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The Sri Lanka environmental flow calculator: a science-based tool to support sustainable national water management

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Abstract

As Sri Lankan water resources are being increasingly exploited, particularly for hydropower and irrigation, ecologists, water practitioners and policymakers alike are realizing the importance of protecting these resources and setting environmental sustainability thresholds. Environmental flows (EF) – the concept that helps define such thresholds – has now become an integral part of environmental impact assessments of river basin development projects. Considering EF is especially vital in the context of the accelerated infrastructure development program, launched after the end of the war in the north and the east of the country in 2009. This paper describes a simple, user-friendly software tool that facilitates quick, first-hand estimation of EF in Sri Lankan rivers. The tool uses 'natural' or 'unregulated' monthly flow time series, at any river location to construct a flow duration curve that is then modified depending on the desired condition of a river – an environmental management class – to generate an EF time series. The tool includes historical flow records from 158 gauged locations, but users may also feed in (observed/simulated) external data. The paper illustrates the application of the tool at two locations of existing/planned infrastructure projects and discusses its usefulness as a policy tool.

Keywords: Environmental flow calculator; Environmental flows; Flow duration curve; Natural flow; Time series; Water resources

Introduction

The term 'environmental flows' (EF) refers to a scientifically estimated river flow regime that is required to sustain freshwater/estuarine ecosystems in an agreed or desired condition, thus maintaining human livelihoods and well-being that depend on these ecosystems. It may be seen, essentially, as a compromise between: satisfying human demands for water, and maintaining ecological integrity of a river. EF aims

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to ensure that water withdrawals from rivers are maintained at levels that do not undermine other ecosystem services. The more the EF mimics the natural flow pattern of the river, the healthier the river ecosystem is. Hence EF is neither a 'minimum', nor a constant, as it used to be seen in the 1970s–1990s (Petts, 2009). In the 1990s and later, the concept of EF (a variable flow regime – as it is seen now) started to be integrated into water resources management policy in several countries, including Australia, South Africa, New Zealand and the UK, to name a few (Environment Australia, 1994; Department of Water Affairs & Forestry (DWAF), 1997; Ministry for the Environment, 2008; Environment Agency, 2013). Interest in EF started to emerge in developing countries too (Tharme & Smakhtin, 2003).

Sri Lanka has 103 rivers radially draining into the sea (Figure 1). The country underwent an extensive water resources development phase during the 1960s through to the 1980s, which included the building of large dams for irrigation and hydropower. The application of EF during this phase of development too was at most limited to prescription of a minimum flow, reflecting the broader practice in the world at large at that time. At present, the majority of Sri Lankan rivers remain 'under-developed' –

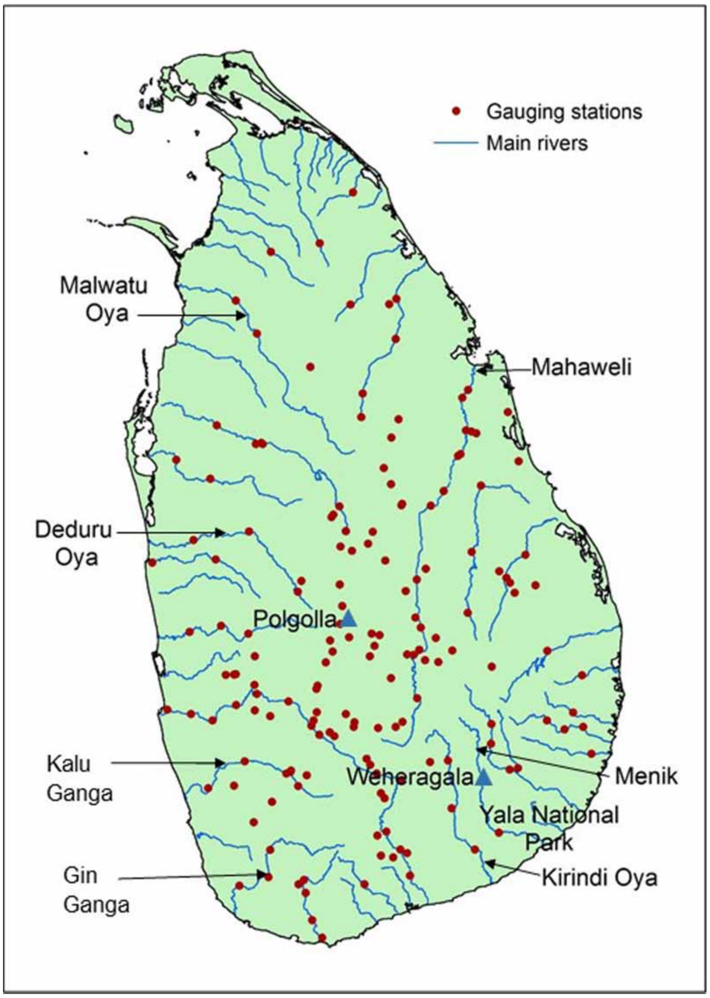

Fig. 1. River basins in Sri Lanka, location of gauged data locations (in black) and the density of data locations in each basin.

at a low level of exploitation, except for a few such as the Mahaweli, Menik, Deduru Oya and Malwatu Oya (Figure 1) which are heavily regulated for domestic/irrigation water supply, and hydropower generation. Developing and implementing scientific guidelines for allocation of EF is more pragmatic at the current state of rivers than at a more ‘developed’ state, since it is easier to accommodate environmental concerns into new development plans than ‘tinker’ with already implemented ones. Such measures may ensure healthy ecological functioning of especially the ‘less developed’ ones in the future, the resources of which are also under pressure due to the current drive for rapid urbanization and infrastructure development, initiated after the end of the war in the north and the east of the country in 2009.

As the country's water resources are being increasingly exploited, ecologists, water practitioners and policymakers alike are realizing the importance of maintaining EF in rivers. An Environmental Impact Assessment (EIA) or an Initial Environmental Examination (IEE) is mandatory for approval of all large river basin development and irrigation projects as per National Environmental (Amendment) Act, No. 56 of 1988 (http://www.cea.lk/images/pdf/acts/act56–88.pdf) and Government Gazette No. 772/22 of June 18, 1993 (http://www.cea.lk/images/pdf/eiaregulations/reg772-22.pdf). EF estimates are required to be presented as part of such EIAs and IEEs of projects involving river regulation/water abstraction although national guidelines on implementing EF requirements have not yet been stipulated. As a result, project proponents continue to assign, for environmental purposes, a certain percentage of the mean annual runoff, a percentile flow or a minimum flow (as a flat rate), without much scientific justification. To quote one of the earlier examples, in the Mahaweli Development Program initiated in 1970, which included the construction of five major dams and several diversions along the river, it was stipulated that ‘the minimum discharge of the Mahaweli should not drop below the historical minimum, in order not to endanger the habitat of fish and other fauna’ (Netherlands Development Company (NEDECO), 1979). Accordingly, a minimum flow of 4.2 m^3/s was prescribed to be maintained in the river downstream of the Polgolla diversion (Figure 1) where part of the Mahaweli river water is diverted to the North Central Province for irrigation of crops and hydropower generation (ACRES, 1985). A more recent example is the Weheragala diversion in Southern Sri Lanka (Figure 1), where nearly 50% of the flow of the river Menik is diverted to another basin (Kirindi Oya) with the commitment that a minimum flow of 1.5 m^3/s is maintained in the river through the Yala National Park, downstream of the diversion (Weligamage, 2011). Typically, the practice in recent hydropower projects has been to assign a certain percentage (ranging from 5 to 41) of the 95th percentile flow (Q95) (Ceylon Electricity Board (CEB), 2012, 2014) or the 90th percentile flow (Q90) (Halwatura & Najim, 2014) as the EF. The regulators, on their part, also face difficulties in granting environmental clearance for water development projects due to the non-availability of clear guidelines on what would be an acceptable EF regime (K. G. S. Jayawardane, Central Environmental Authority (CEA), pers. comm.).

Recognizing the need for clearer scientific guidelines for EF assessment, a national stakeholder consultation forum involving several agencies concerned was initiated in 2012 (http://www.iwmi.cgiar.org/News_Room/pdf/minutes_of_stakeholder_consultations_on_development_of_the_sri_lanka_environmental_flow_calculator.pdf). Three types of organizations are involved in this continuing stakeholder forum:

- agencies responsible for developing and implementing water resources projects (Irrigation Department, Water Supply and Drainage Board, Mahaweli Authority, Ceylon Electricity Board, etc.);
- agencies responsible for granting environmental clearance to water resources projects (Central Environmental Authority (CEA)); and
- other organizations engaged in EF research (International Union for the Conservation of Nature (IUCN), local universities, etc.).

This dialog so far has highlighted the constraints encountered in estimating EF due to the lack of data, guidelines and expertise, policy support and the low priority given to environmental issues in development (which is typical of many developing countries). It became apparent that project proponents favored the use of some rule-of-thumb approaches to EF assessment while regulators repeatedly highlighted the need for more scientific tools/guidelines to determine EF, especially for cases of highly developed rivers. To facilitate this valuable process and support the emerging policies and practices of environmental water allocation in the country, a hydrology-based tool has been developed specifically for Sri Lanka – to bring EF closer to the needs of the country.

This tool – Sri Lanka Environmental Flow Calculator (SLEFC) – aims to provide quick estimates of EF at known locations on major rivers of the country. This paper details the underlying algorithms and functionality of the SLEFC, and its application to two locations, one on the river Mahaweli (the longest river in Sri Lanka) and the other on the river Gin Ganga (Figure 1). The two locations have been identified as potential sites for future hydropower development. The paper also discusses the usefulness of SLEFC as a policy tool and suggests measures to further enhance its capabilities.

The methodology and the software

The methodology

Smakhtin & Anputhas (2006) developed a desktop method, which uses 'natural' or 'unregulated' monthly flow time series to define environmental water requirements for six 'Environmental Management Classes (EMCs)'. An EMC is a prescribed or negotiated condition of a river ecosystem. Six EMCs are defined in this method (named A through F) ranging from 'Unmodified and largely natural' to 'Seriously and critically modified.' The higher the EMC, the more water is needed for ecosystem maintenance and the more flow variability needs to be preserved.

'Natural' or 'unregulated' flow is the flow that would occur at a particular location of a river minus any upstream water resources development (dams, diversions or abstractions). The method converts monthly 'natural' flow time series into a flow duration curve (FDC), a probability distribution function of flows. The FDC is represented by a table of flows corresponding to 17 fixed probabilities of exceedance: 0.01, 0.1, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99, 99.9 and 99.99%. These 17 points ensure that the entire range of possible flow values at a particular location is covered by the estimated FDC. This 'natural' or 'reference' FDC is shifted laterally to the left along the probability axis to generate EF scenarios. The magnitude of the shift is currently regarded as one percentage category (out of the 17). With each shift, a new EF regime (corresponding to an EMC) is defined, in which, although the peak flows have reduced, the natural flow pattern (considered vital for ecosystem health) still remains intact. The step of an FDC shift (between different EF regimes) has been inferred partially from literature sources (e.g., Tennant, 1976; Jones, 2002) and partially through limited 'calibration' of EF estimates for Indian rivers against better tested approaches (Smakhtin & Anputhas, 2006). However, the magnitude of the shifts along the probability axis which would generate each of the six EF regimes is open to further calibration to suit conditions in Sri Lankan rivers through establishing relationships between ecological status and hydrological regimes. The procedure followed in generating the different EF regimes (FDCs) is illustrated with two examples later in this paper.

The estimated environmental FDC is converted back into an EF time series by using an interpolation technique described in Hughes & Smakhtin (1996). This EF assessment method helps to decide: which

EMC best describes (if at all) the present flow regime of a river, how far it is from its natural flow regime, and the most feasible EMC for the river to be maintained in given current and future water resources development in the basin. Alternatively, it is also possible to use expert judgment and available ecological information in order to place a river into the most probable/achievable EMC. Often, a river is placed in a certain EMC using a scoring system (DWAF, 1997; Smakhtin *et al*., 2007; Environment Agency, 2013). Once the EMC is agreed upon, the current flow regime of the river may be related with this EMC, the natural flow regime and the environmental flow regimes for other EMCs may be generated, and the most feasible EMC for the river to be maintained in may be identified.

A 'natural' flow time series of the location of interest is not always readily available since that particular location may be ungauged or significantly impacted by upstream water resources development. In such instances, representative 'unregulated' monthly flow time series have to be simulated, or derived from available observed source records. This can be done by a range of methods including identifying the quantity and timing of upstream water uses and adding these withdrawals 'back' to observed flow records, and various hydrological simulations/analyses (such as hydrological modeling, extending past trends, spatial interpolation, and statistical analysis). A spatial interpolation technique to generate natural flows using time series data of nearby flow stations (Hughes & Smakhtin, 1996) is used in the example applications in this study.

The above forms the core of the SLEFC. It is coded in Visual Basic 2012, and provides a user-friendly interface (Figure 2) in order to enable usage by experts, water practitioners and students alike. The SLEFC builds on two previous similar tools that facilitate estimation of EF globally, and in the Ganges basin in India – both available as free downloads (http://www.iwmi.cgiar.org/resources/models-and-software/environmental-flow-calculators/).

The software

The SLEFC currently offers two different 'pathways' to follow in estimating EF based on two different data retrieval options. The first pathway named 'Default Observed Flow' provides the user access to a database of historical monthly flow time series at 158 gauged locations on major rivers of Sri Lanka (Figure 1), whereas the second pathway ('User Defined File') enables the user to start with an externally input flow time series. The intention of the first pathway is to provide monthly 'natural' or reference flow time series (the starting point for the estimation of EF) at the gauged locations by 'naturalizing' observed flow records obtained mainly from the Irrigation Department and the Mahaweli Authority. In nearly one third of the stations the flow records are less than 5 years long. In order to fully utilize them, the flow records need to be augmented. While this augmentation plus naturalization of observed flow records are in progress, the default database currently consists of observed flow 'as is'. However the second pathway allows external data to be used instead of the default flow data. The users may 'naturalize' an observed flow time series extracted through the first pathway (by using any of the methods described earlier), or use a separate 'natural flow' data set at the same location that they may have in their possession.

All gauged data locations can be viewed on an interactive geographic map of Sri Lanka through the use of a map control called the MapWinGIS ActiveX control (http://www.mapwindow.org/). Tools are provided for zooming, panning and selecting points on the map (Figure 2). Progressive zooming exposes a number of data layers including:

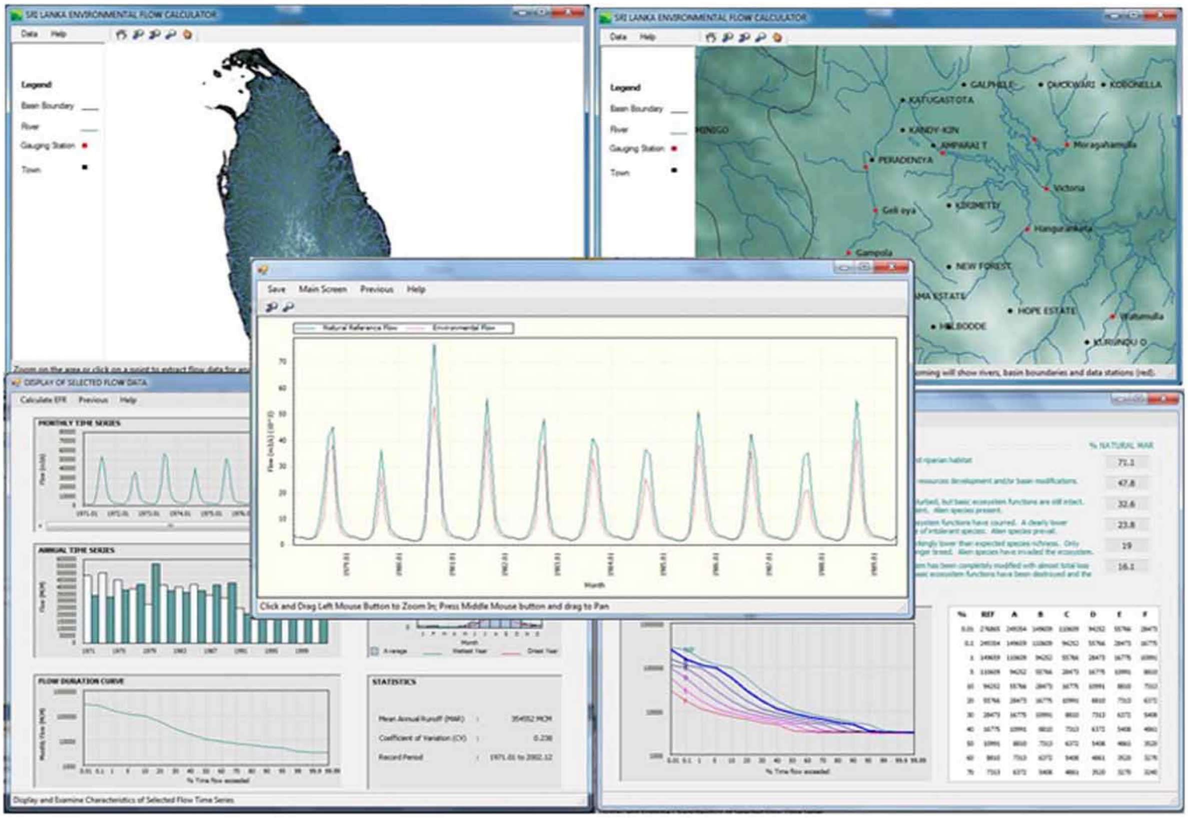

Fig. 2. Screenshots from the Sri Lanka Environmental Flow Calculator (SLEFC).

- Country and river basin boundaries
- River network
- Major cities
- Gauged data locations
- A digital elevation model (DEM) of Sri Lanka.

By clicking on any particular data location (gauging station), the flow time series pertaining to the location of interest may be accessed from the flow database, its main hydrological characteristics displayed, the environmental FDCs for each EMC estimated, and a suitable environmental FDC (EMC) for the river in question selected and converted into an EF time series. The ‘User Defined File’ pathway also follows a similar route except that data retrieval in this case is through a File Open Dialog.

When using the ‘Default Observed Flow’ option it is not only possible to estimate EF at one gauged station at a time, but also to calculate EF for all stations in one go (using the ‘Basin Snapshot’ option). Facilities are also available for writing the complete table of flows for all FDCs, the selected FDC only, the reference natural flow, and the environmental flow time series into text files.

Example applications

The use of the tool is demonstrated by applying it to two locations, Ullapane and Mederipitiya, which are identified as potential sites for future hydropower development. Ullapane lies on the upstream reaches of the river Mahaweli (Figure 3(a)). Considerable flow regulation has already occurred upstream of Ullapane, which in turn influences its current river flow. On the other hand, Mederipitiya is located in the upper watershed of Gin Ganga (Figure 3(b)) and is not impacted by significant upstream development. The SLEFC plays a different role at each site. In the case of Ullapane, it is used to approximate the site's current ecological condition, with upstream water resources development in place, as against its natural condition. In the case of Mederipitiya, it generates a suite of EF scenarios that could be maintained at the site, in case of future water resources development.

Approximating the current ecological condition of Ullapane

The Kotmale Hydro-electricity Project, located on a tributary of the river Mahaweli, slightly upstream of Ullapane (Figure 3(a)), commenced its operations in June 1985. Construction of the project was

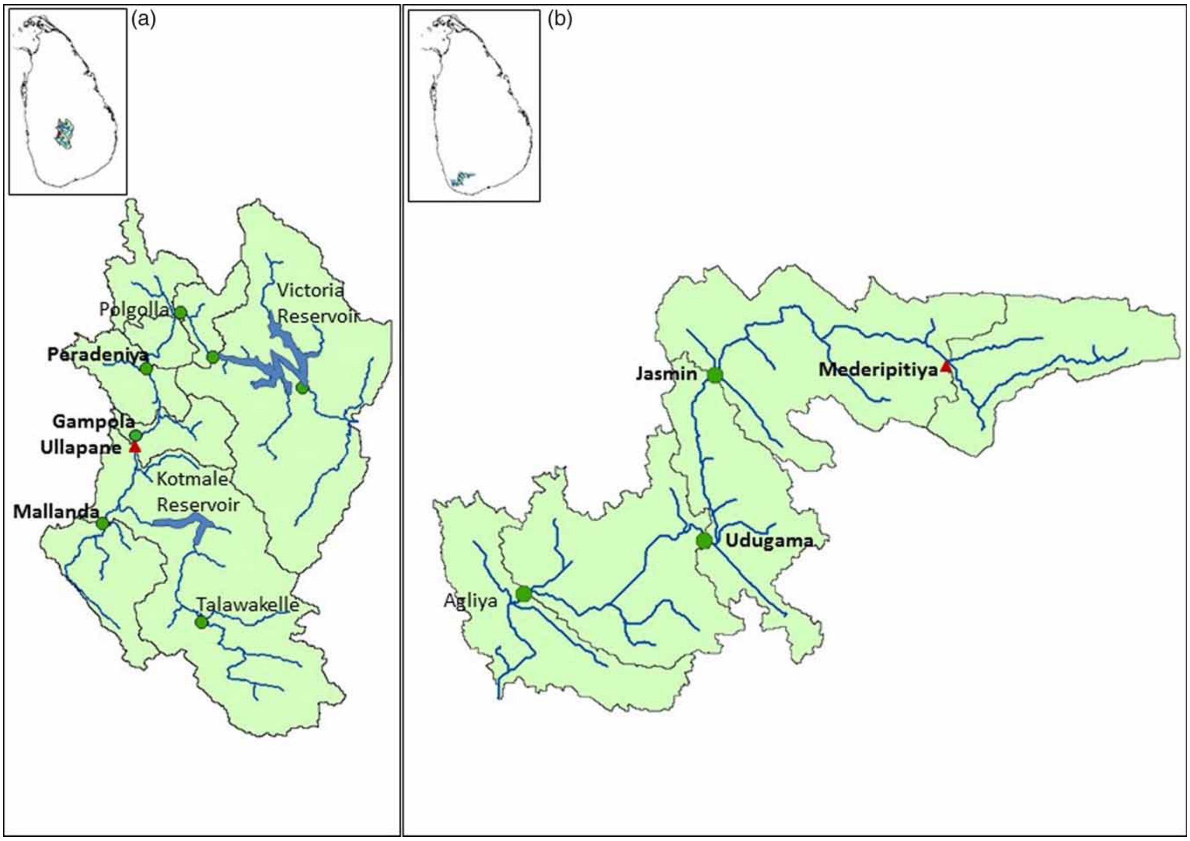

Fig. 3. (a) Location of Ullapane on river Mahaweli and (b) Mederipitiya on river Gin Ganga where EF is estimated (triangles). Gauge locations are shown with circles.

initiated in February 1979. The project components include an 87 m-high rock fill dam to store grossly 174 million cubic meters (MCM) of water, and a tunnel system conveying impounded water to underground turbines, having a combined installed capacity of 201 megawatts (MW). After power generation, water is released back to the river Mahaweli slightly upstream of Ullapane. Since the Kotmale Hydroelectricity Project is the only known major flow alteration that has taken place upstream of Ullapane in recent times, stream flows that occurred at this location before commencement of construction work of the Kotmale project are regarded as natural flows. Measured monthly discharge data are available at locations Peradeniya, Gampola and Mallanda in this stretch of the river (Figure 3(a)) for the period before construction of the Kotmale project, and these data are already incorporated in the SLEFC. Ullapane itself is an ungauged location. Mallanda is approximately 6 km upstream of Ullapane while Gampola and Peradeniya are 6 km and 17 km downstream respectively. Table 1 provides details of all four locations.

The steps followed in approximating the current ecological condition of Ullapane include the following:

- Estimating the natural FDCs for Peradeniya and Mallanda (located on either side of Ullapane and having the longest flow records) by feeding in monthly stream flows before 1979 into the SLEFC (Figure 4(a)).
- Estimating the natural FDC for Ullapane using those of Peradeniya and Mallanda following an area ratio approach (as described below and in Figure 4(a)).
- Generating natural flow time series at Ullapane using that of Peradeniya and a spatial interpolation technique (part of this natural time series is shown in Figure 5(b)).
- Establishing the current FDC of Peradeniya (after regulation by the Kotmale reservoir and hydropower plant) by feeding monthly stream flows from 1987 to 2010 into the SLEFC.
- Establishing the current FDC of Ullapane by extrapolating downwards from that of Peradeniya (as described below).
- Comparing the altered flow regimes of both Peradeniya and Ullapane (Comparison for Ullapane shown in Figure 5(a)) with their natural FDCs and environmental FDCs generated by the SLEFC.

After estimating the natural FDCs of Peradeniya and Mallanda, the natural FDC of Ullapane was generated using those of Peradeniya and Mallanda assuming that the difference in FDC heights at each

Table 1. Details of gauged and ungauged locations employed in estimating EF.

Location	Latitude	Longitude	Contributing catchment area (km^3)	Period of record
Peradeniya	7° 16′ N	80° 35′ E	1,139	1942–2010
Gampola	7° 10′ N	80° 34′ E	919	1951–1978
Ullapane	7° 10′ N	80° 35′ E	814	None
Mallanda	7° 04′ N	80° 32′ E	186	1958–1965
Mederipitiya	6° 21′ N	80° 30′ E	116	None
Jasmin	6° 21′ N	80° 20′ E	357	1973–1986
Udugama	6° 14′ N	80° 19′ E	492	1973–1985

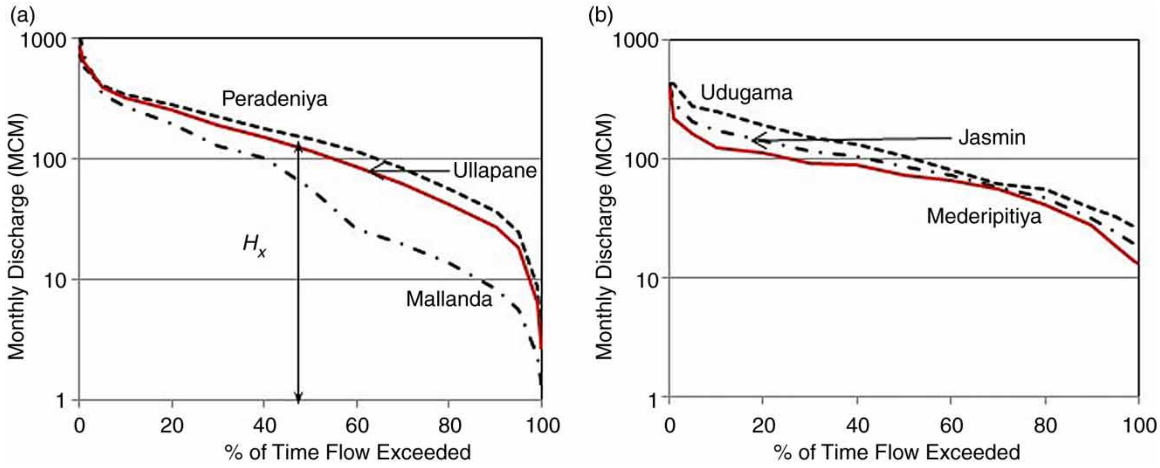

Fig. 4. (a) Simulated natural FDC of Ullapane (continuous line) and (b) simulated natural FDC of Mederipitiya (continuous line) using flow data of adjacent stations.

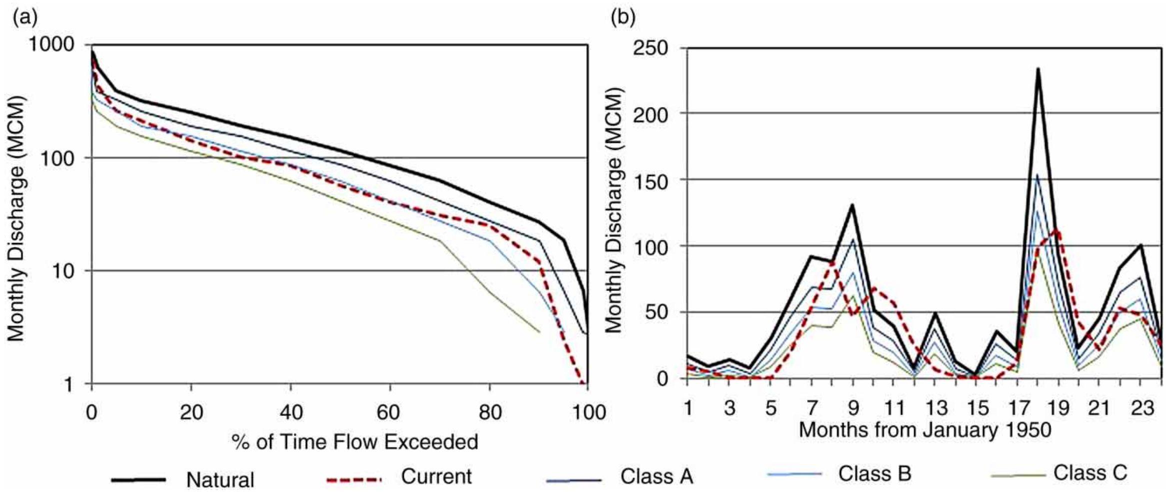

Fig. 5. (a) Simulated natural and environmental FDCs of Ullapane compared with its current flow regime (dashed line) and (b) simulated flow for Ullapane for 1950–1951 (under natural and EMC conditions) compared with its flow for 1992–1993 (under current conditions).

percentage category between any two locations in this stretch of the river is proportional to the difference in their respective catchment areas. Hence, for any location X between Mallanda and Peradeniya (Figure 4(a)),

$$(H_x - H_{\text{mallanda}})/(A_x - A_{\text{mallanda}}) = (H_{\text{peradeniya}} - H_{\text{mallanda}})/(A_{\text{peradeniya}} - A_{\text{mallanda}}) \quad (1)$$

where H_x represents the FDC height at a particular percentage category and A_x is the contributing catchment area at location X. FDC heights (H_x) for Ullapane for all 17 percentage categories were estimated in this manner by solving Equation (1) for H_x with $A_x = A_{ullapane}$ (assumption was tested earlier for Gampola (Figure 3(a)) which is a gauged location). The simulated natural FDC of Ullapane was converted to a monthly time series (Figure 5(b)) by using the spatial interpolation technique of Hughes & Smakhtin (1996), considering that flows at any particular month in Peradeniya and Ullapane occur at similar percentage points on their respective FDCs due to their close proximity to each other. The reason for using Peradeniya as the 'source' station is because it has the longest available observed flow record in this stretch of the river. Although generation of natural FDCs and flow time series at ungauged locations currently requires the use of a spreadsheet tool, such procedures are envisaged to be built into the SLEFC in the future.

After establishing the altered (current) FDC of Peradeniya using the SLEFC, the altered (current) FDC of Ullapane was generated by extrapolating downwards the altered FDC of Peradeniya by the same ratio in heights between the natural FDCs of the two locations at each of the 17 percentage categories. The altered FDCs at both locations (Figure 5(a) shows that for Ullapane) were compared with their natural FDCs. Figure 5(b) indicates a part of the natural and environmental flow time series (for 1950–1951) for Ullapane compared with its current flow time series (for 1992–1993). It is apparent from Figure 5(a) and 5(b) that the peak flows have reduced and the shape of the FDC is altered due to flow regulation. The cumulative effects of these flow reductions and alterations place the current flow regimes of both Peradeniya and Ullapane between EMCs A and C (Figure 5(a)). Any further utilization of river water in this stretch may place the river at a lower EMC. The question to be answered by water managers is: can the river afford to move to a lower EMC, and, if so, what is the most feasible EMC for the river to be maintained in, given current and expected development.

Generating EF scenarios at Mederipitiya

Mederipitiya too is an ungauged site. Natural flow time series at Mederipitiya was generated using a similar approach to Ullapane by employing gauged flow time series at two nearby locations, Jasmin and Udugama, downstream of Mederipitiya (Table 1, Figures 3(b) and 4(b)). Since no major water resources development has taken place upstream of both Jasmin and Udugama, gauged flow records at these locations are considered as natural flows. Hence, the generated flow time series at Mederipitiya (Figure 6(b)) too is considered natural. This natural flow time series was fed into the SLEFC to generate environmental FDCs and time series pertaining to the six management classes (Figure 6(a) and 6(b)).

As opposed to Ullapane, the environmental FDCs and time series for Mederipitiya spell out possible development scenarios for the river, i.e. how much water can be withdrawn/diverted and how much should be left in the river if any one EMC is adopted. The decision on the extent to which the river's current natural flows may be altered depends on its environmental sensitivity and expected human interventions in the future.

The two examples above demonstrate how a coarse scale assessment of the current ecological condition of a river location (segment) may be made, and possible scenarios of EF may be generated using the SLEFC, and other simple methods for simulating FDCs and flow time series at ungauged locations. The decision on the most probable (feasible) EMC the river should be maintained in, needs to consider expected water resources development in the future as well as other socio-environmental requirements. Once the decision on whether to 'downgrade', 'upgrade' or 'maintain' the current ecological condition of the river is made, the relevant FDC may be translated into a flow time series (and subsequently into 12 average monthly flows per year) which may be maintained as EF.

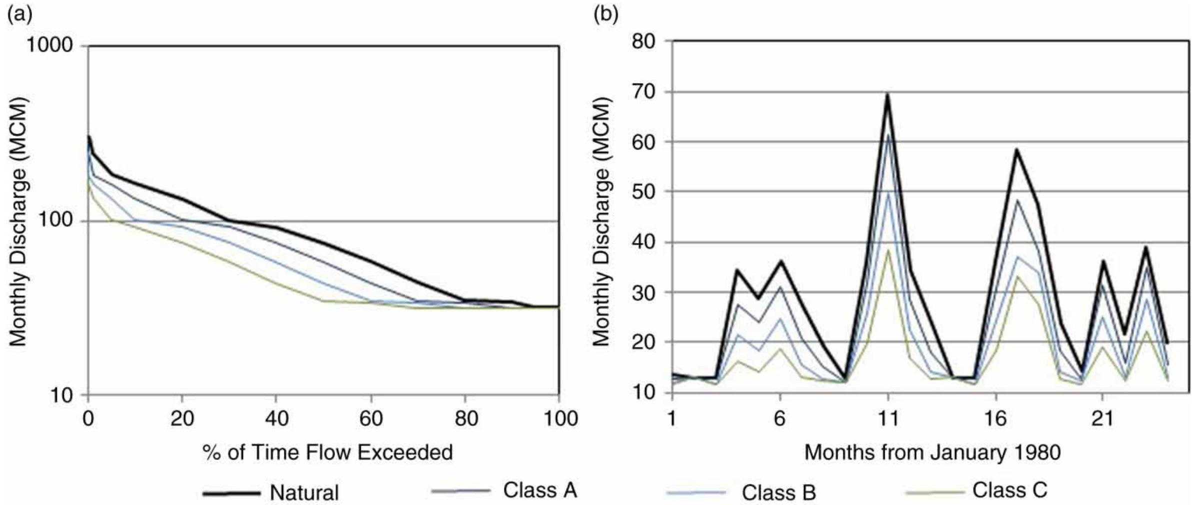

Fig. 6. (a) Simulated natural and environmental FDCs of Mederipitiya and (b) simulated flow for Mederipitiya for 1980–1981 (under natural and EMC conditions).

Application of the SLEFC as a policy support tool

The installed hydropower capacity of Sri Lanka currently stands at 1,358 MW, which is about 74% of the technically feasible potential in the country (Laksiri, 2014). Four more projects, having a combined installed capacity of 210 MW are currently under various stages of implementation, while two new projects (installed capacity 44 MW) are planned for the future; out of the four under implementation, two are multipurpose reservoir projects, which include irrigation water development (Laksiri, 2014). Hence, considering the many new water resources projects planned for the future in the country, the SLEFC may prove a valuable tool for agencies such as the Ceylon Electricity Board (CEB), Mahaweli Authority, Irrigation Department and the Central Environmental Authority (CEA), in maintaining the ecological health of rivers while developing their water resources.

In order to use the tool effectively, the FDC shifts, as prescribed in the method behind the SLEFC need to be 'calibrated' to suit Sri Lankan conditions by establishing the ecological status of rivers where EF is estimated, possibly using an indicator-based approach (e.g. Smakhtin *et al.*, 2007), or a statistical approach to relate human basin modifications and stream flow alterations (e.g. Homa *et al.*, 2013). A first step in this regard would be to categorize as many Sri Lankan rivers (or river segments) as possible into the six EMCs and link their current flow regimes (FDCs) with the current EMC, so that each EMC can be benchmarked against an agreed flow regime (considering the degree and orientation of the shifts from the natural condition). Such an exercise will enable the capture of changes in hydrological regimes more realistically (for example, smaller shifts at the low flow end of the FDC and larger shifts at the high flow end as shown in Figure 5(a) for Ullapane). It will also help to identify rivers which are currently in a 'sensitive' state requiring rigorous EF assessments through more holistic methods. Linking of ecological status and river flow may first be attempted in two pilot river basins having contrasting climates, phases of development, and flow regimes (for example, the Malwatu Oya basin in the dry zone of the country and the Kalu Ganga basin in the wet zone – Figure 1), with the possibility of gradual scaling up to the rest of the rivers.

Conclusions

This paper describes and illustrates the application of a policy support software tool that facilitates quick, coarse scale estimation of EF for any river in Sri Lanka. The tool provides a solid 'starting point' for EF estimation that has been essentially non-existent in Sri Lanka to date. A decision on the need for a more comprehensive EF assessment can also be subsequently made. If the river/site is in a highly 'degraded' state, due to already existing water resources development, a more rigorous EF assessment through holistic methods may be necessary, whereas if it is in a nearly 'pristine' state (such as in the second example above), the results from a coarse assessment may be sufficient. One possible approach to test whether the application of the SLEFC is sufficient for a particular river/site is to compare it against the three phases of river development described by Molden *et al*. (2001): 'Development' (river is in a nearly pristine state with emerging infrastructure development); 'Utilization' (river is in an advanced state of infrastructure development, but emphasis is placed on maximizing returns through improved management of water delivery); and 'Allocation' (water consumed within the basin has approached limits of potentially available water and reallocation of water from lower to higher value uses takes place). The SLEFC may be applicable in the 'Development' and 'Utilization' phases, but not in the 'Allocation' phase.

Currently the SLEFC incorporates only observed data. The examples illustrate how this observed data may be used to generate flow time series at ungauged locations. The tool may be populated with simulated data for the entire country in the future so that more options for retrieving source data are available. Additionally, the 'User Defined File' option provides flexibility by enabling the use of user-generated/observed external data. However, difficulties may arise at certain places in recreating the natural flow regime of a river, particularly identifying the time period which represents natural conditions.

The robustness of the SLEFC can be improved by establishing the link between ecological status of Sri Lankan rivers and their hydrological regimes through calibration. Supplementary algorithms to generate flow at ungauged locations (by using available flow records) may also be incorporated into the tool itself. In addition, the tool may also act as a repository of all available observed/simulated flow time series in the country. With the active participation of the members of the EF stakeholder forum in using the tool, its applicability in Sri Lanka may be further tested. It can be replicated in other developing countries too, to promote the concept of EF and its practice, if sufficient observed or simulated monthly flow data on major rivers is available.

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