Sustainable Urban Stormwater Management: A Case for Tumakuru Local Planning Area, Karnataka, India

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Abstract: ***Along with the growing awareness towards environmental degradation and resource depletion, the need to find indigenous sustainable solutions is called for and it is in this context that one of the traditional water management systems in Karnataka is reviewed through the lens of ecosystem services. Traditional systems when engulfed by urban development lose their intended use and generally get deteriorated and misused. By identifying and understanding the ecosystem services provided by these traditional systems, we can mainstream them into urban planning process inorder to derive the benefits therein. The research reveals that Traditional drainage network provides for regulating, cultural and supporting services in an agrarian landscape and affirms the significant role and opportunity that they provide for urban stormwater management. Based on the ecosystem services provided by TDN, certain restoration, planning and management measures for urban stormwater management are proposed which aid in providing urban ecosystem services. This approach integrates TDN into urban planning process, manage urban stormwater and contribute positively to urban environment.***

Keywords: Ecosystem services, Traditional drainage network, Stormwater management, Urban planning

1. Introduction

Rapid growth of urban population in most Indian cities has put tremendous pressure on many natural resources, water in particular. Indian cities not only need fresh potable water supply but also have to deal with waste water. The awareness towards environmental degradation and resource depletion has been amplified by consequences of global warming and climate change and the need to find indigenous sustainable solutions is called for at local levels. It is in this context that one of the traditional water management systems in Karnataka is reviewed through the lens of ecosystem services for better understanding. Classification and assessment of ecosystem services provides for a scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being [1].

Ecosystem services and sustainable development

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual and other nonmaterial benefits [1]. These benefits from ecosystem services which arise from managed as well as natural ecosystems sustain human existence [2] and any progress towards sustainable development needs to ensure sustainable management and use of these ecosystems and their services [1]

Urban ecosystem services

Ecosystem services derived from urban systems are termed as urban ecosystem services [2]. Urban ecosystem service flows generate both positive and negative impacts on the environment. While parks, urban forests and green belts provide positive ecosystem services like air and water purification, wind and noise reduction amongst others, polluted air and water from urban areas increase pressure on ecosystems of the surrounding regional landscapes [3]. When urban systems are managed more equitably and the loss of ecosystem services is purposefully addressed, the benefits to human well-being can be substantial [3]. Any planning and management efforts should minimize the negative impacts while maximizing the positive ones.

2. Study Area

Tumakuru is a Class I city with a population of 3.05 lakh [4] and located 70km from Bengaluru, the state capital of Karnataka. Historically, the city has been a large trading center for agricultural commodities from the surrounding areas [5]. Due to its proximity to Bengaluru, the city has, over time, developed as an industrial center for medium and small scale industries and ancillary units located in and around the city. It is also a growing educational center with multiple professional and para-medical institutions within the city limits. In recent years the city has grown extensively showing high decadal growth and its growth is expected to continue[6]. In 2015,Tumakuru Urban Development Authority (TUDA) has proposed Revised Master Plan 2031 comprising a conurbation area of 131 sq. km and Local planning area of 310 sq.kms including the green belt.

The geographic location of Tumakuru city is on latitude 13^{o}34'E and longitude 77^{o}1'N, at an average elevation of 822m. It is located on the Southern Karnataka Plateau and is classified under eastern dry climatic zone. It receives an average annual rainfall of 650mm, has gentle slopes with well drained red loamy soils [7]. In terms of its drainage, the city is located close to the main basin divide ridges that divide the three river basins, namely Pennar, Lower Cauvery and Lower Tungabadhra, and the runoff from the city drains into river Shimsa, a tributary to river Cauvery. Owing to the low rainfall and its topographic location, the city is dependent on rainwater and ground water for its water needs as it does not have any perennial surface water source.

3. Stormwater Management and Traditional Drainage Network (TDN)

Owing to its geographical location in the rain shadow area of the Western Ghats and its position close to basin divide on upper catchment region of Cauvery basin, Tumakuru city falls under the semi-arid zone and rainwater was the main source of fresh water until few decades ago. Scarcity of water had made the people realise its significance and water conservation and management techniques have been in practice from a long period of time, mainly for agricultural and domestic purposes in this region [5]. One such significant tradition has been the construction of tanks or *kere* wherein series of check dams or embankments were built in succession across various drainage order streams inorder to impound runoff during rainy days (Fig.1). These check dams followed the terrain and natural drainage pattern. Local terminologies for these tanks can be associated with their drainage order [8]. Tanks on I order streams called as *kunte*, tanks on II and III order streams called as *katte* and tanks on higher order streams called as *kere*(Fig.2).There existed an overflow system from the upper level tank to the lower tank within the series. The rain water received into each tank depends upon the overflow from the higher level tank, the over land flow from the valley areas and the runoff from the side slope catchment areas. A tank has three main components: Catchment area, the tank bed and the command area. Location of the settlements was in relation to the tank and most settlements were located on higher ground close to the embankment of a tank. The cultivation pattern followed the topography of the valley and the side slopes. Coconut plantation was predominant in the valley areas as the soil moisture is high due to series of tanks in the valley [8]. Side slopes were cultivated with rain fed crops and the command area of large tanks had irrigated cultivation. These interconnected series of tanks built over time since 5^{th} century AD [9] and their drainage channels are collectively termed as Traditional drainage network (TDN). The traditional drainage network addressed conservation of water by i) reducing the surface runoff velocity and impounding the runoff water close to source of rainfall ii) detaining water for percolation and ground water recharge iii) retaining water for reuse in agriculture and domestic purposes iv) Conserve soil and reduce soil erosion . There are 84 tanks in the Tumakuru local planning area across various drainage orders (Tab.1). 66% of the number of tanks is across I and II order streams having a 19% in water spread area. The tanks across V order streams which are 9% in number provide for 40% of water spread area.

Figure 1: Tank series within Tumakuru LPA

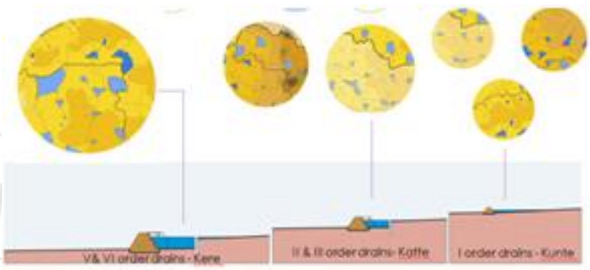

Figure 2: Local terminologies and drainage order

Over the years, there has been a neglect of the TDN owing to various reasons. The institutional setup for maintenance of TDN changed from Panchyats and nirgantis to government departments like the Public works department, Minor irrigation departments etc. This disconnected the maintaining agency from onsite issues and was a centrlised system of maintenance which was not effective [8]. Change in crop cultivation under the green revolution adopted crops with higher water requirements and this was made possible by private irrigation source like wells and tube wells in the valley areas [9]. This private source of ground water reduced the dependency of the farmer on the tank water and eventually led to the deterioration of the tanks and the drainage network.

Table 1: Relating drainage order and tankdistribution

Drainage Order	Number of Tanks	Percentage	Average water spread area in Hectares	Percentage
I	25	30%	8.2	10%
II	30	36%	6.9	9%
III	17	20%	12.5	15%
IV	3	4%	1.1	2%
V	8	9%	33	40%
VI	1	1%	19.8	24%
Total	84			

4. Ecosystem Services of TDN

Establishing ecosystem services of Traditional drainage network will signify its role in water resource management and its benefits to the environment. It will also provide a supporting tool for policy planners to integrate TDN within the master plan proposals.

Tumakuru region has red loamy soil which has low water holding capacity but well drained soils with good permeability and infiltration capacity range of 1.5 to 2.5

cm/hr. [8]. This factor facilitates ecosystem function of filtering the rainwater by soil and recharging ground water aquifers through infiltration of impounded water in the tanks. This amounts to regulating services by regulating provision of fresh potable ground water. In addition, the gentle to very gentle slopes of this well drained topography facilitates base flow from percolated water and there is a substantial increase in soil moisture in the valley areas [8]. This has made possible to grow coconut plantations in dry zone. This amounts to regulating service of modifying soil moisture which our ancestors took benefit to grow coconut and arecanut plantations in the valley areas. The numerous check dams at frequent intervals, especially across the lower orders drainage streams act as silt traps. They reduce runoff velocity which in turn reduces soil erosion from the valley floors and conserves soil. Due to the semi-arid climate, the rate of evapotranspiration is high in this region. The impounded water and the water spread participate in evapotranspiration and regulate the micro-climate of the area which is a much desired effect.

The importance of water and rainfall is embedded into the cultural practices of the local people. When a tank is full, local people offer religious prayer in a gesture of gratitude and the tank shore becomes a social space for religious activities. Tanks and their drainage streams are seasonal in their operation. During the dry seasons, the tank bed of the smaller tanks are dry and the tank bed is used by residents asplay area or as exhibition or *Jatre* grounds. These amounts to the cultural services provided by TDN.

The tank bed is de-silted every year and the soil is used to make earthen pots and bricks, supporting livelihood of people [9]. The shore line of the tanks vary based on the intensity of rainfall over the year and the foreshore supports grass pastures which are used for livestock grazing. The water impounded in tanks across higher order is stored and used for cultivation in the command area. The natural streams support vegetation on its banks due to the availability of soil moisture. This vegetation provides for native biodiversity habitats along the streams. These various services provide for supporting services which aid in soil conservation, primary production and regulating services.
These ecosystem services provided by traditional drainage network (Tab.2) were efficiently taken advantage of by our ancestors primarilyfor agricultural purposes. It is due to these services that there was sustainable agricultural production in the semi-arid region of Tumakuru which even today is a market for various agricultural products from its hinterland.

Due to the development of Tumakuru settlement, the agricultural lands are converted into urban plots and infrastructure corridors. In urban areas, there is no directdependency on the tanks for its benefits due to the change in land use and the TDN is deteriorating and misused. Many tank beds have been allocated for various other land use like vegetable market and road and rail transportation corridors. In addition, the conventional stormwater management practices in the study area of constructing concrete stormwater drains over the natural streams and eventually connecting them to sewer pipes have altered the flow of runoff and denied the tanks of runoff water from their catchment areas. The proposed Master Plan 2031 too has failed to address TDN within an integrated framework and has looked at tanks as isolated pockets of open spaces. There are no guidelines or recommendations with respect TDN, except for buffer areas around tanks and drains, in the proposed Master Plan 2031 for Tumakuru local planning area.

If the TDN is dysfunctional, so will the ecosystem services provided by them. The TDN has provided ecosystem services and it was utilised for anthropogenic benefits by our ancestors for sustainable agricultural practices.There is an imperative need to examine various benefits that urban areas can take advantage of these ecosystem services and accordingly develop restoration, planning and management proposals for sustainable stormwater management and urban development.

Table 2: Ecosystem services facilitated by TDN

Influencing factor	Ecosystem Function		Ecosystem Services
Well drained loamy soil. Good permeability and infiltration range.	i	Ground water recharge due to impoundment of runoff water	Regulating services
Dry climate High rate of evapotranspiration	ii	Microclimate regulation due to presence of water spread	
Gentle to very gentle slopes Well drained loamy soils	iii	Substantial increase in soil moisture due to base flow from percolated water	
Check dam/ Embankment at frequent intervals	iv	Reduces runoff velocity which in turn reduces soil erosion from valley floors and conserves soil	
Tanks are only source of surface water	v	Social space for community/religious activities	Cultural services
Smaller tanks are seasonal in operation	vi	Dry tank bed is used as playground or *maidan* for community activities	
Seasonal variation in shoreline due to difference in rainfall intensity over the year	vii	Supports grass pastures on its foreshore for livestock grazing	Supporting services
Annual de-silting of tank bed	viii	The soil is used by potters and to make bricks	
Higher order streams on gentle slopes and embankment across them	ix	Runoff water is stored for irrigation in the command area	
Natural streams with native vegetation along the banks	x	Reduce runoff velocity due to rough surface of conveyance and encourage percolation along drains. Supports vegetation due to soil moisture	

5. Strategies for sustainable urban stormwater management

Water in arid and semi-arid areas is a valuable resource and urban stormwater needs to be managed as an urban resource.

In the context of TDN, a basic stormwater infrastructure is in place and master plan proposals need to strengthen and integrate this with the objective of deriving urban ecosystem services. Strategies for sustainable urban storm water management (Tab.3) can be categorized under three issues: i) *Restoration measures:* Immediate priority is to restore the TDN and establish its ecosystem services. Separating overland flow from sewer lines and ensuring that runoff water reaches the tank is a primary measure. ii) *Management measures:* It is absolutely vital to keep the TDN functional if the intention is to integrate and derive urban ecosystem services. Regular desilting of tank beds, keeping the natura streams clean and maintaining overflow weirs are some of the measures. iii) *Planning measures*: There is tremendous opportunity here to develop TDN as an ecological infrastructure for the city. This can be multi-functional blue-green corridors dotted with tanks providing ample urban ecosystem services which are mutually beneficial to people and the environment.

Table 3: Sustainable stormwater management strategies for Tumakuru local planning area

Ecosystem Services	Ecosystem Function	Restoration, Management and Planning measures
Regulating services	i	* Separating overland flow from sewer lines and ensuring runoff water reaches tank bed. *Maintaining natural streams and their levels.
	ii	
	iii	*Land use zoning in valley areas can have institutional lands and large residential plots *Land area downstream of the bund to be zoned for large parks, urban forests and other green areas
	iv	*Catchment level measures to reduce soil erosion and runoff pollution. *Regular desilting and maintenance of tank beds
Cultural services	v	*Passive recreational zones along the tank and stream buffer areas. *Drytank beds can bemultifunctional during summer months. *Encouraging community participation in the health and maintenance of the TDN
	vi	
Supporting services	vii	*Encourage native vegetation along the foreshore and buffer areas.
	viii	*Desilted soil can be used to create landscape mounds within park areas
	ix	*Large tanks having perrinial water can be identified as biodiversity parks *Encourage native habitats
	x	*Grassed swales supported with vegetated banks *Variation in measures as per stream order *Encourage native habitats

6. Conclusion

Ecosystem services provided by nature are beneficial to human well-being. The natural streams were modified by ancestors in the study area to gain additional ecosystem services to benefit agricultural produce. Traditional drainage network provides for regulating, cultural and supporting services in an agrarian landscape. Urban ecosystem services can be achieved if the ecosystem functions and their services are maintained and integrated into urban planning process. There exist a tremendous opportunity to build upon the Traditional drainage network and develop ecological infrastructure for the city which can be beneficial to people for their well-being and to the urban environment by regulating microclimate, maintaining water balance, supporting native vegetation and biodiversity and potential for resilience to climate change. An economic valuation of the urban ecosystem services provided by such an ecological infrastructure can further support the cause in terms of valuation.

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