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Effective framework for Environmental-flows estimation for data deficient Indian rivers

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Abstract
Data deficiency is a major problem in recommending appropriate environmental flows (e-flows) requirements for rivers in many parts of the world. Several studies have been done using a variety of e-flows assessment methodologies. Large dams and hydropower projects are major manipulators of the flow regimes resulting in degraded ecosystems ubiquitously. In India attempts have been made to develop e-flows requirements of rivers to maintain a good riverine ecosystem. Most of the studies are based on hydrological methods, which do not take all the variables affecting flow-regimes into consideration. This paper highlights the problems in assessment of e-flows and their on-ground implications in India. In this study, probable solutions to these problems are suggested a conceptual framework for data deficient areas is proposed. This framework is based upon extensive baseline surveys of fluvial morphology, ecology and of indigenous population. Framework has six steps namely: monitoring the baseline conditions, setting up objectives, hydrological analysis, ecological analysis, climatic anomalies incorporation and recommendations. Finally, e-flows recommendations are made based on hydrological studies, habitat suitability curves and area of inland water body which should be maintained in the river basin. All these recommendations are compared and suitable e-flows recommendations are made based on studied variables. The review also suggests for bottom-up approach for e-flows assessment i.e. e-flows assessment and application should be done on small tributaries of rivers in initial phase of projects and those methods which deliver satisfactory results should only be applied to larger rivers.

Keywords: Environmental flows, River basin management, Data deficiency, Indian rivers, Framework design

INTRODUCTION

India has a large network of rivers over which people depend for socio-economic and cultural needs. Physiologically all these river systems are characterized by large seasonal variation in their discharge due to seasonal rainfall and prolonged dry periods. The mainland has 19 major (Amarasinghe *et al.,* 2005), 45 medium and 120 minor rivers which are grouped on the basis of origin into Himalayan and peninsular rivers and east flowing or west flowing on the basis of direction of flow (Rao, 1975). With changing land use pattern, inefficient agricultural practices, growing urban and industrial water demand and high demand of energy, the river system is getting highly disturbed due to which several rivers are under stress conditions (Richter and Thomas, 2007). As per the National Water Policy-2002 water allocation for ecosystem is 4th priority, and there is no mention in water allocation and demand assessment about water required for maintaining river ecosystems (NWP, 2002, 2012). Least preference for water allocation has been given to maintain river health and its ecosystem in all the developmental processes (Smakhtin, and Anputhas, 2006). In India overall water demand is growing at a very high rate of 62.95% i.e from about 656 Km3 in 2010 to 1069 Km3 in 2050 (Thatte, 2009).

In India, a few attempts have been made to evaluate the environmental flows (e-flows) requirements of River systems in past few years. However, the integrated river basin management plans are still lacking in incorporating the e-flows assessment in the planning processes. Being ecologically and culturally diverse, the requirements and availability of river water is not same at all the places in India (CISMHE, 2007). The concept of maintaining the minimum flow in Indian rivers is considered as e-flows for the river (Durbude, 2014) but it cannot work for all water bodies as each water body has an individual natural flow regime (Acreman and Ferguson, 2010).

Environmental flows: Overview, need and evolution: Rivers are lotic water systems which drain landscape, include the biotic interactions among

Table 1. E-flows definition given by different institutions.

Organization	Definition of e-flows	Reference
World Bank	The quality, quantity, and timing of water flows required to maintain the components, functions, processes, and resilience of aquatic ecosystems which provide goods and services to people	Richard and Hirji, 2003
IUCN	The water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated	IUCN, 2011
Conservation Gateway	The quantity and timing of water flows required to maintain the components, functions, processes and resilience of aquatic ecosystems and the goods and services they provide to people	Conservation Gateway, 2010
International Rivers organization	Quantity, timing, and quality of water flows below a dam, with the goal of sustaining freshwater and estuarine ecosystems and the human livelihoods that depend on them	International Rivers organization, 2014

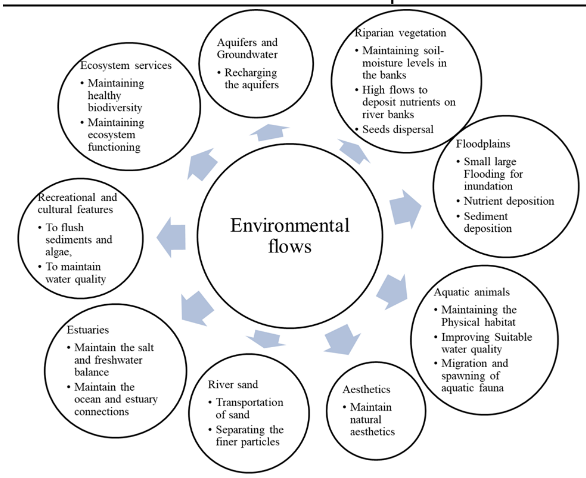

Fig.1. *Ecological and social components of river and their associated functions needed to be addressed while recommending e-flows (Source: Author's own elaboration).*

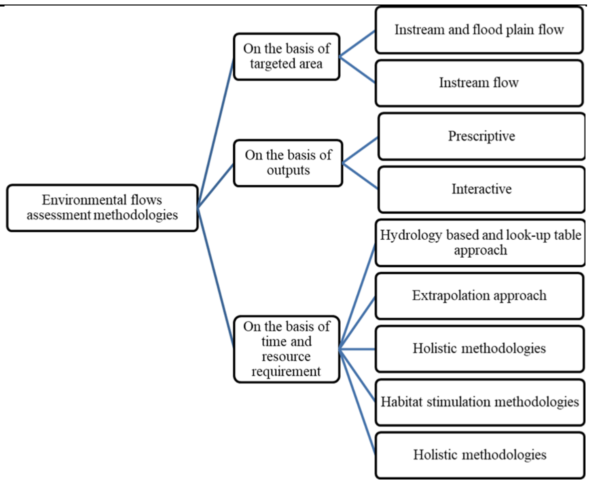

Fig. 3. *Classification of e-flow assessment methodologies based on their targets, output and requirements (Source: Author's own elaboration).*

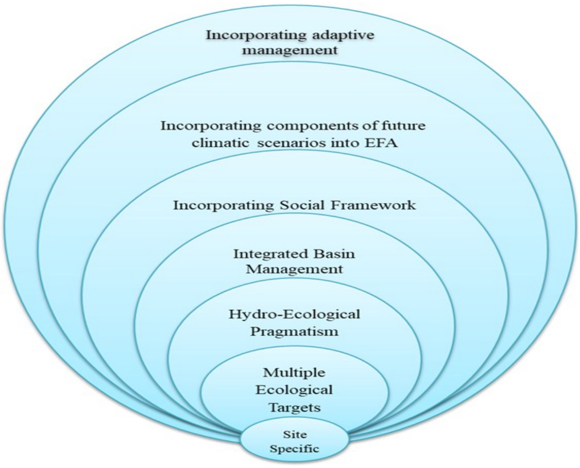

Fig. 2. *The evolution of e-flows methodologies from simple and site specific to more robust methodologies incorporating multiple indicators (Source: Sharma et al., 2016).*

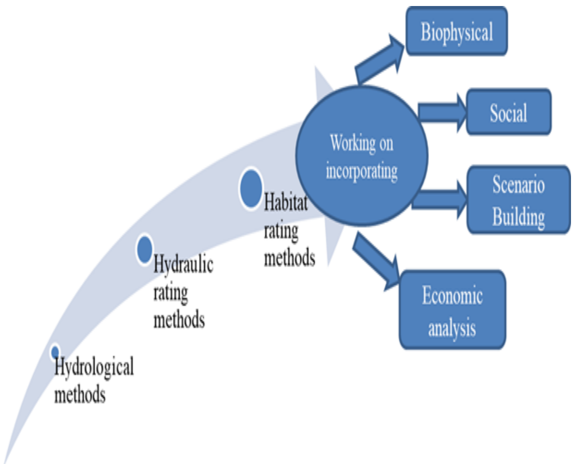

Fig. 4. *Evolution of e-flows methods in South Africa and future desired inputs (Source: Author's own elaboration).*

flora, fauna and micro-organisms, along with facilitating abiotic physical and chemical interactions. These lotic systems need water to stay flowing and deliver variety of ecosystem services (Finn and Jackson, 2011, Wantzen *et al.,* 2016). The construction of dams and over water abstraction has resulted in disturbing riverine ecosystems (Poff *et al.,* 2017). Pollution loading from point and non-point sources is another big problem and reason for degradation of riverine ecosystems. To

Table 2. Showing the studies done different on Indian Rivers, methodology used and recommendations of the study.

S.N.	Location	Methodology used	Recommended e-flows	Recommendations	Reference
1	Cauvery River	hydrological index methods, look up tables, EMC-FDC approach, tennant and modified tennant method	Name of the Site – Maintenance flow (cumec day) Belus – 5.32 Hadige – 20.79 Akkihebal – 12.24 Kollega – 91.22	Maintain the minimum flow in the river to maintain the river ecosystem. Look up table may not be appropriate for Indian condition.	Durbude (2014)
2	Upper Ganga Basin	Building Block Methodology	Name of the Site – Maintenance flows as % of MAR – Drought year flows as % of MAR Kaudiyala – 72% – 44% Kachla – 45% – 18% Bithoor – 47% – 14%	Site specific e-flows Can be applied to other rivers	WWF-India (2012)
3	Mahanadi River	the Tennant method and RVA (Range of Variability Analysis) uses IHA (Indicators of hydrologic Alterations)	Tenant method: minimum (low) flow should be higher than that of 7-day minimum predicted by the RVA analysis For excellent habitat: MAF for the month of October-March (4.93-161.91 cumec) and April-September (62-1186.5 cumec) for the years 1978-2010.	Low flow: Defined as 10% of the total flow (Montana method), whereas for the 7-day minimum flow (RVA analysis), low flow is less than 10% of the total annual flow. As per the results Tennant method isn't applicable for this basin	Bhattacharjee and Jha (2014)
4	Alaknanda and Bhagirathi	Hydrological Index method: Look up table and Q90, Q95 method	Maximum and minimum e-flows recommendation 2% to 15% of MAR	No seasonal recommendations were made to address river variability, Study does not address the cumulative impacts of current power projects,	AHEC (2011)
5	Alaknanda and Bhagirathi	Building Block Methodology (BBM) and Habitat Rating Method	e-flows were recommended to maintain 'C' Environment Management Class, based on flow requirements for two species mahseer and snow trout: the mahseer and snow trout zone – 21.8% of Mean Seasonal Flow no fish zone only for the lean season – 14.5% of the Mean Seasonal Flow other dry zones – 20% of monthly average flow from November to March 25% of monthly average flow in October and April 30% of monthly average flow from May to September	EMC approach is based on two species only the Golden mahseer and snow trout. In conducting a holistic study they missed on socio-economic and cultural impacts, and hence the objective setting is not very clear	Wildlife Institute of India (2012)
6	Brahmani and Baitarani River	Flow Duration Curve approach	FDC were computed for 1-day, 7-day and 30-day mean, the results suggested the 7Q10 FDC was recommended for drought years/low flow periods and 7Q100 FDC was found appropriate for normal precipitation years.	The 7Q10 of FDC yearly mean is beneficial in: protection or regulation of water quality from wastewater discharges or waste load allocations, habitat protection during drought conditions, chronic criteria for aquatic life, and A local extinction flow. 7Q100 is not a common practice	Jha *et al*. (2008)
7	Sone River (Maikalsut)	Global Environmental Flow Calculator (GEFC), desktop software by International Water Management Institute (IWMI) based on Flow Duration Curve (FDC) approach	Name of the Site – flows as % of MAR Indrapuri Barrage – 5.16% and 2-5 % wetted perimeter	As per the analysis: 18.9 % of MAR is required to restore the stretch from Critically modified (F) to Moderately modified Class (C). and to Slightly modified Class (B), 34.2 % of MAR will be required.	Jha *et al* (2014)
8	Kumbh mela (At sangam) in allahabad	Building Block Methodology	Kumbh mela – water depth:1.2 m for Entire Duration and a stage of 73.53±0.11 m Flow: 225 cumecs (7,950 cusecs) surface width: 175 m Special Snan Days: depth of 1.5 m, a stage of 73.83±0.11 m Flow: 310 cumecs (10,950 cusecs).		WWF-India, (2013)
9	Bhadra River	Tenant method (Tenant law (TMC) analysis)	8,855 TMC – poor flow at 10%, 26,565 TMC – moderate flow at 30% 53,129 TMC – excellent flow	Downstream to the Bhardra reservoir 10 times the flow was above the excellent flow conditions. 12 times flow was meeting the poor conditions 10 times flow was above Moderate flow conditions	Babu and Kumara (2009)

(Source: Adopted from Dutta *et al*., 2019 and modified from various sources)

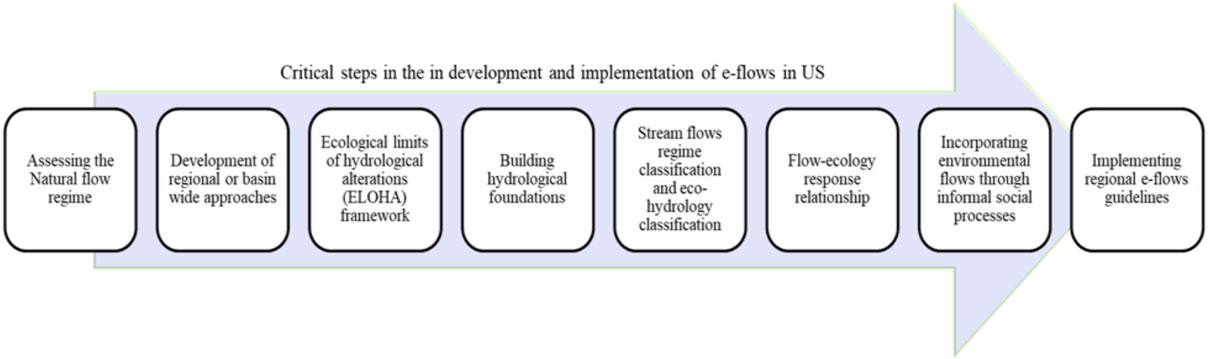

Fig. 5. Critical steps in expansion and implementation of e-flows assessment in United States (Source: Adopted from Dutta *et al.,* 2019)

compensate for changes of flow for the regulated rivers, water may be released from dams and in case of unregulated rivers the over abstraction of water from the river should be protected. For the very first time the e-flows were defined during Brisbane Declaration held in 2007 which stated e-flows as 'the quality, quantity, and timing of water flows required to sustain freshwater, estuarine ecosystem and the human livelihoods' well-being that depend on these ecosystems' (Brisbane Declaration, 2007). This definition was further modified in 2018 and the importance of social and cultural dimensions in e-flow management was also addressed (Arthington *et al.,* 2018). The revised e-flows definition states "environmental flows describe the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being". Other attempts were also made to define the e-flows as per there understanding and requirements of water flow (table 1).

Rivers naturally experience periods of very low or no flow or it could be flooding that occurs every year or occasional large floods that spread out onto floodplains (Richard and Hirji, 2003). This variability of flows is very important in maintaining the functionality and resilience of the river ecosystem and it is very important for the recommended environmental flows to mimic this variability. The river in its undisturbed naturally flowing state is called as the pristine. To fulfill the growing water demands, the natural form of the rivers gets distorted and thus the need to restore the pristine or near pristine flows in the river system came into picture. However, the environmental flow regimes allow for some degree of hydrologic alteration unlike the natural flow regime.

Variable flow is the master variable should be maintained in the river stream to maintain and protect river features such as aquatic animals, riparian vegetation, river sand, estuaries, aquifers and ground water, aesthetic value, recreation and cultural features, ecosystem services as well as overall functioning of environment (Bunn and Arthington, 2002, Lytle and Poff, 2004, Acreman *et al.,* 2014a, Brisbane Declaration, 2007, Poff *et al.,* 2010). A peculiar flow pattern of every river determines the shape of its stream channel, its stream habitats and its biotic components. Both low and high flows are equally important in maintaining diverse flora and fauna (Arthington *et al.,* 2006, Yarnell *et al.,* 2015). Low flows are important for organisms which require low flow velocity whereas small floods are important for fish spawning, flushing away pollutants, cleaning up the river beds, sorting the river stones thus giving a new habitat for seed germination and migration of fishes in river (Yarnell *et al.,* 2015). Large floods are important for maintaining the river channel, cleaning up cobbles and boulder on the river bed, transportation of silt, deposition of silt, eggs and seeds, recharging of soil moisture level in river banks. Large floods occurring once 8 to 10 years are mandatory to clean the connection between estuaries and sea, inundating the back water and promoting growth of new species in the floodplains. These variable flows are also important for creating geological barriers for speciation. Thus any alteration in the flow pattern can lead to depletion in water quality, establishment of invasive species and loss of biodiversity. The ecological and social components of river and their associated functions need to be addressed while recommending the e-flows (Fig.1).

In other parts of the world, the e-flows assessment studies have started with simple hydrological studies which in due course of time have evolved to more robust and suitable for their rivers (Acreman *et al.,* 2014b, Arthington, 2015, Poff and Matthews, 2013, Poff *et al.*, 2017). These studies have also been adapted to other places to manage their rivers to their near natural or pristine forms. Fig. 2, illustrates the evolution of e-flows methodologies from simple and site specific to more robust methodologies incorporating multiple indicators. India is a developing nation, which is in a state of rapid development Thus, it is a crucial to have a robust and well-studied water management plans and infrastructure. Developed nations

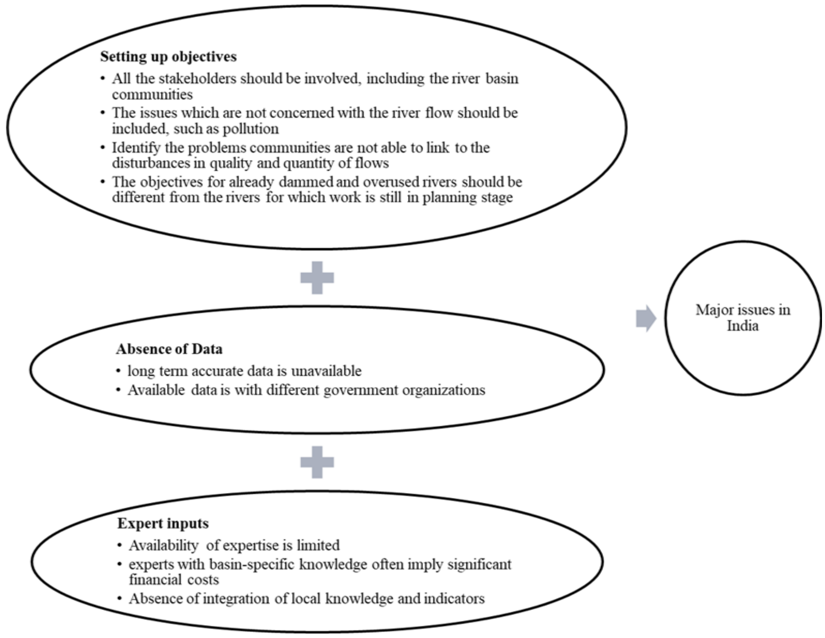

Fig. 6. *Major issues identified in e-flows assessment in India (Source: Author's own elaboration).*

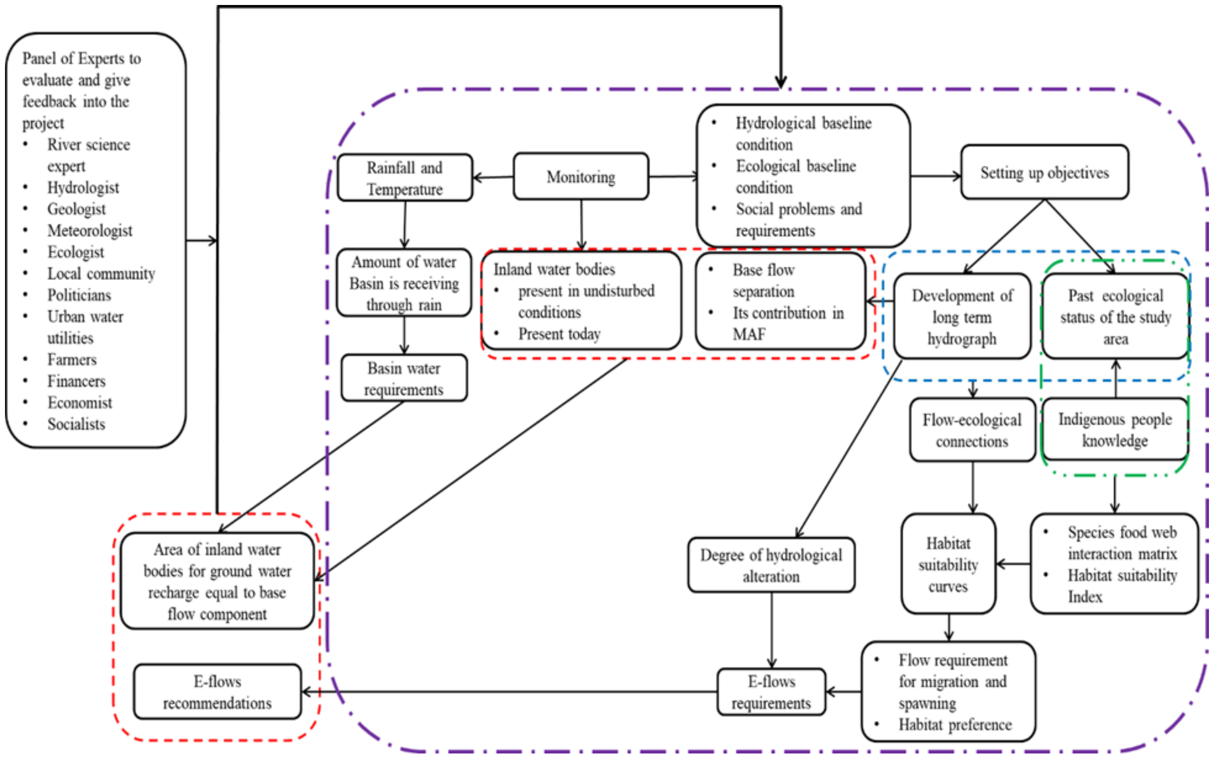

Fig. 7. *Framework for determining environmental flows requirements for data deficient Indian rivers (Source: Author's own elaboration).*

have gone through this stage years back where they have regulated their water bodies to a major extent to store water and harness hydro-energy. However, it took them many years to Figure out the adverse effects those ambitious programs had on the local biodiversity and river ecosystems. Even today large sections of the rivers are getting modified due to damming, channelization and water diversion projects such as Mekong Basin Southeast Asia has more than 80 dams in process (Verma *et al.,* 2009), Himalayas in India has over 300 (Grumbine and Pandit, 2013) and Andes has more than 150 (Finer and Jenkins, 2012) dams which are resulting in drought conditions in the lower basin areas of the rivers (Poff and Matthews, 2013). River Gomti had got channelized as a result it has lost its natural flow and biodiversity (Dutta *et al.,* 2018). E-flows assessment methodologies have been categorized into broad categories based their targeted areas, output requirements and resource and time requirements (Fig. 3).

In United States and South Africa, multiple methods have been developed for e-flows assessment and are still working on improving the existing methodologies. South African scientists have used Hydrological, hydraulic rating and Habitat rating methods, yet they are not able to deliver the satisfactory results to manage their rivers (King and Brown, 2006, King and Brown 2018). Further studies are under process to incorporate the biophysical, social, scenario based and economical analysis. In US, work is in process to suggest and implement the e-flows through strict guidelines on regional basis (Poff *et. al.,* 2007, Poff *et al*., 2010, The Nature Conservancy, 2012, Poff and Matthews, 2013, Poff *et al*., 2017).

Effect of hydrological alteration and e-flows study in India: India is home for variety of rivers, each behaving in a very distinct way in terms of its flow, channel forms and biodiversity supported. Half of rivers are perennial and half are seasonal. Most of the perennial rivers originate from Himalayas and most of the seasonal rivers originate from peninsular ranges. Himalayan rivers get their flow from snow melt and monsoon water both and keep flowing round the year. Peninsular rivers receive water from monsoon rains due to which they have alternate wet and dry period of flow. We are constantly developing structures to tap or store the water at its place or far from its natural pathways. This has left desiccated rivers, life less with distorted ecosystem and loss of livelihoods. Anthropogenic articulation to prevent every single drop of water from going into sea; thus disturbs the whole water cycle which changes the ecological processes downstream to the dams and sets in motion a complex chain of reactions that completely transform the floodplain vegetation dynamics (Wieringa and Morton, 1996, Pandit and Grumbine, 2012). Very few studies have been reported in India to study the effect of hydrological alterations on the terrestrial and downstream riparian ecosystems (Dudgeon, 2000, Grumbine and Pandit, 2013). Study done in Himalayan region pointed the adverse impacts on terrestrial biodiversity in the Indian Himalaya as well as the trends of land-use changes from 292 dams proposed by Government of India (Pandit and Grumbine, 2012, GOI, 2008). The ambitious projects to harness maximum hydropower are showing continental-scale effect favoring spread of cosmopolitan, non-native species on the expense of native biota (Poff *et al.,* 2007). Maximum hydropower projects in India are proposed in species-rich subtropical and temperate zones in the Indian Himalaya (Pandit, 2007). Not just the damming will alter the flow regimes it will also lead to submergence of a large area resulting in direct elimination of species and land use change. Other negative impacts will be fragmentation, loss of forest, sudden species loss and loss of livelihoods of the local inhabitants of that area (Terborgh, 1974, Terborgh *et al,* 2001, Pandit, 2013, Grumbine, and Pandit, 2013). Study done on Bhadra River at Lakkavalli, Shimoga District of Karnataka State (India) focused on the adverse ecological impacts downstream of Bhadra Dam (Kumara *et al.,* 2010). Downstream to the dam the river bed is gradually shrinking as a result a massive loss of riparian, aquatic habitat and water quality is visible. The disturbance in the natural ecosystem of Bhadra River has not only effected the riverine vegetation, birds, reptiles and various aquatic life forms but also more than 60% of the downstream dwellers have changed their livelihood occupations. Another study was done to study the effects of Sardar Sarovar Dam in Kutch, western India, showed that the extensive canal networks of large dams in Rajasthan have made the deserts bloom same as happened in Arizona (Mehta, 2001, McCully, 1996). Attempts to understand the ecological dynamics and people interactions with the environment have been done with both local and scientific perspective (Dahlberg and Blaikie, 1999). In India the existing pattern of inter-state virtual water trade as another big issue which further exacerbates scarcity in already water scarce areas (Verma *et al.,* 2009).

In India, the e-flows assessment and environmental water demands has gained popularity in recent years. India is witnessing rapid urbanization, industrialization and intensification of agriculture, all of which is greatly affecting the rivers in different ways. This is resulting in degradation of the rivers and associated ecosystems. All this is not only limited to the environment, we humans are also suffering the consequences of all these developmental activities. In India very limited studies have been done to assess the environmental flows in river systems. The first National Workshop on Environmental Flows, held at New Delhi, in March 2005, brought together over 60 participants from national agencies and research institutions. The workshop generated a significant interest to the concept of environmental flows in the country and it also revealed the existing confusion in this field. One of the major problems with developing environmental flow work in our country is that despite existing significant knowledge on some aquatic ecosystem components (e.g., fish), its contribution in environmental flow assessments is still limited. There are few studies for e-flows assessment has been done in India.

This review highlights that studies done so far based on hydrological methodologies alone are unable to recommend suitable e-flows. The studies based on Holistic method Building Block Methodology (BBM) lack in considering the holistic ecological conditions. As their e-flows recommendation are based on Environment Management Classes (EMC) which are not developed specifically for the studied area. The ecological requirements were based upon only two species thus effects on the overall food web and community interactions are not taken into consideration (Wildlife Institute of India, 2012). Thus there is a need for a framework suitable for rivers where suitable real time data is not available.

Problem identification and effective framework for e-flows estimation: In India first National water policy was drafted in 1987 for planning, development and management of water resource. India's water policy was later amended in 2002 and 2012. In the first issue of National water policy (1987) the focus was on environmental protection and rehabilitation of project affected peoples and livestock, public health consequences of water impoundment and dam safety. With time new issues came into picture and further in 2002, 2012 National water policy (NWP, 2002, 2012) improvements were made to address the issues like water resource planning and watershed management strategies which emphasis on hydrological perspectives for management studies, soil conservation, catchment area treatment, preservation of forest, increase in forest cover and construction of check dams. However the effect of water storage behind dams, diversion and river basin encroachment were not paid much attention. Indian water policies have the following objectives:

On priority water is allocated for different uses;

Priorities are set among different uses of water;

Conservation of water resources;

Water is Implemented as the fundamental human right;

Satisfactory water quality should be maintained for various uses;

Safeguard water for human survival and poverty eradication;

Water in India falls in Concurrent list thus power is considered by both the central and state government. When it comes to having a state water policy out of 29 states and 7 union territories only 14 states have their own water policies to manage the state water resources. Out of all the state policies only Assam state has a mention of water allocation for river life, flood management, wetland and water body restoration, watershed area management and environmental water allocation strategies. A Goa State policy has put special attention on the ecological sustainability of Western Ghats. The main loopholes in both National and state water policies is that they have not incorporated the ecological and environmental water requirements. In the planning process worldwide major issue is that human being is kept at the center of all the planning and management works.

Other problems include on-ground implementation of environmental laws incorporating the environment impact assessment. India's National environmental impact assessment (EIA) law enacted in 1994 with special concern for threatened and endangered species, protected areas, and other biodiversity concerns. But on ground application and strict implementation of these laws is still lacking. On paper their implication remains uncertain (Dudgeon, 2000), but slight attention had been paid to ecological evaluation and proper implementation of EIA processes in large-scale development projects in India (Pandit and Grumbine, 2012, Bandyopadhyay and Gyawali, 1994, Agrawal, 2010, Singh, 2006).

The other problems in assessment and recommendation of e-flows in India are setting relevant objectives, as there is no correct method for e-flows assessment its completely depends on the people, social, and political desires from a river (Anantha *et al.,* 2017, O'Keeffe and Le Quesne, 2009). Absence of real time, accurate data is another big issue and the data available is headed by different departments. The most crucial part is to have an expert of all the fields such as hydrology, hydraulics, geology, ecology, economics, and quality control. In the paucity of availability of such experts, getting the expert advice would incur significant financial costs (Anantha *et al.,* 2017). Major issues in conducting e-flows assessment in India are listed in the flow diagram (Fig. 6)

E-Flows estimations framework: Tropical rivers are very dynamic with a variety of flows and physical properties. In a developing nation, there is still time to learn from other's mistakes and plan for better future. In this study we have studied the e-flows assessment works done in India and the methodologies adopted to conduct these studies. In the light of the problems identified in this study we suggest solutions to the identified problems.

A single data repository should be constructed where data from all the government departments should be radially available.

A committee of 2-3 members of each field should be made having scientists from all parts of India. These scientists will not only bring their scientific knowledge but will also bring the indigenous knowledge in the assessment processes.

The process of objective setting should be done from river's perspective and not from human perspective.

The extra water available in river should only be eligible for abstraction. The urban water utilities should not only act as water suppliers or service providers rather they should focus on proper management of the available water resources in both demand and supply perspective.

Feedback mechanism and constant adaptation at in all the development projects around rivers.

This framework is designed to recommend e-flows requirements for data deficit areas. This method is a multi-steps process including extensive biological sampling and social surveys. This framework is based upon extensive fluvial morphology, ecological and social surveys. The steps of the designed framework are as follows:

Monitoring the baseline conditions: This step includes the survey of the fluvial morphology and ecology of the study area.

Further the social surveys were conducted to understand their association with the river. These surveys also helpful in understanding the riverine condition prior to the disturbances occurred in recent years.

Thus these surveys will help in understanding the extent of damages River and its ecosystem had gone.

Setting up objectives: Objectives were set from the river's perspective i.e River should be able to sustain its ecological services.

The problems and requirements of indigenous peoples directly dependent on river for their socio-economical requirements should also be considered.

Hydrological analysis: Hydrological data is used to develop long term hydrographs, to understand the variability of flow river experiences.

The base flow share in the mean annual flow was also estimated.

The baseline hydrographs were compared with the historic hydrographs to understand the degree of hydrological alterations.

E-flows estimation was done based on hydrological and hydraulic methods.

Ecological analysis: The food and habitat preference of all the aquatic fauna were studied.

The indigenous people knowledge about the changes they have noticed in the aquatic biodiversity was recorded. The secondary data available in public domain as well as with government organizations were also incorporated in the study.

The species food web interaction matrix and habitat suitability index were prepared. Based on the habitat suitability matrix for most dominant and species acting as interlinks between the food chains, e-flows requirements for migration and spawning was recommended.

Climatic anomalies incorporation: Rainfall and temperature data was used to estimate the net amount of water river basin is receiving. This will be helpful in estimating the area of inland storage required to store this water was estimated.

Recommendations: The environmental flows requirements based on the method.

The area of inland water bodies should be present in the basin to sustain the base flow requirements. In this method, focus is to have decentralized water storage systems in the basin rather stressing the river to meet all the water requirements. Further we propose that water left after meeting the river's requirements should only be abstracted from the river. This amount of water abstracted should be managed in the best by the water utilities. Here the role of water utilities should not only be of a water supplier but they should act as an integrated part of water resource management. The water utilities view their role as:

Water supplier: Their role should be to evaluate water availability, consumer demand, and treatment capacities required.

Service provider: As a service provider the role should be to provide quality services and built efficient treated water supply and wastewater collection system.

Integrated water resource management: Return water back to nature of quality harmless to natural water bodies.

Feedback is an important component for success of any project. The feedback system should be composed of experts from all the fields associated thus they can bring their knowledge into the next stage of the work. This will be helpful in addressing issues from all the associated spheres and would increase the chances of getting a success multiple folds.

DISCUSSION

In data deficient areas such as India, it is a tricky job to conduct e-flows assessment studies. The studies reported so far are based on hydrological methodologies (Jha *et al.,* 2008, Babu and Kumara, 2009, AHEC, 2011, Durbude, 2014, Bhattacharjee and Jha, 2014) and only a few studies have used holistic methods (Rajvanshi, 2012, WWF, 2012, 2013,). There is no study done reporting the implementation of recommended e-flows and its outcome. Lack of strong legislature remains a loophole in on-ground implication of e-flows assessment exercise for all river basins of India as well as to implement it on ground. We are still in the developing stage so we have an advantage of learning from others mistake and success stories in developing our own e-flows assessment frameworks. In place of top down approach in river management plans i.e. we are currently focusing on managing large rivers first and no focus is on small tributaries. It could be dangerous as we are still in phase of hit and trial process of using e-flows assessment methodologies. Rather we should adopt bottom-up approach i.e. we first start managing small tributaries and those methods which deliver satisfactory results should be taken further for managing larger rivers.

In this study a conceptual framework is developed for recommending e-flows in data deficient rivers. This study is mainly based on base line conditions present and the conditions present in long past at the study area. This framework has six steps to recommend e-flows, as well as the area of inland water bodies required for adequate ground water recharge to be maintained the base flow component in the river basin. The feedback system of this framework is an important step to fulfill the knowledge gaps in this framework (Wohl, 2015) as all these experts will bring knowledge from their allied field. This step will help in improving this framework at each stage of its commencement. Thus, this method will be able to reach long term goals of river basin management for data deficient rivers with its flexibility and adaptability.

Conclusion

Data deficiency is a major issue in recommending the appropriate e-flows requirements. India being a developing nation lacks in accurate real time data collection for majority of river basins. The availability of data is not just the only problem. There are other problems as highlighted in this study that is also posing problems in e-flows assessment studies and their on-ground implementation. With this study we have also tried to suggest probable solutions to the Figured problems. Finally, a conceptual framework is also proposed for the assessment of e-flows in data deficit areas. This method is in its initial stage of development and there is a whole room for its further improvement. This method is less data intensive but is based on extensive field survey. But in future the availability of data and expert knowledge will be helpful in further refine and development of robust holistic method. This study also suggests using bottom-up approach for e-flows assessment. Taking small steps in river management will give ample of time to the river to adapt to the changing conditions. The e-flows assessment studies should be made compulsory before taking up any hydropower or river beautification project. A strong legislature framework and strict implementation is also needed for future success of the river basin management plans.

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