Maheswaran Rathinasamy
S. Chandramouli · K. B. V. N. Phanindra
Uma Mahesh *Editors*

Water Resources and Environmental Engineering I

Surface and Groundwater

Springer

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Foreword

Judicious management of water resources is fundamental for achieving sustainable management of natural resources and ensuring environmental integrity. Technologies, such as remote sensing, navigation, space communication, geospatial tools, Internet of things, are extremely useful in developing newer applications and tools for scientific data management and decision making.

The international conference organized by the Department of Civil Engineering, MVGR College of Engineering (A), Vizianagaram, from 30 March to 01 April 2018 provided a much-needed platform to discuss the emerging technologies and opportunities in water, environment and climate change facets.

The effort of the organizers in bringing out a scientific book on conference deliberations and a compendium of papers needs a special compliment.

I strongly believe that the technical insights presented in this book will enrich the scientific community and provide inspiration to readers and lead to newer technological applications that would support human society in coping up with the challenges posed by impending climate change.

I wish the organizing committee of the conference a grand success.

Hyderabad, India

Y. V. Krishna Murthy
Director
National Remote Sensing Centre

Preface

With the ever-increasing demand for development, the stress on water resources and environment is increasing day by day. The changing climate further amplifies the effect resulting in severe drought, flood and pollution problems. In order to provide a platform for eminent scientists, researchers and students to discuss the emerging technologies in mitigating the problems related to water and environment, the International Conference on Emerging Trends in Water Resources and Environmental Engineering (ETWREE 17) was conducted by MVGR College of Engineering, Vizianagaram, Andhra Pradesh, India, during Mar–Apr 2017. About 100 participants from three different countries attended ETWREE 17. ETWREE 17 was organized by the Department of Civil Engineering, MVGR College of Engineering, and was sponsored by Science and Engineering Research Board (SERB) and National Remote Sensing Centre (NRSC).

The proceedings of this conference contain 60 papers which are included as two volumes. The response to ETWREE 17 was overwhelming. It attracted quality work from different areas relating to water resources, environmental engineering and climate. From a total of 120 abstracts, we selected around 80 papers through a rigorous peer review process with the help of our programme committee members and external reviewers for the presentation.

Dr. Y. V. N. K. Murthy, Director, NRSC Hyderabad, conducted a special session on "Application of Remote Sensing in Water Resources". A special session on "Enigma of Climate" was conducted by Prof. Rakesh Khosa, IIT Delhi. Professor D. Nagesh Kumar from IISC Bangalore delivered a lecture on "Remote Sensing, GIS and DEM for Water Resources Assessment of a River Basin". Professor Uma Mahesh, NIT Warangal, gave a lecture on "Non-Stationarity in Rainfall Intensity". Dr. Brijesh Kumar Yadav, IIT Roorkee, conducted a session on "Engineered BioRemediation". Dr. K. B. V. N. Phanindra, IIT Hyderabad, delivered a keynote on "Modeling Soil Water Disease Interactions of Flood Irrigated Mandarin Orange Trees".

Dr. Shishir Gaur, IIT BHU, conducted a special session on "Application of Simulation Optimization Model for Management of Groundwater Resources". Dr. L. Suri Naidu, NUS Singapore, delivered a lecture on "Food, Water and Energy

Nexus". Professor G. V. R. Srinivas Rao, Andhra University, conducted a session on "Multivariate Statistical Analysis of River Water Quality". Professor T. V. Praveen, Andhra University, delivered a lecture on "Salinity Intrusion Modelling". Dr. Y. R. S. Rao, NIH Kakinada, provided a lecture on "River Bank Filtration".

These sessions were very informative and beneficial to the authors and delegates of the conference. We thank all the keynote speakers and the session chairs for their excellent support to make ETWREE 17 a grand success. The quality of a contributed volume is solely due to the reviewers' efforts and dedication. We thank all the members of the advisory board of the conference for their support and encouragement.

We are indebted to the programme committee members, Mr. A. V. S. Kalyan, Mr. Varaprasad and Mr. Sridhara Naidu, for extending their help in preparing the manuscript.

We express our heartfelt thanks to the Chief Patron, Sri Ashok Gajapathi Raju, Chairman, MANSAS, and Patron, Prof. K. V. L. Raju, Principal, MVGR College of Engineering, for their continuous support and encouragement during the course of the convention. We also thank all the faculty and administrative staff for their efforts.

We would also like to thank the authors and participants of this conference, who have made it for the conference. Finally, we would like to thank all the student volunteers who spent their assiduous efforts in meeting the deadlines and arranging every detail to make sure the smooth running of the conference. All the efforts are worth if the readers of this contributed volume find them inspiring and useful. We also sincerely thank the press, print and electronic media for their excellent coverage of this convention.

Vizianagaram, India — Dr. Maheswaran Rathinasamy
Vizianagaram, India — Dr. S. Chandramouli
Hyderabad, India — Dr. K. B. V. N. Phanindra
Warangal, India — Prof. Uma Mahesh
December 2017

About This Book

The book covers a variety of topics related to water, climate and environment. The topics mainly focus but not limited to hydrological modelling, water resources management, water conservation practices, applications of recent techniques for solving water-related issues, land use impact on water resources, climate change impacts, wastewater treatment and recovery, advances in hydraulics in rivers and ocean. The book is a collection of best papers submitted in the First International Conference on Emerging Trends in Water Resources and Environmental Engineering held from 28 March 2017 to 1 April 2017 at MVGR College of Engineering, Vizianagaram, Andhra Pradesh, India. It was hosted by the Department of Civil Engineering, MVGR College of Engineering, with the support of Science and Engineering Research Board, India.

Contents

About the Editors

Dr. Maheswaran Rathinasamy is currently Associate Professor, Department of Civil Engineering, MVGR College of Engineering, Vizianagaram. He received his bachelor's and master's degree from Anna University, Chennai, and BIT Mesra, respectively. He obtained his Ph.D. from IIT Delhi. He is a recipient of INSPIRE Fellowship from the Department of Science and Technology, India, and Humboldt Fellowship from Alexander Von Humboldt Foundation, Germany. He has postdoctoral experience in the University of Minnesota, USA, and Potsdam Institute of Climate Impact Research, Germany. He is principal investigator of funded research projects on the order of 1.5 crore rupees. He has around 30 international journal publications and 25 international conference publications. His research interests include stochastic hydrology, hydrological modelling and hydro-meteorological forecasting.

Dr. S. Chandramouli currently serves as Professor and HOD, Department of Civil Engineering, MVGR College of Engineering, Vizianagaram. He received his M.Tech. with water resources engineering as specialization from NIT Warangal in 2002. He obtained his Ph.D. in civil engineering from Andhra University, Visakhapatnam, in 2013. He has worked in several organizations such as CES(I) Pvt. Ltd., Hyderabad; GVP College of Engineering, Visakhapatnam; and GMRIT, Rajam, for a period of 10 years. He is working with MVGR College of Engineering since 2011. He has published more than 50 technical papers in various reputed journals and conferences. He has attended more than 60 professional training programmes organized by prestigious institutions in India. He is the life member of ISTE and IEI. He has completed one DST project as a co-principal investigator. He has reviewed many journal papers published by prestigious journals and conferences. He has organized many faculty development programmes and student training programmes.

Dr. K. B. V. N. Phanindra currently serves as Assistant Professor of Civil Engineering at IIT Hyderabad, India. He received his master's degree in hydraulics and water resources engineering from IIT Kanpur and Ph.D. in water resources engineering from New Mexico State University (NMSU). He also holds a graduate

minor degree in GIS from NMSU. To his credit, he has nine journal publications of international repute, three technical reports, one monograph and one chapter. He has completed three research projects funded by various ministries from the Government of India to the tune of about 1.6 crore rupees. His research interests include hydrogeologic characterization, groundwater flow and transport modelling, soil–water–crop interactions, remote sensing and GIS applications in groundwater.

Prof. Uma Mahesh is currently serving as Professor in the Department of Civil Engineering at National Institute of Technology, Warangal, Telangana, India. He has earlier served as Head of the Department from July 2008 to June 2010, as Dean, Students' Welfare from July 2012 to March 2013 and as Dean, Planning & Development from April 2013 to June 2014. His area of specialization is water resources with a focus on water resources systems, hydrologic modelling, irrigation management, water quality modelling and management, applications of soft computing techniques and modelling impacts of climate change. He is a recipient of the Jalamitra Award by the Government of Andhra Pradesh in 2003 for successful implementation of Watershed Development Project in Warangal District, G. M. Nawathe Award for the paper presented at Hydro 2004 (annual conference of the Indian Society for Hydraulics) and Central Board of Irrigation and Power (CBIP) Award. Eight Ph.D. students have graduated with Prof. Uma Mahesh as their advisor. He is currently advising six Ph.D. students at NIT Warangal. He has published more than 60 papers in various reputed journals and conferences.

What Constitutes a Fair and Equitable Water Apportionment?

Himanshu Tyagi, A. K. Gosain and Rakesh Khosa

Abstract Water has been a source of conflict since time immemorial. Numerous mechanisms have been proposed for solving such conflicts but multiplicity of water uses and users along with self-serving definition of equitable, makes dispute resolution challenging. Doctrines advocating water appropriation based on the notion of equity and fairness are intuitively appealing. However, subjectivity of this concept impedes their translation to universal principles for water allocation as fairness quotient of any mechanism is determined unitedly by gamut of diverse factors. Thus, the present study critically reviews the connotations of equity and equality to arrive at a procedurally and distributionally just apportionment policy for real-world water conflicts. It seeks an equal opportunity paradigm for deservedness-based resource distribution that could be unanimously amenable to all stakeholders. The study is very apposite as there is a lurking fear of heightened water conflicts that could have bitter socio-political ramifications.

Keywords Conflict resolution · Egalitarianism · Equity and fairness
Proportionality · Transboundary rivers

1 Introduction

Water is undoubtedly one of the most indispensable resources for sustaining life on this planet. With 40% of global population residing within 263 international transboundary river basins in 145 countries [1], there have always been tensions over sharing water resources. Moreover, with burgeoning demands for freshwater and deteriorating sources of supply, there is a lurking fear that there will be a rise in occurrence and intensity of such water conflicts [2].

Transboundary water disputes are of multi-disciplinary nature and involve an array of natural, hydrological, social, political, and economic issues [3, 4].

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Gamut of factors like geography, hydrological spatio-temporal variability, population pressure, unsustainable utilization, vested interests, geo-politics, industrialization, budding human expectations, etc., can play a pivotal role in triggering a possible conflict in any communal interstate or international basin [5–7].

Most transboundary rivers are shared between just two countries, but there are about 13 basins which have 5–8 stakeholder nations. While rivers like Congo, Niger, Nile, Rhine and Zambezi have 9–11 riparians, Danube River navigates through 18 countries [1]. With such multiplicity of stakeholders, chances of arriving at consensus diminish [8]. It has also been observed that the contenders deliberately overvalue their strong attributes and underrate their negative characteristics to get advantageous outcomes [9]. Further, as everybody considers themselves to be more rational [10, 11], dispute resolution becomes challenging due to vested interests and justice bias [12]. Nevertheless, if conflicts remain unresolved, eventually there may be trust deficit issues which might do severe long-lasting socio-political damages. However, it may be noted that so far no war has been fought over water as it is neither hydrographically effective nor economically worthwhile [8].

In the history of transboundary conflicts, several approaches have been employed to resolve differences over water sharing through negotiations, public consultations, third party adjudication/arbitration, decree, water markets, river basin authorities, decision support systems, etc. [2, 13]. Also, various water laws and doctrines have evolved from historical practices of handling shared resources. However, subjective understanding of such principles by researchers and administrators has proved to be a serious impediment in formulation of universal water allocation doctrines.

Naturally, doctrines advocating appropriations based on the paradigms of equity and fairness, carry great appeal. But objective translation of this concept beyond philosophy has not been very successful [14] and consequently it is difficult to decide entitlements in real world conflicts on the basis of this vague concept. Therefore, this study intends to define the concepts of equity and fairness for an equitable allocation policy that can be used to resolve water sharing conflicts.

2 Theory of Equity and Fairness

The concept of equity and fairness is a worldwide social concern and is therefore intuitively appealing since time immemorial. Traditionally, the idea of equity was limited to the professions of law, public welfare and social sciences [7]. But its connotation and application changed gradually with evolving socio-political scenarios, and is now pertinent for administrators, economists and scientists too who often grapple to interpret equity in their respective fields. For example, administrators essentially look for equity in affirmative actions [15] and employment plans [16]. In economics, equity is a key issue in studies involving distribution of income [17]. Researchers exploring the idea of water rights principally study the notions of equity [14].

Studies from diverse areas have often used the terms, equity and fairness, interchangeably considering their similar scope and definition. While Webster describes equity as fairness, impartiality, justice; Oxford English Dictionary defines fair as equitably, honestly, impartially, justly, according to rule.

The twin concept of equity and fairness is vague and idiosyncratic as every individual has his own perceptions of equity and fairness, and consequently there is barely any consensus on its precise and objective articulation. Literature review reveals that researchers from different disciplines have struggled to develop an objective definition of equity. Marsh and Schilling [18] presented a framework to choose the most suitable measure of equity from the existing equity measures. But there has been a continuous argument on whether a method is equitable or not as multiple issues and parameters determine the equity quotient of any proposed distribution mechanism [19].

Peyton Young in his book, Equity: In Theory and Practice [17], states that the notion of equity is multifaceted and thus cannot be easily defined. He says that to define equity for a particular case, contextual details must be considered too as equity is greatly influenced by stakeholder attributes, social beliefs, precedents and the resource being distributed. He was of the opinion that equity helps in determining the most appropriate outcome based on uniformity and neutrality, and thus it legitimates the allocation choice. He suggests to consider following questions before arriving at any equity solution:

- What form should the allocation take?
- What are the eligibility criteria?
- What counts in the distribution?
- What are the relevant principles?
- What are the relevant precedents?
- How should competing principles and criteria be reconciled?
- What incentives does a rule create?

3 Envy and Superfairness

Superfairness analysis originates from games like fair division of cake in which one person gets the opportunity to cut the cake in two parts whereas the other person chooses the slice he wants. In this case, a distribution is termed superfair if both the persons fancy their own share more than the share received by each other, i.e., nobody envies each other [20]. Varian [21] calls such an allocation equitable while terming an equitable as well as Pareto optimal distribution as fair.

A distribution principle that allots water among various co-riparians on the basis of a particular criterion or a specific combination of criteria that confers a certain advantage only to a particular riparian is destined to create envy amongst the other claimants and hence cannot lead to a consensual solution. Tinbergen [22] proposed the idea of an envy-free equitable system in which nobody wants to be in somebody

else's position. But this concept was not realistic as envy is an inherent trait in humans due to which they always compare themselves with others and then try to compensate their weaknesses with any of their positive attributes. Foley [23] suggested a more practical approach stating that it is not essential to have an envy-free society but nobody should prefer anybody else's allocation. For instance, if different fruits are being distributed, everyone should prefer his own fruit over the fruits that others got on belief that they got the fruit that they desired the most.

4 Normative Theory of Justice and Aristotle's Maxim

Moulin [24] defined distributive fairness through Nicomachean Ethics based Aristotle's famous adage: 'Equals should be treated equally and unequals unequally, in proportion to relevant similarities and differences'. However, Bazerman et al. [25] highlighted the difficulties associated with definition and measurement of equity suggested by Moulin [24].

Equal treatment of equals' advocates that if the claimants have same characteristics in all the relevant areas, they should get the same share in the resource being distributed. In contrast, the principle of unequal treatment is ambiguous but it can be said that it suggests that the resources should be shared in a proportion that highlights the differences between the claimants or in other words, the deservedness of the stakeholders [26].

5 Procedural and Distributive Justice

Any fair distribution mechanism should address the following two concerns, namely, (i) Is the distribution fair? (ii) Is the outcome fair? While the first question relates to procedural justice, the second question examines the distributive justice [24].

Psychologists studied resource sharing from the perspective of exchange between different individuals and these studies led to the development of procedural justice concepts. Furthermore, the aspiration for equity in social justice schemes resulted in the theory of distributive justice. Apropos social welfare policy, Rasinski [27] reported that equity has two elements, viz., proportionality and egalitarianism. While the former recommends individual apportionments based on individual deservedness, the latter involves equal opportunities in resource distribution.

According to equality principle, everyone should be treated equally. However, it may be noted that equality does not necessarily entail equal allocation for all stakeholders but is more suggestive of the distribution process involved. Thus, equality ensures procedural justice and it can be said that if the process is just and equal, then the resulting allocations are likely to be easily accepted by the stakeholders [28]. Proportionality is an established norm to ensure distributive justice

[17]. The proportionality doctrine advocates resource allocation based on claimant's contribution to that resource measured on a cardinal scale.

In series of studies, the authors Syme, Nancarrow and McCreddin [29–31] developed socio-psychological theories of justice, equity and fairness for water allocation decision-making and presented the correlation between procedural and distributive justice. These studies emphasized on the importance of environmental, economic and social issues for attaining sustainability. Instead of social impact assessments of different water policies, the studies evaluated the fairness of different outcomes as an indicator for social criteria.

Syme and Nancarrow [29] assessed the ethical considerations that are relevant to water allocation systems. They conducted primary investigation in three areas: (i) philosophical basis for deciding allocations, (ii) attitude towards planning approaches, and (iii) concept of procedural justice.

Using major equity, distributive justice and procedural justice variables identified through previous studies, Syme and Nancarrow [30] also examined the apparent fairness of water allocation decision-making through a questionnaire survey administered on water literate people. The study showed that people can take assertive decisions on fairness after getting well-versed with procedural and distributive aspects of the system under examination. Also, following observations were made: (i) water seen as a public good, (ii) environment seen to have water rights, (iii) procedural issues are important in water allocation decision-making, and (iv) situational fairness is also important.

Syme et al. [31] conducted studies to find those measures which can reveal how people evaluate justice, equity and fairness. The authors concluded that the participants' notions are likely to change with time and hence the fairness heuristic may vary temporally according to the socio-political dynamics.

6 Conclusion

The preceding discussion may be summarized as follows:

- Subjective nature of water sharing principles severely hinders the formulation of universal water apportionment doctrines.
- The concept of equity and fairness is nebulous and can hardly be objectively articulated.
- Equity does not essentially mean equal distribution of the sought resource, but it implies an equal opportunity paradigm where everyone is equal before the law and the actual distribution is based on deservedness.
- Procedural justice requires an equal opportunity decision-making process that is perceived as open, transparent and unprejudiced.
- Distributional justice involves equitable resource allocation. Proportionality or deservedness is often seen as a rational model for distribution of a given resource.

- Water apportionment purely on the basis of a particular criterion may generate envy among co-riparians and therefore a holistic approach is required to fix the quantum of allocations.

Based on above conclusions, it can be recommended that a coercion-free platform should be given to all the stakeholders of a water dispute wherein each of them can propose a quantifiable criterion that can be most advantageous to him in deservedness-based entitlements. A multi-criteria mathematical formulation should then be used to derive respective proportional apportionments of each claimant. This decision-making mechanism is not only egalitarian but is distributively just also, and thus can be effectively used to resolve transboundary water allocation conflicts.

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Impact of Anthropogenic Interventions on the Vembanad Lake System

Raktim Haldar, Rakesh Khosa and A. K. Gosain

Abstract Estuarine and coastal zone processes have always been topic of research due to their being prime centers of rich resources like diverse habitat and natural beauty. Other than ecological reasons these aquatic bodies act as important economic centers, tourist places, serve in navigational purposes, and fishing. One of the India's most valued natural sites is the Vembanad Lake and estuarine system that lies on the western coast in the state of Kerala. This natural system, which comprises the lake, the Kuttanad wetland region and the Cochin estuary, is included in the Ramsar list of important wetland sites. Six major rivers, namely, Periyar, Muvattupuzha, Pamba, Manimala, Meenachil, and Achenkovil contribute to the system. The whole system has been vastly modified throughout the last couple of centuries owing to sedimentation and human-driven factors. On the other hand, there has been constant reclamation of the low-lying areas on the periphery of the lake and the wetlands, leading to reduction in the spread area. The special characteristics of these lands that lie to the east of the lake is that the ground level is lower than the lake water level. Therefore, the lake water easily serves for irrigational purpose in these adjacent lands. According to tentative proposals in the recent years it was intended to make further developments in the catchment areas for various purposes. The present paper takes a modeling approach to find out what would be the possible impact on the lake water profile as well as salinity/solute concentration if these proposals are implemented. The study has been carried out using the two-dimensional hydrodynamic modeling software MIKE 21 with HD and AD modules. The results from the hydrodynamic model of the lake, although not fully representative, show that the lake water levels and salinity might face quantitatively relevant changes which can pose a threat to the natural environment.

Keywords Wetland · Lake · Estuary · Modeling · Ecosystem Hydrodynamics · Vembanad

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1 Introduction

Water being a limited resource, and having users in multiple sectors such as agricultural, domestic, and industrial, the competitive interaction between its supply and demand prevails in all places of the world. Especially in India, where the population has risen at a high rate, demand for more water and at times, occurrence of floods, have forced us to create interventions that would somehow make the situation in hand more suitable in accordance with our needs. With the passage of time we have created many such changes which are irreversible. It is recently that we have started to understand the ecological aspect of water resources [1], as compared to history of agricultural and industrial development. Governments in developing countries like India have recently started to consider environmental flows and wetland conservation in framing water laws and regulations. Undoubtedly, we should attempt to understand the natural systems to the best of our ability and then take further steps towards development or modification in them. The Vembanad Lake (Fig. 1) in the state of Kerala is one such aquatic system which has suffered vast amount of anthropogenic interventions in the past couple of centuries [2].

The environmental condition of the Vembanad Lake has been in steady decline due to various anthropogenic activities. The major problems are (i) decrease in water holding capacity of the lake; (ii) weed infestation (iii) decrease in water

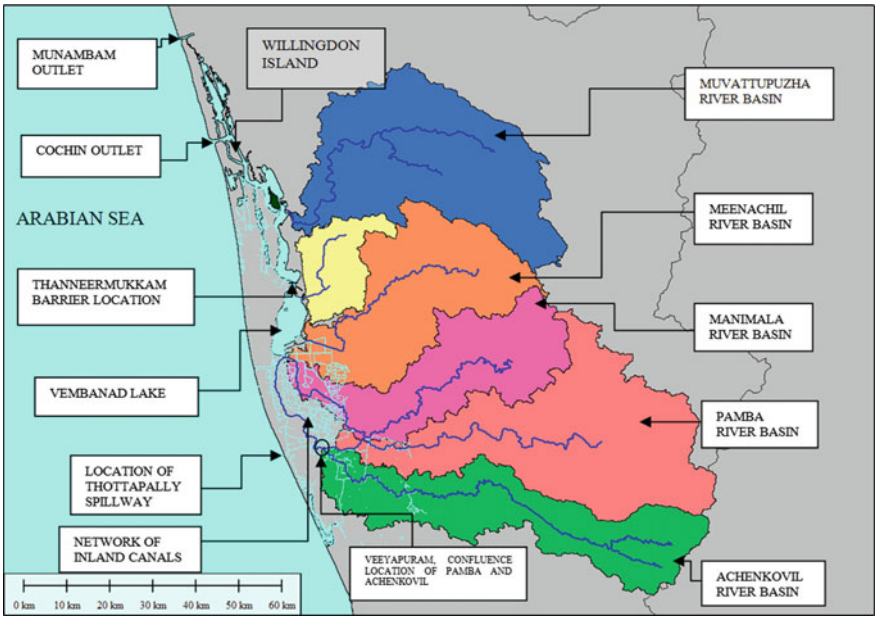

Fig. 1 The Vembanad Lake along with the contributing river basins *Muvattupuzha, Meenachil, Manimala, Pamba* and *Achenkovil*