the paper to understanding water sharing in the Nile basin.

RESPONSE:

1. While it is true that the method for determining transfer payments was not developed using stakeholder input, we do not believe that this weakens the impact of the methodology. We have an objective point of view and our analysis is a benchmark or reference point. We have updated the paper to include a mention of this in the text. A paragraph has been added to Section 3.5 which reads *“It should be noted that, for this study, the properties for this rule were not developed with stakeholder input as this was beyond the scope of this research project. Although stakeholder involvement is imperative in this institutional arrangement, in this case study, we are giving an objective viewpoint and this analysis serves as a benchmark or reference point.”*
2. Please see the response to comment 1.2.2 for a detailed response to the question of water sharing agreements in the basin.

Allan, J. A., Keulertz, M., Sojamo, S. & Warner, J. eds. (2013). Handbook of Land and Water Grabs in Africa: Foreign Direct Investment and Food and Water Security. Routledge International Handbook. Routledge, Abingdon.

Whittington, D, J. Waterbury, and M. Jeuland (2014), The Grand Renaissance Dam and prospects for cooperation on the Eastern Nile, *Water Policy*, 16, 595–608.