Is Environmental Management A Cornerstone Of Urban Disaster Resilience? A Case Study of Urban Wetlands In Colombo, Sri Lanka

Abstract

Colombo is a city surrounded by a large and interconnected system of natural wetlands. Apart from the significance of these wetlands as ecological features in an urban area, they have been offering a range of water and environmental services to the people living in the city and suburbs of Colombo for centuries. The rapid and partly ad-hoc urbanization in the past 15-25 years in Colombo is commonly believed to have caused a steady degradation of these wetlands. Some of the services provided by these wetlands have been severely threatened by the degradation and the frequency of urban disasters (such as floods) has also increased during the period. These events increased the risk factors involved in development activities and directly affected the urban poor. Despite many infrastructure and environmental improvement projects and institutional changes in environmental, urban development and disaster management sectors the floods in Colombo city seems to be continuing in a persistent and ever increasing manner. This paper presents a long term research project to understand the nature and extent of degradation in a selected segment of the Colombo Flood Detention Area (CFDA) wetlands. Through analyzing the long term change of landscape level parameters, water-quality, vegetation and soil quality, the authors emphasize the potential of an outright ecological regime change in the wetland system that severely threatens the water related ecosystem services. The paper also qualitatively explores how the gradual changes in watershed and the wetland ecology affected flood control and drainage services leading to full-blown disasters despite the repeated efforts of the authorities to contain them. It underlines the importance of ecosystem health of urban ecological features in strengthening the disaster resilience of cities. The research is an ongoing project and the paper also briefly sketches the theoretical framework of its future undertakings.

Keywords: Urban Wetlands, Urban Resilence, Ecological Regime Change, Ecosystem Serivces

1. Background

Urban disaster resilience is an emerging interest in disaster management literature. Increasing frequency and magnitude of disasters in urban areas in the recent times is the key reason behind this elevated academic enthusiasm. Most of the major disasters recorded in past decade such as the Asian Tsunami -2004, Gujrat Earthquake (India) – 2005, Haiti Earthquake -2010, had Japanese Tsunami- 2011 devastating impacts on urban areas. In addition to these high impact sudden disasters a many urban areas are facing chronic build up of low magnitude hazards, which accumulate and cause major disasters. Urban flooding in Mumba (India) and Colombo (Sri Lanka) and ground water drawdown in Coimbatore (India) are examples for such situations. Owing to the seminal works of Holling (1973) and Levin (1998) our understanding about how social-ecological systems move through phases of slow development (Conservation) and rapid transformation has immensely increased in the past two decades. Authors such as Walker and Salt (2006) applied this theory to the resilience of different social-ecological systems and demonstrated that slow environmental change is a key factor among others to many disaster events that emerge time to time. Much attention has been paid to global phenomena such as Climate Change and their connection to disasters. However the effects of local environmental problems on impending disasters in many urban areas around the world are far less investigated.

Colombo is a city surrounded by a large and interconnected system of natural wetlands. Apart from the significance of these wetlands as ecological features in an urban area, they offer a range of water and environmental services to the city and suburbs. The rapid and partly ad-hoc urbanization in the past 15-25 years in Colombo is commonly believed to have caused a steady degradation of these wetlands (CEA,1994). Some of the services provided by these wetlands have been severely threatened by the degradation and the frequency of urban disasters (such as floods) has also increased during the period. These events increased the risk factors involved in development activities and directly affected the urban poor. Despite many infrastructure and environmental improvement projects, floods in Colombo city have steadily increased from 2005 onwards. This paper presents a long term research project to understand the nature and extent of degradation in a selected segment of the Colombo Flood Detention Area (CFDA) wetlands. Recent research has revealed that urban wetlands can be easily pushed in to non-equilibrium ecological states that do not support their status quo ecosystem services (Ehrenfeld,2004). Flood retention and drainage are such services that can be easily altered with changes in vegetation structure and soil physical properties in a wetland. The paper also qualitatively explores how the gradual changes in watershed and the wetland ecology affected flood control and drainage services, leading to full-blown disasters despite the repeated efforts of the authorities to contain them. The lack of avoidance based strategies has been identified as a major reason for the inability of the authorities to control degradation of urban ecological features that

support critical ecosystem services (Clare et al, 2011). Integrate regional level environmental planning and community based environmental-monitoring have been suggested as solutions for current disjointed approach towards environmental management and disaster prevention in many regions. However these contentions are yet to be supported by adequate empirical research. The research is an ongoing project and the paper also briefly sketches the theoretical framework of its future undertakings.

2. Methods

The paper presents the study in a case form. The study area 'Kolonnawa Marsh' is located within the Colombo Flood Detention Area (CFDA) wetland in Colombo Sri Lanka (CEA,1994). It is a tropical freshwater marsh (214 ha) and forms the largest segment of CFDA. The research project entailed comprehensive data collection on water quality, soil quality, vegetation diversity, faunal diversity and socio-economic drivers of wetland degradation. Primary data was collected from 2007-2009 through field surveys and laboratory testing, whereas secondary data dating back to 1995 was used in the analysis. The results discussed here were adopted from already published work of the authors (Hettiarachchi et al, in print (A); Hettiarachchi et al, in print (B)) and analysed in a different perspective.

3. Results and Discussion

3.1 Conversion of the wetland to upland

Our mapping of the Kolonnwa Marsh area of CFDA and surrounding paddy fields showed that 13.5% of marsh and around 60% of the paddy land has been converted non-wetlands use from 1980 to present. This is an alarming conversion rate for a wetland system that forms the core of flood control and drainage system of the city and suburbs. However it should be noted that the area demarcated as the protected portion of the CFDA wetland by Sri Lanka Land Reclamation and Development Corporation (SLLRDC) remained largely intact from 1999 onwards.

3.2 Conversion of the wetland to upland

The variation of daily average water level in the main waterway of Kolonnawa Marsh showed strong increasing trend during 2000-2005 period (Hettairachchi et al, In print (B)).The variance of water level between consecutive years was highly significant for the same period. However in contrast the variation of rainfall form 2000-2005 showed no trend within the period.This indicates that the average water level in the main water ways of the marsh has steadily increased

both in magnitude and variance, without a significant increase in water input to the system (rainfall).

3.3 The fluctuations in Water Level

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Water and soils: The dark side

In wetland literature physical and chemical parameters that describe the soil and water quality are taken as the primary indicators and causal variables of higher level changes in ecological parameters and the ecological regime as a whole (Mitsch and Gosselink,2007). Our investigation clearly indicated that the surface water quality and soil quality of Kolonnawa marsh deviates significantly from the standards (table 1 and table 2) and are in par with other degraded urban wetland systems such as the forested wetlands of New York and New Jersey – USA (Ehrenfeld,2004) and urban shallow lake system in Coimbatore – India (Mhanraj et al,2000).

Table 1: Soil parameters in peripheral and interior plots (Source: Hettiarachchi and de Alwis,2009)

Parameter	Plots in interior			Plots near periphery		
	Median	Max	Min	Median	Max	Min
pH	4.78	6.14	3.95	5.79	6.73	4.28
Conductivity (µS/cm)	159.3	485	18.63	67.4	532	15.54
Soil Organic Matter content (%)	56.52	72	27.04	36.36	58.34	13.636
Extractible N (mg/kg)	130	260	15	280	310	120
Extractible P (mg/kg)	30	170	16	46	270	16
Total P (mg/kg)	260	580	240	160	520	100

Table1 2: Percentiles of the water quality values (Source: Hettiarachchi et al, In print a)

Parameter	Median	25th percentile	75th percentile	Standard	Source
DO / (mg/l)	4.67	2.91	6.63	5.0	USEPA
Temp (^{0}C)	29.6	29.0	30.5	N/A	-
Turbidity (NTU)	11	7	15	N/A	-
pH	6.55	6.25	7.00	6.5 - 9.0	USEPA
NO_3 / (mg/l)	0.5	0.3	0.8	10	USEPA
PO_4 / (mg/l)	0.21	0.12	0.37	0.1	USEPA
BOD_5 / (mg/l)	29.5	24	32	4.0	-
FC / (nos / 100ml)	2600	1300	7250	1000	SL-std
TS / (mg/l)	170	120	273	N/A	-

USEPA: US Environmental agency ambient water quality standard, Sl-std: Sri Lankan standard for water quality for human use

The long term trends in water quality indicated that contaminants such as Biochemical Oxygen Demand (BOD_5) and ammonia had been showing a steadily increasing trend from 2000 onwards (Hettiarachchi et al, In print (B)). The high content of extractible N and P in soil (Table 2) is an indication of nutrient over loading to the wetland. Table 2 also shows that both extractable P and N are higher in peripheral areas of the wetland areas than the interior, indicating a nutrient contamination originating from residential or built up areas. A similar observation was made in water quality where the major contaminant concentrations (BOD_5, PO_4, fecal coliform) were higher in peripheral canals that the interior water ways. Based on the water and soil quality characterization it was concluded that there is high level nutrient build up in the wetland, mainly due to the nutrient inputs form residential neighbourhoods of the watershed (Hettiarachchi and de Alwis,2009).

3.4 The ecological nightmare

Triggered by the discovery of high rate of wetland conversion, water level fluctuations and nutrient based pollution we also investigated the overall ecological changes in the study area. The results were as alarming as other aspects of the wetland environmental. It was clearly visible that the vegetation structure of the wetland was changing from the emergent grasses native to the marsh environment to a habitat which is dominated by invasive woody shrubs or small trees such as *Annona glabra* (Hettiarachchi and de Alwis, 2009). Trend was observed earlier by Central Environmental Authority studies also (CEA,1994), however our study revealed that 44% of original marshy habitat of Kolonnawa Marsh has now been transformed in to shrub habitats. In all parts of the wetland a high occurrence of invasive plant were found. In addition to the change in general vegetation structure, it was also discovered that the soil type has also changed from typical marshy fibric soils into a semi-mineral (mucky mineral) soil (Hettiarachchi and de Alwis,2009). Fibric (peaty) soils have a much higher water holding capacity (with 80% pore volume) than the sapric soils (<50% pore volume) (Mitsch and Gosselink, 2007). The reduction of the water holding capacity of the soil affects

hydrological regime of wetland and its capacity to provide flood control and drainage services. It was also discovered that along with these ecological changes the fish and bird diversity of the wetland has also dropped significantly from 1994 to 2008.

3.5 What the changes imply: the hidden danger

Based on the adverse changes observed in all aspects of wetland environment we concluded that the study area (and CFDA in general) is undergoing an ecological regime change that may negatively impact capacity of the wetland to provide its critical ecosystem services. In addition to the visual destruction of the wetland due to outright conversion into non-wetland use, there is an equally significant danger of marsh habitat being transformed into a shrub wetland with much less water holding capacity and reduced bio-diversity. It can be strongly argued that this ecological change is triggered mainly by the nutrient related pollution of the marsh along with other factors such as fragmentation of the habitat and hydrological modifications by humans. The direct impact of both conversion and habitat change on ecosystem services –especially flood control- cannot be overestimated. The effects are visual through the increasing trend in water level of main waterways in the marsh. A newspaper content analysis done by us revealed that a major or moderate flood has been reported every year after 2005 in the CFDA watershed. 2011 recorded most severe flood in the history of Colombo rendering nearly 15,000 people homeless. The disturbing ecological trends understood in our study indicate that the worst is yet to come.

3.6 The drivers of ecological change

The socio-economic survey carried-out by us corroborated the pollution trends suggested by soil and water quality analysis. There are significant inputs of nutrients and organic pollutants from the urban households and small and medium industries in watershed. 87% households within 200m from the periphery of the wetland did not have sanitary latrines, 44% directly discharged there gray water into the wetland or connected canals and 23% dumped their solid waste in the wetland. There were 11 medium scale vehicle servicing stations and numerous small restaurants and fast food shops are discharging untreated or partially treated wastewater directly or indirectly to the wetland (Hettiarachchi and de Alwis,2009). There were only two major industries in the whole watershed, which strongly confirmed the fact that degradation of the study area (and largely CFDA) is caused by urban households than industries. The census data (Department of Census and Statistics Sri Lanka) reveal that the population of the area has increased by 3,861 p/km^2 from 1980 to 6,277 p/km^2 2007. 80% of migrants in 1994 have settled in the area after 1980. The free market economic policies (neo-liberal) followed by the successive governments in Sri Lanka after 1977 created, more economic opportunities in and around Colombo than in traditional agricultural areas.

This can be a main reason for migration as well as expansion of the small and medium business sector in the CFDA watershed. The key informant interviews strengthened this argument and also added that the population became more heterogeneous with increasing migration, both in terms of ethnic/religious groups as well as the belief systems. Calre et al (2011) identified increasing population heterogeneity as a factor that makes wetland management difficult. The elderly key informants contended that the younger generation has lost touch with the environment. However discussions with school teachers revealed that the scientific understanding about the environment in the younger generation has improved immensely with incorporation of environmental studies to school syllabus. The survey also indicated that that 37% of the households discussed environmental issues regularly at home and around 20% of the respondents were willing to pay an additional tax to improve the condition of the wetland. These observations show that the stakeholder population of the study wetland is not totally unappreciative of the wetland and the related problems. Although the negative environmental attitudes of the community should not be underestimated, the constraints beyond the control of individuals such as population pressure and lack of infrastructure are more prominent as drivers of degradation of the wetland.

3.7 The institutional quagmire

Wetlands are complex ecological systems to be managed within a urban context (Ehrenfeld,2000). Although as land they may be subjected to both public and private tenure, the multitude of services that flow through the wetlands have common pool resource characteristics. This makes the defining of property rights for urban wetlands as resource systems a very difficult task (Adger and Luttrell,2000). A resource system with vague property rights is a system poorly managed. This fact is very visible in the context of CFDA. The tenure of most part of CFDA as land is held by Sri Lanka Land Reclamation and Development Corporation (SLLRDC). However the actual ecological boundaries of a wetland far extend and much less enforceable than the legal boundaries marked on a cadastral map (McMullen and Meachem,1996). Although SLLRDC clear institutional right to control any material flow across the legal boundaries of CFDA, an uncontrollable influx of nutrients, organic contaminants, pests and invasive seeds takes place in a daily basis from its urban neighborhoods. The responsibility of curtailing such inputs lie with the Local Government Councils (LGAs) and Central Environmental Authority of Sri Lanka (CEA). The institutional setup of CFDA displays a group of strong action arenas (groups of individual and organizational policy actors) with well defined institutional domains but very little interaction. Each action arena has its own rights and responsibilities; for example the land tenure of CFDA is held by SLLRDC and they are responsible for maintenance of the wetland and controlling floods. CEA has the right to issue the environmental licenses and approvals for development projects in urban areas while being responsible for control of environmental impacts of development activities on sensitive environmental features. The Disaster Management Center (DMC) has the right and resources to mobilize the disaster response mechanisms

in the times of need and the responsibility of minimizing and mitigating the impacts of disasters on the communities. These three actors operate under different line ministries sanctioned by three different legislations passed at different times under entirely different conditions. Yet CFDA is a single social-ecological system. Managing the urban flood controlling service of the wetland is inextricably connected to environmental management of its urban neighborhood in demand side and disaster management in the city in the supply side. As observed in the Kolonnawa Marsh system, the accumulation of slow environmental degradation reduces the ability of the wetland to provide flood control services and leads to increased flood incidents and disaster situations.

In the other hand there is another paradox in the utilization of ecosystem services offered by the wetland. Most of the regulatory ecological services of wetlands (flood control, drainage and nutrient assimilation) are viewed both by the public and the wetland mangers as public goods. But in contrast to public goods that would not diminish with marginal increase in usage, the services such as drainage and nutrient assimilation will reduce with increased use; a condition known as 'overconsumption' in environmental economics literature. In the CFDA system the upland communities are overusing the nutrient/pollutant assimilation service of the wetland by discharging untreated wastewater and solid waste. The ecological responses to nutrient build-up compromises the wetland's ability provide the flood control services. Although this seems coincidental, it's a situation created by an institutional paradox at a higher level. Due to rising population pressure and scarcity of funds for infrastructure development, the development policy and institutional arrangements in Colombo facilitates the raw overconsumption of ecosystem services of CFDA. In the other hand the increasing disasters and environmental problems press the policy makers to bring in different institutions that call for prevention of overconsumption. A paradoxical situation is created by this, where opposing policy actors are now simultaneously calling for promotion and prevention of overconsumption of ecological services of CFDA.

3.8 Untangling the Gordian Knot?

Although the current institutional setup of CFDA idiosyncratically gives rise to a host of operational problems, it should be noted that the environmental management and urban development institutions of Sri Lanka are well defined at a broader level. Through the institutional study we concluded that management of CFDA wetland has three components 1. Sustainable utilization of the ecosystem services in urban development 2. Disaster mitigation or adaptation 3. Protection of the natural ecosystem (Hettairachchi et al, In print (A)).These three aspects are sufficiently covered by the mandates and statutory powers of the stakeholder agencies of CFDA at present. However the disintegrated nature of these three components seems to be the key deterrent in proper flood management in CFDA watershed. We contend that a

Figure 01: Three component of integrated urban wetland management

successful management can only be achieved through an integration of these components (Fig 01). The key agencies leading each action arena of urban development (UDA,SLLRDC,LGAs), environmental management (CEA) and disaster management (DMC) are sufficiently equipped to both legally and technically handle issues in their own domain. However when it comes to cross-sectional (multi-domain) issues such as nutrient flow, the lack of coordination becomes a critical weakness as discussed above. Therefore a sustainable management of the CFDA wetlands can only be achieved through integration of the current roles of these agencies. We suggest that this form of integration can be achieved by providing a common platform for the stakeholder agencies to communicate specifically on CFDA issues. Such a platform should be established at the appropriate level, which is large enough in scale for effective decision-making and small enough to focus on CFDA system (Hettiarachchi et al, In print (A)).

4. Conclusion

The CFDA wetland system has clearly undergone severe ecological changes that have compromised the ability to provide its main ecosystem service –flood protection– to the city of Colombo. It is clear that nutrient based pollution from the urban watershed of CFDA is equally responsible for these ecological changes as the direct conversion of the wetland to non-wetland land-use. The pollutants are originated in urban households and small and medium businesses rather than by major industrial operations. The failure of the flood control service of CFDA wetland is increasingly leading to disasters (floods) in its urban watershed. Although the urban development, disaster management and environmental management sectors of Sri Lanka are institutionally well defined and fairly well resourced, the current disintegrated institutional structure make them weak at the face of cross-sectoral problems such as case of CFDA. This case study provides a good example why environmental management should be a cornerstone of urban planning to achieve urban disaster resilience. Only way to achieve this in fast growing regions such as Colombo-Sri Lanka, which already have established institutional structures is to provide platforms for the policy actors effectively interact and device the required level of integration.

References

1. CEA. 1994. *Wetland Site Report and Conservation Management Plan – Colombo Flood Detention Areas, Sri Lanka*. Wetland Conservation Project – Central Environmental Authority of Sri Lanka
2. Clare, S., Krogman, N., Foote, L., Lemphers. 2011. *Where is the avoidance in the implementation of wetland law and policy*, Wetland Ecol Mange
3. Ehrenfeld JG. 2004. *The expression of multiple functions in urban Forested wetlands*, Wetlands, 24, 4, 719-733
4. Hettiarachchi, M., Anurangi, J. In Print (B). *Characterization and Description of Surface Water Quality in the Threatened Urban Wetlands around the City Of Colombo*, Jnl. of wetland ecol.
5. Hettiarachchi, M., de Alwis, A.P. 2009. *Interim Report: Research Project on Sustainable Utilization of Water Services of Wetlands around the City of Colombo in Urban Development*, Department of Chemical and Process Engineering, University of Moratuwa.
6. Hettiarachhi M, Athukorala K, Peiris R and Alwis AP. In Print (A). *A Case Study of the Environmental Policy, Wetland Management Strategies and the Water Related Ecosystem Services of Colombo Flood Detention Area Wetlands*, in Gunawardane N, Gopal B., Kotagama H. (ed), Ecosystems and Integrated Water Resources Management in South Asia, Sage India, New Delhi
7. Holling, C.S. 1973. *Resilience and stability of ecological systems*. Annual Review of Ecology and Systematics. Vol 4 :1-23.
8. Levin, S. A. 1998. *Ecosystems and the biosphere as complex adaptive systems*. Ecosystems 1:431–436.
9. McMullen and Meachem PA. 1996. *A Comparison of Wetland Boundaries Delineated in the Field to Those Boundaries on Exisiting and Federal wetland Maps in Central New York State*, in Mulamoottil G, Warner BG, McBean EA. Ed. Wetlands Environmental Gradients, Boundaries and Buffers, Lewis Publishers, New York, 19-45
10. Mhanraj, R., Sathishkumar, M., Azeez, P.A., Sivakumar, R. 2000. *Polltion status of Wetlands in Urban Coimbatore, Tamil Nadu, India.* Buul Environ. Contam. Toxicol.,64, 638-643.
11. Mitsch WJ, Gosselink JG. 2007. *Wetlands*, 4th Ed, John Wiley and Sons, New York
12. Salt, D., Walke, B. 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Island Press, Washington, D.C.