Article:

Lowe, Ben, Oglethorpe, David R. and Choudhary, Sonal (2018) Marrying unmarried literatures:The water footprint and environmental (Economic) valuation. Water (Switzerland). 1815. ISSN 2073-4441

https://doi.org/10.3390/w10121815

water

MDPI

Commentary

Marrying Unmarried Literatures: The Water Footprint and Environmental (Economic) Valuation

Benjamin H. Lowe *, David R. Oglethorpe and Sonal Choudhary

Sheffield University Management School, Conduit Road, Sheffield S10 1FL, UK; d.oglethorpe@sheffield.ac.uk (D.R.O.); s.choudhary@sheffield.ac.uk (S.C.)
* Correspondence: benjamin.lowe@sheffield.ac.uk; Tel.: +44-(0)114-222-3269

Received: 12 September 2018; Accepted: 1 December 2018; Published: 10 December 2018

check for updates

Abstract: In this commentary, we set out the rationale for bringing together two research fields: Water Footprint Assessment and environmental (economic) valuation, which have evolved separately. This has the potential to inform the efficient allocation of virtual water flows at a global scale. It would also address some of the aims and objectives in the Water Footprint Assessment Manual regarding the assessment of environmental impacts and their sustainability, which thus far have not been covered in the literature. We also indicate how established practice in the environmental valuation community would need to develop to facilitate productive exchange between the two fields. Finally, we outline the key developments in the non-peer reviewed grey literature that signal the merit of such an exchange.

Keywords: benefit transfer; supply chain management; value of water; virtual water; water footprint assessment

1. Introduction

By virtue of its Editor-in-Chief, this journal is associated with the concept of the water footprint. A special issue on the economics of water resources management then seems the ideal opportunity to highlight the underexplored intersection of these two research fields.

In what follows, we advocate for the introduction of a sub-discipline of environmental economics—environmental valuation—into the water footprint field, for two principal reasons. First, it encourages and offers what appears to be the primary goal of Water Footprint Assessment, namely the efficient allocation of limited fresh water at a global scale [1,2]. Second, it addresses specific aims and objectives set out in the Water Footprint Assessment Manual concerning sustainability assessment at the catchment scale [3]. These have not been addressed in the literature to date.

The goal of this commentary is not to advance the 'monetary water footprint' or any derivation similar to the stress-weighted or scarcity-weighted water footprint [2]. On the contrary, the goal here is to suggest how the well-established tools provided by environmental valuation might be applicable in a context that focuses on water dependencies within cross-border supply chains (Sections 3 and 4) [4]. We also address how the field of environmental valuation could develop to better support a productive exchange between the two research fields (Section 5). Finally, we highlight the developments in the non-peer reviewed grey literature that indicate the merit of such an exchange (Section 6). We begin with a brief overview of the water footprint and environmental valuation approaches (Section 2).

2. The Water Footprint and Environmental Valuation: A Brief Overview

2.1. The Water Footprint

The idea of the water footprint built on the work of Tony Allan and the concept of virtual water [5–7]. This concept of virtual water (the water used to produce a product along its supply chain) focussed attention on the spatial disconnects between places of production and consumption. It also highlighted the possibility for countries to externalise their water demands, particularly in the Middle East and North Africa. However, the water footprint introduced greater spatiotemporal specificity and a full methodology. This methodology accounts for the consumption of green water (rainfall stored in the soil as moisture) and blue water (surface and groundwater), as well as the volumes of water appropriated to assimilate waste (grey water) [3]. In addition, in the guise of Water Footprint Assessment (WFA), accounting for green, blue and grey water volumes along the supply chain was extended to include subsequent phases that focus on the sustainability of these water volumes, and the formulation of policy interventions. Whilst the water footprint is perhaps most closely associated with product supply chains [8], the WFA methodology can also be used to account for the water dependencies of other entities such as individual consumers, businesses and nations [9].

2.2. Environmental Valuation

Environmental valuation refers to the estimation of welfare values for the goods and services provided by the natural environment. These are goods and services that are typically not responsive to markets and the signals they send about relative resource scarcity [4]. In a water context, the requirement for welfare values, denominated in monetary units, occurs for a wide variety of reasons [10]; these include market failures, such as the provision of public goods and externalities, and institutional failures [11,12].

The theoretical foundation of environmental valuation is the concept of Willingness to Pay (or Willingness to Accept), which is estimated by Marshallian or Hicksian demand curves using a wide variety of revealed and stated preference techniques [13,14]. Benefit (or value) transfer is a secondary data based method that involves transferring existing values, which have been estimated for a particular 'policy site,' to a new 'study site' of interest [15].

3. Environmental Valuation for Efficient Allocation at the Global Scale

There is an ongoing debate between the water footprint and Life Cycle Analysis communities regarding the appropriate focus for assessing water use along a product supply chain. Specifically, should the focus be on the global allocation of water resources or local impacts of water use at each supply chain tier? In addition, should the focus be characterised by volumetric measures or stress-weighted impact indices [2,16–25]? In the context of this debate, environmental valuation would appear to offer potential insights to both sides of this discussion.

Figure 1 provides an example of a simplified agri-food supply chain depicting pasta production. Here, estimates of the relative economic value of water consumption and degradation in the different locations where crops are sourced (tier 1) would provide a monetary estimate of the relative impact in each location. In addition, the differing values in each tier 1 location would also offer a monetary and economic foundation—*ceteris paribus*—for sourcing from lower valued areas. In other words, it would provide a rationale for allocating production to locations where water may be more abundant, rather than those where water may be more scarce. Indeed, unlike inter-sectoral allocation where economic theory suggests that the same drop of water should be utilised by the highest valued user, in this context where values are relative to different drops of water, the optimal location would be where the value of water consumed or degraded was the lowest. Continuing with the example of water used in crop cultivation, artificially applied irrigation may simply add to yield in predominantly rain-fed agriculture, whereas elsewhere it may be critical for crop viability. As a result, the value of blue water is likely to be much lower in the case of locations which are predominantly rain-fed, thus providing an incentive to grow crops in geographies that enjoy rain-fed conditions and the lower opportunity costs and negative environmental externalities associated with green water [26,27].

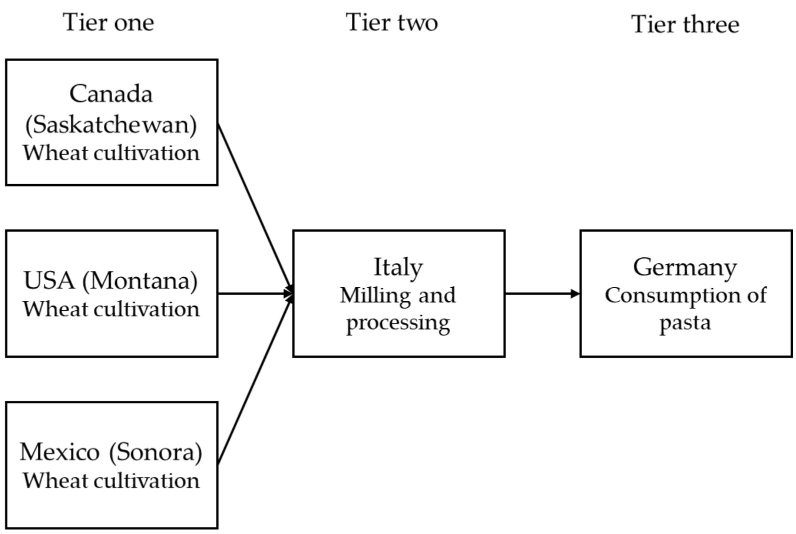

Figure 1. Simplified pasta supply chain.

To allocate water at the global scale based on relative economic value in different locations, two factors would seem to be important. First, the valuation techniques would need to be fully consistent and generalisable for the appropriate spatial scale of analysis in each location. In the case of the crop cultivation example above, this would ideally mean utilising an approach that provides an 'aggregate value' [11]. This would better reflect a geographical region but would not be specific to a crop variety. Alternatively, taking an average from multiple field-level estimates recorded across a specified geography would also be an option. Second, further attention should be paid to the value of green water and the relative value between green and blue water, as these are topics that have only seen limited coverage to date [28].

4. Environmental Valuation for Sustainability Assessment at the Catchment Scale

The detailed guidelines for assessing sustainability contained in the Water Footprint Assessment Manual are based on understanding whether the water use component along the product supply chain (or other water footprint account) is located in a geographical hotspot. A hotspot is defined in different ways: In economic terms, a hotspot occurs when the full costs of water use in a catchment (defined as "externalities, opportunity costs and a water scarcity rent") are not charged to the user, and when water is not allocated and used efficiently [3] (p. 88). In social terms, a hotspot is partly indicated by whether "basic rules of fairness" such as the user and polluter pays principles are being observed [3] (p. 87/8). In addition to the geographical context, WFA asks whether the water footprint of a process can be "avoided altogether or reduced at a reasonable societal cost" [3] (p. 92). There is also a recognition of the "secondary impacts" of the water footprint within a basin on "ultimate ecological, social and economic values such as biodiversity, human health, welfare and security" [3] (p. 192).

None of these issues seem to have been addressed directly in the empirical applications of WFA. Nonetheless, they are all areas that could clearly be informed by the application of environmental valuation. Strictly speaking, environmental valuation focuses more on the additive components of the Total Economic Value of water ecosystem goods and services [29]. This is distinct from the Marginal Opportunity Cost of water use which is less encompassing and similar to the definition of full cost used in WFA [26]. In this guise, valuation has been used to assess the relative direct use value of competing water applications within the same basin to inform inter-sectoral allocation [30,31]. It has also been used to determine damage assessments in order to internalise negative externalities (i.e., the polluter pays principle) [32]. Fundamentally, however, environmental valuation focuses on the allocation of a wide range of goods and services provided by environmental systems under conditions of scarcity to maximise societal welfare. Environmental valuation is therefore ideally suited to contribute to the kinds of issues that WFA scholars have identified as important in the context of the supply chain (e.g., regarding "societal costs" and "ultimate values"). These issues have not been addressed in the literature to date. Indeed, the water footprint literature has focussed on assessing sustainability and promoting efficiency and equitability by suggesting a range of bespoke tools and approaches. These include water footprint benchmarks for crop cultivation [33,34] and comparisons between the water footprints of processes and maximum sustainable water footprints in geographical areas [35].

A focus on supply chains would also represent a change for the academic valuation literature that has focussed on geographically bounded applications [36], rather than those encompassed within cross-border contexts and the differences in relative values therein.

5. Developing Established Practice in Environmental Valuation—Promoting Volumetric Units for Use in Benefit Transfer

Whilst the volumetric nature of the water footprint literature could benefit from a focus on welfare values for the reasons given above, conversely the environmental valuation community may also find added relevance through a focus on water volumes.

Welfare values are denominated in different units depending on the aspect of water being addressed. For instance, the value of water for recreational purposes is typically provided per day and the value of irrigation is often provided per hectare. The volumetric valuation of water (i.e., per cubic metre or acre foot) by comparison is a somewhat poor relation, perhaps because the water uses that are most susceptible to valuation in these terms—principally where water is used as an intermediate input in agricultural and industrial production—are also relatively neglected themselves [12]. However, the complementary provision of water values that would marry with volumetric measures would appear to be of great relevance given the magnitude of water use in supply chains (and in particular agri-food supply chains), its often hidden nature [37], and the push by businesses to increasingly understand these dependencies [38].

To achieve this and provide values that could be applied in a supply chain context (which may include agricultural, industrial and consumer use tiers), there are several areas that need addressing across both off-stream and in-stream water services. In terms of off-stream services, a reliable means of estimating the economic value of water in agricultural production, across any potential geography that a supply chain might span, seems of primary importance. This is particularly true given the geographical reach of modern supply chains and the challenges this represents for primary valuation studies. In addition, the value of water in industrial production also needs to be re-addressed in a concerted manner given the paucity of existing studies in this area [39–41].

For in-stream water services, such as wildlife habitat, recreation and hydrological functions, which are all impacted by extractive water uses, the question is two-fold: (1) Can existing methods be adapted to provide volumetric estimates of value? (2) If so, can this be done to provide meaningful estimates at the low spatial resolutions that would typify an assessment of water use in the multiple countries encompassed by a supply chain? On the first of these, methods can and have been adapted to provide volumetric estimates, e.g., this has been done in a recreational context by taking into account variations in the level of water flow [30,31]. As for the second, we offer this as an open question to the environmental valuation and natural science communities. Are the environmental systems that give rise to in-stream ecosystem services too complex and location specific to estimate suitable welfare values? In particular, is this possible at low spatial resolutions given that these estimates would likely rely on secondary data techniques such as benefit transfer?

6. Developments in the Non-Peer Reviewed Grey Literature

PUMA (the Germany-based sportswear manufacturer) pioneered the Environmental Profit and Loss account in 2011 [42]. The water component of this approach estimates the value of the in-stream ecosystem services impacted by consumptive blue water use in the business's supply chains. It makes use of a meta-analytic benefit transfer model that appears to be largely based on secondary data compiled in one paper [43]. In conjunction with other similar approaches [44,45], as well as the advent of the Natural Capital Protocol (which provides a standardised framework for recording natural capital dependencies along the supply chain) [46], this provides evidence that current business practice sees the valuation of supply chain impacts as worthwhile. Therefore, it also provides a further incentive for bringing together the environmental valuation and water footprint communities for fruitful exchange.

We will shortly be offering our own contribution on this subject following a detailed review of existing water value data. Based on this, we will then assess what methods might be feasible in the context of geographically disaggregated supply chains which pose a challenge to primary environmental valuation studies. However, the assignment of welfare values to water use in the supply chain seems worthy of far wider discussion, particularly amongst both the natural and social scientific disciplines that will be of the focus of this special issue.

Author Contributions: B.H.L. wrote the draft; all three authors contributed equally to the finalisation of the paper.

Funding: This research was funded by The Economic and Social Research Council grant number [ES/J500215/1] and The University of Sheffield.

Acknowledgments: We would like to thank the three anonymous reviewers for their comments and suggestions, which have helped to improve the paper.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

References

1. Hoekstra, A.Y. The global dimension of water governance: Why the river basin approach is no longer sufficient and why cooperative action at global level is needed. *Water* **2011**, *3*, 21–46. [CrossRef]
2. Hoekstra, A.Y. A critique on the water-scarcity weighted water footprint in LCA. *Ecol. Indic.* **2016**, *66*, 564–573. [CrossRef]
3. Hoekstra, A.Y.; Chapagain, A.K.; Aldaya, M.M.; Mekonnen, M.M. *The Water Footprint Assessment Manual: Setting the Global Standard*; Earthscan: London, UK, 2011; Available online: http://waterfootprint.org/media/downloads/TheWaterFootprintAssessmentManual_2.pdf (accessed on 6 August 2018).
4. Champ, P.A.; Boyle, K.J.; Brown, T.C. (Eds.) *A Primer on Nonmarket Valuation*; Kluwer Academic Publishers: Dordrecht, The Netherlands, 2003; ISBN 1402014457.
5. Allan, J.A. Policy responses to the closure of water resources: Regional and global issues. In *Water Policy: Allocation and Management in Practice*; Howsam, P., Carter, R., Eds.; Chapman and Hall: London, UK, 1996; ISBN 0419216502.
6. Allan, J.A. Virtual water: A strategic resource global solutions to regional deficits. *Ground Water* **1998**, *36*, 545–546. [CrossRef]
7. Allan, J.A. Productive efficiency and allocative efficiency: Why better water management may not solve the problem. *Agri. Water Manag.* **1999**, *40*, 71–75. [CrossRef]
8. Jefferies, D.; Muñoz, I.; Hodges, J.; King, V.J.; Aldaya, M.; Ercin, A.E.; Canals, L.M.; Hoekstra, A.Y. Water footprint and Life Cycle Assessment as approaches to assess potential impacts of products on water consumption. Key learning points from pilot studies on tea and margarine. *J. Clean. Prod.* **2012**, *33*, 155–166. [CrossRef]
9. Chapagain, A.K.; Orr, S. *UK Water Footprint: The Impact of the UK's Food and Fibre Consumption on Global Water Resources*; WWF-UK: Godalming, UK, 2008; Available online: https://waterfootprint.org/media/downloads/Orr_and_Chapagain_2008_UK_waterfootprint-vol1.pdf (accessed on 29 October 2018).

10. Savenije, H.H. Why water is not an ordinary economic good, or why the girl is special. *Phys. Chem. Earth Parts A/B/C* **2002**, *27*, 741–744. [CrossRef]
11. Gibbons, D.C. *The Economic Value of Water*, 1st ed.; Resources for the Future: Washington, DC, USA, 1986; ISBN 0915707233.
12. Young, R.A.; Loomis, J.B. *Determining the Economic Value of Water: Concepts and Methods*, 2nd ed.; Taylor and Francis: Oxon, UK, 2014; ISBN 0415838509.
13. Brown, T.C. Introduction to stated preference methods. In *A Primer on Nonmarket Valuation*; Champ, P.A., Boyle, K.J., Brown, T.C., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherlands, 2003; pp. 99–110, ISBN 1402014457.
14. Boyle, K.J. Introduction to revealed preference methods. In *A Primer on Nonmarket Valuation*; Champ, P.A., Boyle, K.J., Brown, T.C., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherlands, 2003; pp. 259–267, ISBN 1402014457.
15. Wilson, M.A.; Hoehn, J.P. Valuing environmental goods and services using benefit transfer: The state-of-the art and science. *Ecol. Econ.* **2006**, *60*, 335–342. [CrossRef]
16. Hoekstra, A.Y.; Gerbens-Leenes, W.; van der Meer, T.H. Reply to Pfister and Hellweg: Water footprint accounting, impact assessment, and life-cycle assessment. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, E114. [CrossRef]
17. Ridoutt, B.G.; Eady, S.J.; Sellahewa, J.; Simons, L.; Bektash, R. Water footprinting at the product brand level: Case study and future challenges. *J. Clean. Prod.* **2009**, *17*, 1228–1235. [CrossRef]
18. Bayart, J.B.; Bulle, C.; Deschênes, L.; Margni, M.; Pfister, S.; Vince, F.; Koehler, A. A framework for assessing off-stream freshwater use in LCA. *Int. J. Life Cycle Assess.* **2010**, *15*, 439–453. [CrossRef]
19. Ridoutt, B.G.; Pfister, S. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. *Glob. Environ. Chang.* **2010**, *20*, 113–120. [CrossRef]
20. Kounina, A.; Margni, M.; Bayart, J.B.; Boulay, A.M.; Berger, M.; Bulle, C.; Frischknecht, R.; Koehler, A.; i Canals, L.M.; Motoshita, M.; et al. Review of methods addressing freshwater use in life cycle inventory and impact assessment. *Int. J. Life Cycle Assess.* **2013**, *18*, 707–721. [CrossRef]
21. Pfister, S.; Ridoutt, B.G. Water footprint: Pitfalls on common ground. *Environ. Sci. Technol.* **2013**, *48*, 4. [CrossRef] [PubMed]
22. Ridoutt, B.G.; Pfister, S. A new water footprint calculation method integrating consumptive and degradative water use into a single stand-alone weighted indicator. *Int. J. Life Cycle Assess.* **2013**, *18*, 204–207. [CrossRef]
23. Boulay, A.M.; Bare, J.; De Camillis, C.; Döll, P.; Gassert, F.; Gerten, D.; Humbert, S.; Inaba, A.; Itsubo, N.; Lemoine, Y.; et al. Consensus building on the development of a stress-based indicator for LCA-based impact assessment of water consumption: Outcome of the expert workshops. *Int. J. Life Cycle Assess.* **2015**, *20*, 577–583. [CrossRef]
24. Ridoutt, B.G.; Pfister, S.; Manzardo, A.; Bare, J.; Boulay, A.M.; Cherubini, F.; Fantke, P.; Frischknecht, R.; Hauschild, M.; Henderson, A.; et al. Area of concern: A new paradigm in life cycle assessment for the development of footprint metrics. *Int. J. Life Cycle Assess.* **2016**, *21*, 276–280. [CrossRef]
25. Pfister, S.; Boulay, A.M.; Berger, M.; Hadjikakou, M.; Motoshita, M.; Hess, T.; Ridoutt, B.; Weinzettel, J.; Scherer, L.; Döll, P.; et al. Understanding the LCA and ISO water footprint: A response to Hoekstra (2016) "A critique on the water-scarcity weighted water footprint in LCA". *Ecol. Indic.* **2017**, *72*, 352–359. [CrossRef]
26. Turner, K.; Georgiou, S.; Clark, R.; Brouwer, R.; Burke, J. *Economic Valuation of Water Resources in Agriculture: From the Sectoral to a Functional Perspective of Natural Resource Management*; FAO: Rome, Italy, 2004; Available online: http://www.fao.org/docrep/007/y5582e/y5582e00.htm (accessed on 6 August 2018).
27. Aldaya, M.M.; Allan, J.A.; Hoekstra, A.Y. Strategic importance of green water in international crop trade. *Ecol. Econ.* **2010**, *69*, 887–894. [CrossRef]
28. Hoekstra, A.Y.; Savenije, H.H.G.; Chapagain, A.K. The value of rainfall: Upscaling economic benefits to the catchment scale. In *Towards Catchment Hydrosolidarity in a World of Uncertainties, Proceedings SIWI Seminar, Stockholm, Sweden, 16 August 2003*; Stockholm International Water Institute: Stockholm, Sweden, 2003; Available online: http://www.ayhoekstra.nl/pubs/Hoekstra-et-al-2003.pdf (accessed on 6 August 2018).
29. Pearce, D.W.; Turner, R.K. *Economics of Natural Resources and the Environment*; Harvester Wheatsheaf: London, UK, 1990; ISBN 0745002250.

30. Creel, M.; Loomis, J. Recreation value of water to wetlands in the San Joaquin Valley: Linked multinomial logit and count data trip frequency models. *Water Resour. Res.* **1992**, *28*, 2597–2606. [CrossRef]
31. Loomis, J.; McTernan, J. Economic value of instream flow for non-commercial whitewater boating using recreation demand and contingent valuation methods. *Environ. Manag.* **2014**, *53*, 510–519. [CrossRef]
32. Arrow, K.; Solow, R.; Portney, P.R.; Leamer, E.E.; Radner, R.; Schuman, H. Report of the NOAA panel on contingent valuation. *Fed. Reg.* **1993**, *58*, 4601–4614.
33. Mekonnen, M.M.; Hoekstra, A.Y. Water footprint benchmarks for crop production: A first global assessment. *Ecol. Indic.* **2014**, *46*, 214–223. [CrossRef]
34. Chukalla, A.D.; Krol, M.S.; Hoekstra, A.Y. Green and blue water footprint reduction in irrigated agriculture: Effect of irrigation techniques, irrigation strategies and mulching. *Hydrol. Earth Syst. Sci.* **2015**, *19*, 4877–4891. [CrossRef]
35. Hoekstra, A.Y. Sustainable, efficient, and equitable water use: The three pillars under wise freshwater allocation. *WIRES Water* **2014**, *1*, 31–40. [CrossRef]
36. Oglethorpe, D.R.; Miliadou, D. Economic valuation of the non-use attributes of a wetland: A case-study for Lake Kerkini. *J. Environ. Plan. Manag.* **2000**, *43*, 755–767. [CrossRef]
37. Ercin, A.E.; Aldaya, M.M.; Hoekstra, A.Y. Corporate water footprint accounting and impact assessment: The case of the water footprint of a sugar-containing carbonated beverage. *Water Resour. Manag.* **2011**, *25*, 721–741. [CrossRef]
38. Carbon Disclosure Project. A Turning Tide: Tracking Corporate Action on Water Security (CDP Water Report 2017). Available online: https://www.cdp.net/en/research/global-reports/global-water-report-2017 (accessed on 6 August 2018).
39. Wang, H.; Lall, S. Valuing water for Chinese industries: A marginal productivity analysis. *Appl. Econ.* **2002**, *34*, 759–765. [CrossRef]
40. Renzetti, S.; Dupont, D.P. *The Value of Water in Manufacturing*; CSERGE Working Paper ECM, 03-03; Economic and Social Research Council Centre for Social and Economic Research on the Global Environment: Swindon, UK, 2002.
41. Kumar, S. Analysing Industrial Water Demand in India: An Input Distance Function Approach. 2004. Available online: http://econpapers.repec.org/paper/npfwpaper/04_2f12.htm (accessed on 6 August 2018).
42. PUMA. PUMA's Environmental Profit and Loss Account for the Year Ended 31st December 2010. Available online: https://glasaaward.org/wp-content/uploads/2014/01/EPL080212final.pdf (accessed on 6 August 2018).
43. Frederick, K.D.; Hanson, J.; VandenBerg, T. *Economic values of freshwater in the United States*; Resources for the Future: Washington, DC, USA, 1996; Available online: http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-97-03.pdf (accessed on 21 August 2018).
44. Park, A.; Gao, S.; van Ast, L.; Mulder, I.; Nordheim, A. Water Risk Valuation Tool: Integrating Natural Capital Limits into Financial Analysis of Mining Stocks. 2015. Available online: https://www.bbhub.io/sustainability/sites/6/2015/09/Bloomberg_WRVT_09162015_WEB.pdf (accessed on 6 August 2018).
45. Ridley, M.; Boland, D. Integrating Water Stress into Corporate Bond Credit Analysis. 2015. Available online: https://naturalcapital.finance/wp-content/uploads/2018/11/INTEGRATING-WATER-STRESS-REPORT_FINAL.pdf (accessed on 3 December 2018).
46. The Natural Capital Coalition. The Natural Capital Protocol. 2017. Available online: https://naturalcapitalcoalition.org/natural-capital-protocol/ (accessed on 6 August 2018).