Geomorphological and Ecological Implications of River Restoration Approaches in Sri Lanka

G.D.W.N. Galhena[1] and R.L.H.L. Rajapakse[2]
Department of Civil Engineering, University of Moratuwa, Sri Lanka

ABSTRACT: River restoration is defined as the establishment of improved hydrologic, geomorphic and ecological processes in a degraded watershed system, returning its lost, damaged or compromised biotic, structural and functional elements to the pre-disturbance and self-regulating state. Due to the rapid urbanization and fast growth of the population and industries in Sri Lanka, most of the water bodies have been affected and continuously degraded due to direct or indirect impacts of anthropogenic interventions. At present, there exists no proper approach to monitor ongoing river degradation nor to recognize in advance, the possible extent and degrees of potential degradation in river systems, in order to implement policies and other preventive measures timely and proactively to arrest further adverse impacts. Therefore, a river classification or grading system to recognize the present level of degradation is deemed extremely useful to inventory over large regions and provide a geomorphologically stratified framework for more detailed observations. The present study was thus focused on recognizing the causes and implications of river degradation with respect to geomorphological and ecological aspects in several selected major basins in Sri Lanka.

1 INTRODUCTION

Water is a major natural source, essential to sustain life on earth. In addition, it is an indicator of biodiversity, ecological patterns and overall ecological processes. Historically, human settlements were established along the riverbanks for easy access to water. However, this has eventually led to the degradation of river systems due to the discharge of great amounts of anthropogenic, mainly agricultural and industrial dissolved contaminants throughout the river basin. Goonathilake et al (2005) revealed that due to the rapid development and rapid growth of the population in Sri Lanka, most water bodies have undergone severe pollution continuously by various point sources such as industrial discharges and non- point sources of pollution that primarily include the stormwater runoff from residential, industrial and agricultural lands uses.

As a solution for problems in rivers and streams caused by human activities and natural causes, river restoration has become an essential requirement. River restoration is defined as "the assisting the establishment of improved hydrologic, geomorphic and ecological processes in a degraded watershed system and replacing lost, damaged or compromised element of the natural systems" (Ellen et al., 2005).

River restoration can be influenced by ecological, geomorphological, technical and socio-economic factors, which all interact in complex ways. Jochim et al. (2013) identified that their impact was strongly correlated with the complexity of the restoration target.

In this purview, a river and stream classification system can be extremely useful for inventory over large regions and provide a geomorphologically stratified framework for more detailed observations. Proper classification system forms an initial basis for suggesting restoration strategies once project objectives have been determined.

2 OBJECTIVES

The purpose of this research is divided into three components.

- To form a river grading system suited to Sri Lankan fluvial environment
- To develop guiding geomorphological principles for restoring river channels
- To identify the ecological implication for river restoration approach in Sri Lanka

1 Former Student 2 Senior Lecturer e-mail : lalith@uom.lk

3 METHODOLOGY

3.1 Study area for River Grading System

In order to formulate a river grading system suited to Sri Lanka, information about available river grading or classification systems were collected. By considering the parameters used for such grading systems and methods used and specific features and perspectives pertaining to the local context, an appropriate grading system that is suited to the river network of Sri Lanka was a developed. Five river systems have been selected in order to represent the characteristics of developed grading system. The water quality data for the selected rivers were collected for the period of September 2009 to September 2014 from National water Supply and Drainage Board (NWSDB), Sri Lanka.

The data obtained was then statistically analyzed to identify the variation of each parameter and obtain the Chemical Grade of each river.

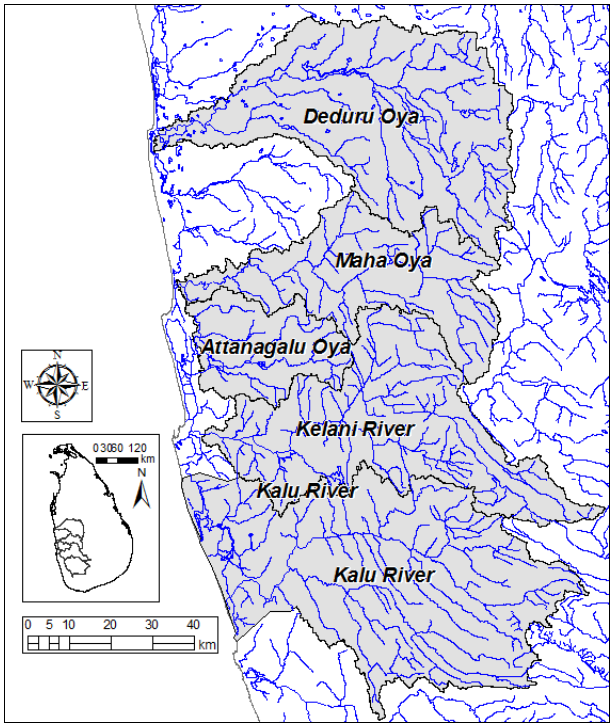

Fig. 1 Selected river basins for study with associated main river channels and stream networks

3.2 Study area for Identifying Geomorphological and Ecological Implication

An extensive literature survey was carried out and the important characteristics and principles of fluvial geomorphology and ecology were gathered in order to study the implication of those factors to river restoration approaches in Sri Lanka. Based on the above and information collected from relevant authorities, a detailed list of identified degradation trends and associated facts in the selected river systems were formulated, recognising the main issues which affect the river geomorphology and ecology. Subsequently, the contributory principles and applications for river restoration approach were developed to overcome the identified issues in Sri Lankan river systems with respect to geomorphological and ecological aspects.

4 ANALYSIS

4.1 River Grading System

Table 1 The mean concentration of each parameter at each River for 5 years (Sep-2009 to Sep-2014)

Parameter	Kalu River	Kelani River	Deduru Oya	Maha Oya	Aththanagalu Oya
Colour(Hz)	37.29	10.89	155.32	93.78	9.24
Turbidity NTU	20.37	15.66	28.71	21.57	5.42
pH	6.51	6.28	6.59	6.67	6.59
Nitrate (as N)mg/l	0.29	0.55	2.44	1.66	1.66
Tot.Phosphate (as PO_4)mg/l	0.11	0.17	1.11	0.58	0.30
COD mg/l	26.79	12.90	-	13.65	6.44
DO mg/l	5.99	7.10	2.00	4.22	3.91
BOD mg/l	4.44	2.28	-	0.63	0.77

Guideline values were obtained from ambient water quality standards enacted by Central Environmental Authority (CEA). Weighting factors were selected by considering importance of factors for river water quality. Water quality parameters were selected in order to classify the human impact of water quality and protection of aquatic life (Tables 1 – 4).

Table 2 Guiding values and Weighting Factors of grading system

Parameter	Value	Weighting Factor
Colour(Hz)	100	1
Turbidity NTU	10	2
pH	6.0-8.5	1
Nitrate (as N)mg/l	5	1
Tot. Phosphate (as PO_4)mg/l	0.4	1
COD mg/l	15	2
DO mg/l	3	2
BOD mg/l	4	2
Total		12

$$ROI = \frac{Total\ Score}{Maximum\ Score\ Possible} \times 10 \quad \text{.....(1)}$$

where RQI is River Quality Index used for categorizing the stage and status of degradation at each basin.

Table 3 Rating Score and Grade of grading system

Rating Score	Class
10≥RQI≥9.5	A: Not impacted
9.5≥RQI≥8.5	B: Slightly Impacted
8.5≥RQI≥7	C: Impacted
RQI<7	D : Severely Impacted

Table 4 Grade obtained for selected rivers

River	Obtained Value	Grade and Impact
Kalu River	5	D : Severely Impacted
Kelani River	8.3	C: Impacted
Deduru River	2.5	D : Severely Impacted
Maha Oya	7.5	C: Impacted
Attanagalu River	10	A: Not impacted

4.1.1 River Grading System according to Physical Parameters

Above criteria used for classification basically depend on the chemical parameters of river or stream. In order to achieve balanced classification system, the channel morphology and other physical parameters in each river system should also be considered. Therefore, a separate criterion was suggested to evaluate the physical parameters. These parameters were evaluated in qualitative manner for each river system.

- Land use pattern
- Urbanization
- Nature of river ecosystem
- Habitat
- Species Diversity
- Condition of Riparian Zone

By considering above parameters, proper grading for physical aspects could be suggested.

4.2 Geomorphological Implication to Restoration Approaches

4.2.1. Channel symmetry and Bank stability

River bank erosion and channel asymmetry are key components that contribute to generating the need of river restoration. In Sri Lanka, despite various natural reasons causing riverbank and bed erosion, anthropogenic effects like sand mining and land use changes are presumed to further aggravate the subsequent adverse impacts. As a result, the width: depth ratio of a river channel is increased and the cross-channel water movements that trigger eddy formulations thus leading to excessive bank destabilization tend to be reinforced.

Control measures can be categorized as bed stabilization devices, bank stabilization devices and hydrological measures.

In order to maintain channel symmetry, the required width: depth ratio should be provided in restored channel sections.

Bed Stabilization Devices

Channel bed aggradation and degradation are main causes for bed instability. Bed aggradation can be addressed in river restoration by stabilizing eroding channel upstream, controlling erosion on the watershed or installing sediment traps, ponds or debris basins. Bed degradation can be controlled using stabilizer sills that are weir-type structures buried in channel beds or drop structures that are usually weirs with stone-protected stilling basins (Torres and Jain, 1984).

Bank Stabilization devices

Bank erosion can be controlled by protection of the eroding bank with some form of revetment ranging from hard riprap, blockstone or gabion structures, as observed in main river and stream or canal sections, but the applications based on softer methods using vegetation were not common.

4.2.2. Over widening and Over deepening

In Sri Lanka, due to erosion and sand mining most of the river sections have been over widened and over deepened. In addition, lateral erosion of riverbanks can happen due to unhealthy riparian areas with unstable stream banks. Ultimately, this will lead to increase in stream width and decrease in stream velocity which is ideal for sediment deposition. Channel morphology may be changed from a single channel to braided channel because of extreme sediment deposition.

Restoration of over widened channels may require the use of excavated substrate material and importing gravel and cobble or blocks of riparian vegetation to narrow stream channel.

4.3 Ecological Implications

4.3.1. Causes for River Ecosystem Degradation

Ecosystems of major rivers in Sri Lanka have been seriously affected by sand mining and human activities that destroy the river environment while deforestation, desertification and habitat destruction are also caused due to sand mining. There are some other causes of habitat reduction and riparian zone degradation; Dams and Diversions, Groundwater withdrawal and Stream channelization and levee construction.

4.3.2 Suitable Ecosystem Restoration Methods to Sri Lanka

As habitat enhancement and riparian zone management are major factors that govern the ecosystem restoration, restoration project objectives should be focused on those two aspects.

To enhance the habitat:

- Deflectors, small weirs and sills
- Reinstatement of substrate
- Devices providing direct cover

To ensure protection of the riparian zone, implementing hydrological and geomorphological modifications to degraded river sections is required to make certain that further damage to riparian zone will be eliminated, because most of the riparian zone has been damaged in Sri Lanka due to bank instability, bank erosion and changes in channel morphology and hydrology. The re-vegetation of degraded riparian zones is another suitable practice in riparian restoration. Re-vegetation can be accomplished through active or passive means, or a combination of the two.

5 CONCLUSION

According to the developed river grading system, Deduru oya river system is severely affected by human impacts while Attanagalu oya is in good condition with respect to chemical characteristics. Further, Kelani river and Maha oya are impacted to significant extents. In order to classify the rivers with respect to physical characteristics suggested, the identified physical parameters should be evaluated in detail along the entire channel length as well as through the river section, floodplain and river ecosystem.

River restoration is an area less addressed in Sri Lanka. Only few projects have been carried out in urban areas to restore the polluted canals due to urbanization and to control the flooding caused by bank overtopping. Those projects have focused mainly on aesthetics and flood control. Therefore, geomorphological and ecological aspects were less discussed in those developments. Most of the major rivers in Sri Lanka have been degraded to different extents during the course of the last few years. Therefore developing a classification scheme to identify the present condition of rivers and planning suitable restoration procedure to minimize the degradation of rivers have become an urgent development requirement in Sri Lanka. Further, river restoration projects should be planned and designed based on an understanding of geopmorphological and ecological processes to better cater for the restoration needs in these complex eco-systems.

6 RECOMMENDATIONS

To ensure that geomorphological and ecological criteria are incorporated into river restoration projects, there may be a need to consider the following pertinent issues:

a). Project manager should have good understanding about how to specify and request geomorphological and ecological inputs

b). Establishing programmes for monitoring and visiting other implemented or ongoing sites within area or region

In order to develop restoration systems with geomorphological and ecological perspectives as well as hydrological aspects, suitable approach to river restoration and design can be proposed as follows.

a). Use guiding hydrological, geomorphological and ecological principles to determine data requirements

b). Collect additional data pertinent to the site or region

c). Consider hydraulic constraints and water environment and land use issues

d). Analyze hydraulic and geomorphological data

e). Consider the potential for either natural or enhanced recovery

f). Evaluate available alternate options

g). Choose final design

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