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Summary

Globally, it is predicted that there will be water shortages by 2050. Urban water ecosystems become important in this scenario as they help maintain ground water tables in cities along with providing other critical urban services. Rapid urbanisation have put these ecosystems under threat. The outlook to managing environmental resources have up until now been based on the assumption that all changes will be gradual without accounting for potential multilevel interactions. Such incomplete approaches need to be relooked at in the present scenario in which urban ecosystems provide services for social benefits and are increasingly becoming vulnerable to changes (International Lake Environment Committee, 2005). Apart from finding a solution to deal with unpredictability and uncertainty of changes subjected to resource systems, the challenge involves, uniting various actors at multiple scales to agree upon methods to manage the dynamics of SES's (Folke, et al., 2005).

Bangalore, a city once known for its lakes, presents a challenging case to study the current institutional arrangements which are guiding lake basin management efforts in the city. Lakes in Bangalore which were man made tanks traditionally built to supply the city with drinking and usable water, now remain in a state of disrepair because of extensive pollution and encroachments. The management of these tanks or lakes have seen a drastic transfer from local communities to overlapping government regimes. The use of these lakes have also evolved with time. Historically used for domestic, agricultural and religious purposes, these lakes now find use in providing spaces for recreation and exercise to surrounding residents.

This study is focussed towards analysing the influence of institutional arrangements on sustainability of urban lake basins in Bangalore. Ostroms socio-ecological framework is used to analyse why some lakes have shown an improvement in the way they are managed and why some have not and still remain deteriorated. The variables from Ostroms framework are selected based on their link with collective action, namely: resource size, number of actors, social capital and trust, presence of leadership, operational rules, monitoring rules, networking activities and existing government policies. The type of research in this study is explanatory, using the case study method of analysis of 3 lakes in Bangalore: The Puttenhalli lake, the Kowdenhalli lake and the Kaggadaspura lake which are all at different phases of redevelopment.

This research mainly concludes that the SES framework by Ostrom has helped to successfully draw on the impact of the non linear relationships between institutional variables on sustainability of lake basins. The results from this study highlights the necessity for polycentricism when it comes to institutional arrangements in urban areas. A system where the local community is able to self organise and be a part of the management process which is contextual, based on local requirements is essential. However, this research also concludes that working in collaboration with government agencies especially on structural, engineering interventions will make the institutional system more robust.

Keywords

Ostroms Socio-ecological framework, Institutional Arrangements, Sustainability of Lake Basins, Lakes in Bangalore

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Noireeta Chowdhury
Bangalore

Abbreviations

BBMP	Bruhat Bangalore Mahanagara Palike
BDA	Bangalore Development Authority
KSPCB	Karnataka State Pollution Control Board
PNLIT	Puttenhalli Neighbourhood Lake Improvement Trust
CPR	Common pool resource
SES	Socioecological system
CPCB	Central Pollution Control Board
PIL	Public Interest Litigation
ESG	Environment Support Group
LDA	Lake Development Authority
KLCDA	Karnataka Lake Conservation and Development Authority
MoEF	Ministry of Environment and Forest

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Chapter 1: Introduction

1.1 Background

Urban inhabitants constituted around 55% of the population of the world in 2018. The urban population is increasing rapidly from 30% in 1950 to a projected 68% by 2050 (United Nations, 2018). 35% of this increase in urban population is expected to be seen in India, China and Nigeria . India is projected to add 416 million urban dwellers (Aguilar, 2008; DeFries and Pandey, 2010) . This rapid growth of cities has resulted in inconsistent urbanisation creating transition zones between urban and rural areas. This shift from rural to urban lifestyles has had an impact and puts pressure on the lifestyle of inhabitants, local production, urban morphology and most importantly on the local environment and urban ecosystems (Aguilar, 2008; DeFries and Pandey, 2010).

The correlation between the environmental, social and economic spheres of development forms the foundation of sustainability (Basiago, 1998; Beck and Stave, 2011). In the context of rapid urbanisation, establishing a successful linkage between these can reduce the pressure on ecosystems (Basiago, 1998; Beck and Stave, 2011). Furthermore, the Millennium Ecosystems Assessment (2003), points out that improving the management of ecosystems positively influences sustainable development and human wellbeing.

The last few years, has not only seen drastic changes in urban ecosystems but also witnessed changes in the social participation shaping not only the increasing demand on ecosystems but also the chances to respond to increasing pressures on them. Users of urban ecosystems have become more involved in decision-making processes. This involvement of many actors in decision making has resulted in the necessity to provide and distribute information to them (Alcamo, 2003).Sustainable management of ecosystems are especially necessary where the incentive to maintain the resource is least for example managing common pool resources with open access (Ostrom, 1990). Improved principles of urban ecosystem management to promote sustainable development, is recommended to encompass new policy and governance frameworks with a revised outlook to access and uses of resources. In the context of drastic social change, this is not a far fetched target (Alcamo, 2003).

Amongst various ecosystem resources provided to urban inhabitants, fresh water is especially important for humans to survive in settlements worldwide (Berghöfer, et al., 2011) . It is predicted that there will be water shortages by 2050 and while cities will struggle to meet water demands there will also be unprecedented changes in the distribution of water. Cities in India and China that are witnessing rapid urban growth will experience water shortage by 2050(McDonald, et al., 2011). Lakes become critical in this context as they contain 90% of the earths liquid fresh water supporting a variety of biodiversity. They are an important source of social, economic and aesthetic benefits and play a vital role in the water cycle (International Lake Environment Committee, 2005). According to Ostrom (2007), from the management perspective, lakes can be categorised as common pool resources (see chapter 2 for detailed description). The management for sustainable use of lake basins firstly needs to consider the value of resource for not only the present but future generations as well by reconciling conflicts amongst the currently competing beneficiaries of lakes (International Lake Environment Committee, 2005).

Thus, it is essential to grasp the impact of lake basin management on the sustainability of urban lakes through interactions between multiple users of the natural environment.

1.2 Problem Statement

Cities from ancient times have been facing a degeneration of environmental quality and vulnerability as consequences of urbanisation (McGranahan and Satterthwaite, 2014). Presently, the environmental load is shifting from the developed world to developing countries, who rely mostly on natural resources for their livelihood and vulnerability of these natural ecosystems are eminent (McGranahan and Satterthwaite, 2014). The problems resulting from the increasing demand of services provided by ecosystems is becoming more visible. These issues are aggravated by the decreasing ability of ecosystems to provide these utilities (Alcamo, 2003).

According to Pahl-Wostl, Mostert and Tabara (2008), the issue with our approach to sustainability is not our knowledge of how ecosystems function but the gap in our grasp of how institutional frameworks relate to cultural organisations and their interactions at different scales with socio ecological systems. Furthermore, how we incorporate this empirical understanding with policies. We need to relook our governance systems for sustainable relationships positioned primarily on problems at stakeholders and beneficiaries involved (Pahl-Wostl, Mostert and Tàbara, 2008).

In the case of water resources, the concept of sustainable water resource management has gone through several changes in the last decade. “Initially, water resources management followed an instrumental ‘prediction and control’ approach, dominated by technical end- of-pipe solutions” (Pahl-Wostl, Mostert and Tàbara, 2008). Collapse of this approach to management - right intentions but unsuccessful outcomes, emphasise the need to develop new identities, build the capacities at individual and institutional levels, that are more socially and ecologically sturdier with the common objective of sustainable development (Pahl-Wostl, Mostert and Tàbara, 2008).

With respect to lakes in India over the last ten years, on one hand environmental policies have reflected the importance of urban lakes and on the other, urban lake sustainability is challenged by the growing pressures on them for services and by the lack of proper governance to sustain and meet the societal demands (Van Ast, Bouma and Bal, 2013a) . There is a pressing demand to document practical lessons from managing lake basins in developing countries because of the rising pressures on these resources. (International Lake Environment Committee, 2005). While the goods and services that lakes provide are absolutely essential, a substantial amount of them cannot be part of market transactions and therefore usually end up being undervalued (International Lake Environment Committee, 2005).

Bangalore like many other mega cities, is experiencing rapid urban growth due to unprecedented development initiatives and with a focus on industrialisation for economic growth. This has led to environmental degradation and landuse changes (Ramachandra, et al., 2017) . Lakes in the city appear to be drying, encroached upon and polluted.
There is a lurking need to upgrade policies and institutional strategies through the inter-related understanding of social and ecological systems (Berkes, Colding and Folke, 2008)

1.3 Research Objective

Within the broader goal of socio-ecological sustainability, the objective of this research is to analyse the interface between institutions and ecosystems on one hand and social systems on the other : where they conflict, transgress, converge, or reinforce each other. The objective is also to enable policy makers solve collective action problems in the face of sustainability challenges.

1.4 Research Question

The main research question is:
How do institutional arrangements affect the sustainability of lake basins in Bangalore

1.4.1 Research Sub-questions

The research sub questions are

1. What are the institutional arrangements with respect to lake basins in Bangalore?
2. What are the factors with respect to institutional arrangements that become barriers or facilitators to sustainability of lake basins in Bangalore?
3. What are the constraints to collective action in lake governance in Bangalore?

1.5 Significance of the Study

In the context of Bangalore, there has been a few lake restoration projects in the recent past but most of them have been unsuccessful. Firstly, this study will help understand the non structural factors that affect lake management in the city. Secondly, analysing lake ecosystems through the perspective of common pool resource theory can strengthen and reinforce research in the field if conducted in different situations. Further, establishing the causality between institutional arrangements and sustainability of socio ecological systems has not been explored before. In recent years ecosystem management methods focussed on technological end of pipe solutions. This study helps give an understanding of the qualitative, non-structural factors that impact sustainability of lake basins.

1.6 Scope and Limitations

Within the budget, time, human and financial limitations, this research is restricted to explaining the influence of institutional arrangements on sustainability of lake basins in Bangalore, by analysing variables proposed in Ostroms socio ecological framework. Although Ostrom herself explains that investigating the co-relations between the variables is already challenging enough and attributing causality to them is difficult (Ostrom, E., 2009; Nagendra and Elinor, 2014), this study still tries to best establish the influence of institutional arrangements on sustainability of lake basins.

Chapter 2: Theory Review

2.1 Urban Lake Ecosystems

"Urban ecosystems are those where the built up area covers a large ratio of the land surface, or those which have a characteristic high population density" (Pickett, et al., 2001). Parks, gardens, lakes, rivers, forests and other green and blue spaces can be categorised as urban ecosystems (Costanza, et al., 1997). The services that these ecosystems provide and their functions is known as urban ecosystem services. The value of these services are not captured by the 'market' or quantified like economic services, hence they are not prioritised while policy decisions are taken. This neglect finally compromises the sustainability of humans (Costanza, et al., 1997). An integrated analysis of urban ecosystems also includes the understanding of the emergence and existing social structures (Pickett, et al., 2001). The concept of social differentiation determines the distribution of resources and social hierarchies is a result of this allocation. "5 types of sociocultural hierarchies are critical to patterns and processes of human ecological systems: wealth, power, status, knowledge, and territory" (Burch Jr and DeLuca, 1984). Hence, apart from bio physical aspects, urban ecosystem studies should be consolidated with the knowledge of social structure and assignment of institutional and natural resources along with social distinction(Pickett, et al., 2001)

"A lake ecosystem is a larger hydrological system that normally comprises of catchment area, lake shore, inflow channel and outflow channel of the lake and the associated ecosystems and biodiversity". These can also be called lake basins. The land area that directs all the water into the lakes is known as lake catchments and can be much larger than the lake itself (Bal, 2015).

Schueler and Simpson (2001) describe urban lakes based on the following 6 criteria:

- They tend to be small
- They are usually shallow which are usually 20 feet deep
- The lake basin drainage area is of the ratio 10:1
- 5% of ground coverage in a lake watershed should be impervious surface
- An urban lake ecosystem must be valued as a source of water supply, recreation, flood control and other specific human usage
- These lakes should be strongly influenced by ground water

Urban lakes as the name suggests, are associated with an urban context with the increasing stress from its physical and social background (Van Ast, Bouma and Bal, 2013).

2.1.1 Need for Urban Lake Management

Lake ecosystems have the following benefits (International Lake Environment Committee, 2005)

- Supply of drinking water
- Providing water for agriculture
- They act as buffers for downstream areas against floods and droughts
- They filter out contaminants to protect downstream areas
- They provide a habitat for various species
- Several cultural and religious uses

- Fisheries

The conditions of lakes deteriorate either due to overuse or a clash between the stakeholders of lakes. Communities depend on lakes for their food, water and livelihoods, but as populations grow, lakes come under immense pressure. Most issues in lake basins result from activities in the land around the lakes. Hence to successfully manage a lake basin, it is imperative to manage the catchment and drainage basin. The necessity to learn better methods of lake basin management has become an urgent requirement especially in developing countries with rapid urbanisation (International Lake Environment Committee, 2005)

Water resource management is becoming extremely demanding because of problems like decrease in the supply and increase in demand of water resources, geographical inconsistencies between the society and water ecosystems, irregular distribution of resources annually and low capacity to benefit from even abundant water resources (Pandey, et al., 2011). The values that the society choses to associate with ecosystems and ecosystem services is reflected in the water governance of lakes (Van Ast, Bouma and Bal, 2013b).

2.2 Ecosystem Value and Services

"Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions". Ecosystem services play an important role in human welfare directly or indirectly and also in the economic valuation of the planet (Costanza, et al., 1997) Gómez-Baggethun and Barton (2013) classify the value of ecosystems based on 3 categories namely: socio-cultural , economic and insurance values.

Economic value: Research suggests that when there is deterioration or loss of ecosystems, it results in higher economic costs. As these costs are hidden, there is a strong tendency in cities, for urban ecosystems to be overshadowed by urban built infrastructure with loss of ecosystem services (Gómez-Baggethun and Barton, 2013) For instance, changes in landuse that result in diminishing water regulation services in drainage basins in cities, result in high investments in water purification plants (Daily and Ellison, 2012).

Social-cultural values: The value of ecosystems is also affected by the cultural, religious, educational and aesthetic attitudes of users towards ecosystems (Maes, et al., 2013). These bonds generate a sense of belonging to a place which results in social cohesion and community participation (Gotham and Brumley, 2002). Socio-cultural values are intangible and might be difficult to measure and their analysis might use tools like constructed scales, qualitative assessments or narratives (Chan, Satterfield and Goldstein, 2012).

Insurance values: "The contribution of ecosystem services to increased resilience to shocks can be referred to as a form of insurance value". For example, vegetation and green cover in urban environments prevent damages caused by flooding and landslides by reducing surface runoff and binding soil with leaves and roots (Gómez-Baggethun and Barton, 2013). Since sudden changes caused by climate change involve high investments to reverse, insurance values are also seen as having an embedded economic cost to them (Walker, et al., 2010).

2.3 Common Pool Resources

There is no universally accepted definition of 'the common' (Ostrom, Elinor, 2008). The figure below shows the classification of goods according to Ostrom (1994)

Figure 1: Catergorisation of goods (Ostrom, Elinor, et al., 1994)

Four Types of Goods that are identified are
1. Private
2. Public
3. Toll, and
4. Common-pool

Private goods characterised by the ease of exclusion of potential users of a resource system and the notion that usage by a beneficiary will reduce the benefits of the same resource available to others. The opposite is seen in regards to public goods which have lack of excludability and subtractability (Ostrom, et al., 1994).

A common pool resource provides the appropriate environment for resource units to exist in the system. These stocks enable the availability of the *flow* of resource units within the system. Some common pool resource examples are : the fishing grounds and tons of fish; Parking garages and parking spaces inside them (Ostrom, et al., 1994).

Two characteristics of common pool resources are
1. The complication of excluding potential users from using a resource
2. The subractability: When one individual gains from consuming from the system, it reduces the availability of the same benefits for the other users

The tendency to exploit a resource system shared with others, by extracting its resource units is seen commonly at different scales of time and space. These resource systems are called common pool resources (CPR's) which produce limited flows where it is tough to exclude beneficiaries (same as public goods) and they share the characteristic of high subtractability (same as private goods).

With the example of herdsmen using a pasture to graze his cattle, Hardin introduces the concept of 'tragedy of commons'. It is assumed that at the minimal cost of over grazing, each herdsman will receive significant profits by selling his animals. Even once the capacity of the pasture is exceeded, the herdsmen will keep adding to their stock of cattle to maximise their personal gains at the shared cost of gradually exhausting the common resource. Thus, he says that "There in is the tragedy. Each man is locked into a system that compels him to increase

his herd without limit – in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons" (Ostrom, 2008).

According to Hardin (1968), beneficiaries are trapped in a situation and are unable to remove themselves from exploiting the benefits of a resource system. Conducted experiments show that allowing users unlimited access to resource systems results in over use of units (Ostrom, 2008) however, users can overcome the tragedy of the commons by communicating and agreeing upon rules that upgrade their shared outcome (Ostrom, et al., 1994). According to Ostrom, Hardins assumption that all CPR's have open access is untrue, infact CPR's can have defined property rights and can be owned privately, government owned or even common property.

It is now known that the beneficiaries of a CPR tend to (Ostrom, 2008) :

1. Spend sufficient energy and time to design a practical institutional framework to manage commons
2. Follow expensive regulations with knowledge that other users will follow them as well
3. Monitor each other's adherence with these rules; and
4. Impose sanctions on each other at a cost to themselves

Managing urban commons is central to the systems of urban governance. The large scale of urban societies makes them very vulnerable to tragedies of the commons (Hardin, 1968).

2.4 Socio Ecological System

A socio ecological system (further referred to as an SES) is an ecological system that is influenced by one or more social systems. An arrangement in which the biotic and abiotic resource units are interconnected with each other is called an ecological system (Anderies, Janssen and Ostrom, 2004) A social system simply refers to interdependent networks and interactions created by humans by others of their own type (Dictionary, 1996)

2.4.1 The SES framework

The Socioecological framework is a multilevel structure to analyse a socio-ecological system through potentially relevant variables and can be used for data collection, fieldwork and drawing an understanding of the sustainability of a socio ecological system(Ostrom, 2009). This framework helps understand the impact of various institutional arrangements on stakeholders from different backgrounds, and their influence on the socio ecological system under consideration. It brings together knowledge from multiple scientific disciplines with their own technical language to enable the understanding of socio ecological systems (McGinnis and Ostrom, 2012a).

According to literature "This framework can be applied to circumstances involving resource management in which resource users extract resource units from a resource system, and provide for the maintenance of that system, according to rules and procedures determined by an overarching governance system, and in the context of related ecological systems and broader social-political-economic settings. The processes of extraction and maintenance were identified as among the most important forms of interactions and outcomes that were located in the very center of this framework". (McGinnis and Ostrom, 2012b)

The core structure of the SES framework comprises of the following variables which are further divided into sub variables (Ostrom, 2009)

1. **Resource system (RS)** refers to the bio-physical characteristics of the resource. Eg: the water enclosed in a lake system
2. **Resource units (RU)** refers to the functions generated by resource system. Eg the fish in the lake
3. **Actors (A)** refers to the stakeholders using the socio ecological system and their actions which are influenced by the institutional arrangements within a particular socio-economic-political setting. Eg: local residents using a lake for recreation
4. **Governance systems (GS)** refers to the institutional framework which includes the government and other organisations that manage the SES through specific regulations and how these rules are made. Eg: policies for lake management
5. **Socio-economic, political settings (S)** refers to the broader geo political system encompassing the focal resource system, the actors and the governance systems. Eg: Demographic trends
6. **Related Ecosystem (ECO)** is the broader ecological (including physical-urban externalities like infrastructure) context within which the focal resource system, the actors and the governance systems are located. Eg: climate threat to a region
7. **Interactions (I)** refers to the communication between the users and resource systems, users and the resource units and users and the governance systems, governance systems and resource systems, governance systems and resource units and governance systems and users. Eg: lobbying activities
8. **Outcomes (O)** refers to the are general concepts that include performance of both the social systems and the ecological systems. Eg: accountability of the stakeholders and the level of bio diversity in a lake system.

Below is the revised SES framework presented by McGinnis and Ostrom in 2012 encompassing the above main variables

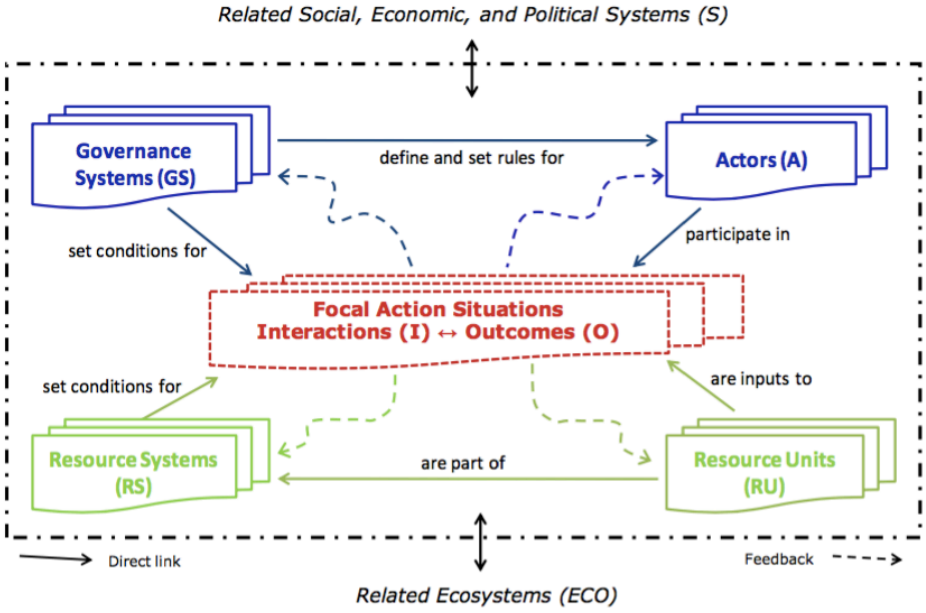

Figure 2: SES framework; Source: (McGinnis and Ostrom, 2012)

The above variables forms the main structure of the socioecological framework of Ostrom, but in order to understand complex interactions and outcomes among these, it is necessary to

break the main variables down to sub variables. The research interest and specific research questions will guide the selection of these subvariables (Ostrom, 2009) The subvariables as prescribed by Ostrom are listed in the below:

Socio, Economic and Political Settlings (S)			
S1- Economic Development	S2-Demographic trends	S3-Political stability	S4-Governance and resource policies
	S5-Market Incentives	S6-Media organisations	
Resource systems (RS)		**Governance systems (GS)**	
RS1 - Sector		GS1 - Govrnment organisations	
RS2 - Clarity of system boundaries		GS2 - Non-government organisations	
RS3 - Size of resource systems		GS3 - Netwrk struture	
RS4 - Human constructed facilities		GS4 - Property rights systems	
RS5 - Productivity of system		GS5 - Operational rules	
RS6 - Equillibrium properties		GS6 - Collective choice rules	
RS7 - Predictability of system dynamics		GS7 - Constitutional rules	
RS8 - Storage characteristics		GS8 - Monitoring and sanctioning rules	
RS9 - Location			
Resource Units (RU)		**Actors (A)**	
RU1 - Resource unit mobility		A1 - Nature of actors	
RU2 - Growth or replacment rate		A2 - Socio economic attributes of actors	
RU3 - Interaction among resource units		A3 - Hitory of use	
RU4 - Economic value		A4 - Location	
RU5 - Number of units		A5 - Leadership/entrepreneurship	
RU6 - Distinctive markings		A6 - Social Capital	
RU7 - Spatial and temporal distribution		A7 - Knowledge of SES	
		A8 - Importance of resource	
		A9 - Technology used	
Action situation: Interactions (I) - Outcomes (O)			
I1 - Harvesting levels		O1 - Social performance measures	
I2 - Information sharing		O2 - Ecological performance measures	
I3 - Deliberation process		O3 - Externalities to other SES's	
I4 - Conflicts			
I5 - Investment activities			
I6 - Lobbying activities			
I7 - Self organising activities			
I8 - Networking activities			
I9 - Monitoring activities			
	Related Ecosystems (ECO)		
ECO1- Climate patters	ECO2-Pollution patterns	ECO3-Flows into and out of SES	

Figure 3: Sub-variables of SES framework; Source: (McGinnis and Ostrom, 2012)

The SES framework "associates with many different concepts, theories, and methods under two broad conceptual pillars: (1) understanding SES functioning and (2) understanding all aspects related to the development, implementation, and transformation toward normative sustainability goals" (Partelow, 2018). After review of literature , it can be said that urban lakes are socio ecological systems that can be managed as common pool resources.

2.5 Sustainability of Urban Water Resources

The Brundtland commission defines sustainable development as "the ability to meet the needs of present without compromising the ability of future generations to meet their own needs" (Brundtland, et al., 1987). The logic to justify the use of the concept of sustainability in this research is that sustainability of ecological systems reflect the sustainability of cities. In the late 20th century, the relationship between environmental conservation and economic development was understood and the understanding that economic growth can be realised only with the protection of the environment and social inclusion (Marques, da Cruz and Pires, 2015).The definition that supports this theory is "sustainability means the maintenance of the

capacity (functions) of an ecological system to support social and ecological systems over time" (Berkes, Colding and Folke, 2008).

Scott Campbell looks at a city through three different perspectives (Campbell, 1996):

1. The *economic* lens looks at the city as a space which is contesting other cities and supports production, consumption, innovation and distribution.
2. The *environmental* lens looks at the city in competition with nature and as a user of resources and producer of wastes.
3. The *social and equity* lens looks at the city as a space which clashes with itself over the distribution of services, resources and opportunities.

According to Marques et al., there is no widely accepted definition of sustainability of urban water resources specifically, and questions the possibility of operationalization of such a limitless notion of sustainability which presents conceptual limitations (Marques, da Cruz and Pires, 2015) . The triple bottom line framework which constitutes environmental, social and economic aspects generally defines sustainability(Thornton, et al., 2007). The 'people, planet and profit' definition by Shell find a correlation to the triple bottom line but authors like Marques et al., and Schneider et al., argue whether this is the appropriate concept to understand and explain sustainability of water resources (Schneider, et al., 2015; Marques, da Cruz and Pires, 2015).

Few years ago, the sustainability of water services was defined by the quantity of water available, the quality of drinking water and sufficient pressure (Brattebø, et al., 2013). Now, the need of the day is that urban water should not only have the above features but should also integrate concepts of efficiency and customer responsiveness. Part that organisations can play through CSR initiatives must also be recognised (Brattebø, et al., 2013).

According to Brattebø et al. (2013), the users and stakeholders with divergent and different objectives and visions adds to the complexity of governance issues (e.g. participation and transparency) with respect to urban water resources. There is also increasing concerns about the costs associated with waste water services and the necessity to push these costs onto the polluter instead of distributing them to be absorbed by normal citizens. "Urban water systems are central for the social and economic cohesion of society. Not only does the population wish to have sound and transparent drinking water services at affordable prices but the customers also need to feel the value for money spent. The awareness that the sustainability of communities and cities (the so-called 'city of the future') calls for the sustainability of urban infrastructure and particularly of urban water resources is also increasing" (Brattebø, et al., 2013). Water services play a very important role in livability and sustainability of cities (Binney et al., 2010).

Brattebø et al. (2013) proposed a conceptual model to understand sustainability of urban water resources in the TRansitions to the Urban Water Services of Tomorrow (TRUST) research project encompassing the governance and the assets dimension along with the 3 pillars of sustainability.

Figure 4:Sustainability Framework to Assess Urban Water Services (Source: (Brattebø, et al., 2013)

Based on this background and conceptual model of Brattebø et al. (2013) , the principles of sustainability of urban water resources as detailed by Marques et. al., are as follows:

1. **Social** - The 'social' principle mainly addresses the fulfilment of the needs of users, access to the water resource services, the public approval and the appropriate role in the community of these services (Fleming, 2008) There should be available water for peoples use in recreation and household apart from economic benefits like production of food or other goods and services(Schneider, et al., 2015) . Based on stakeholder interviews and participatory visioning methods Brattebø et al. (2013) identified the acess to urban water services and the ability to meet users needs as variables to understand social sustainability.

2. **Environmental** - Ecological and hydrological integrity of water resources needs to be maintained for present and further generations. Effectively minimising downstream negative impacts and optimising the use of water, energy and materials can be encompassed in the principles of environmental sustainability (Kondratyev, et al., 2002)

3. **Economic –** This dimension focusses on the economic objectives related to urban water sustainability for example: financial investment in resource to ensure economic sustainability (Marques, da Cruz and Pires, 2015).

4. **Governance – "**Governance relates to the political, social, economic and administrative processes which affect the development, delivery or management of water resources and services"(Brattebø, et al., 2013) . It is a framework based on which the society makes decisions and shares responsibilities. It encompasses mainly on horizontal and vertical interactions between the society and organisations that enable decision making(Moench, et al., 2003) Key considerations within this dimension would be public participation, accountability and clearness and measurability of policies (Brattebø, et al., 2013) .

5. **Asset –** Along with being correlated with physical infrastructure, this dimension also constitutes soft infrastructure like collective action, information and knowledge management. Ensuring presence of human capital by ensuring adequacy of training,

capacity building and knowledge transfer are considerations in this dimension of sustainability (Schneider, et al., 2015).

Against this background, the goal of this thesis is to put forward a conceptual and methodological approach for an interdisciplinary sustainability assessment for urban lake basins. Furthermore, the SES framework by Ostrom is best suited to understand sustainability of socio ecological systems (Ostrom, 2009). The co-relation between the variables help to establish a causality to understand the influence of institutional arrangements on sustainability of lake basins in Bangalore.

2.6 Relationship between Institutional Arrangements and Sustainability

This research tries to explain the impacts of institutional arrangements on the sustainability of socio ecological systems. Ostrom's SES framework in this study, proposes the variables to understand the institutional framework which guide the management of sustainable common pool resources. These variables directly or indirectly through interventions which are a result of institutional arrangements affect the sustainability of common pool resources.

According to review of literature on neo-institutionalism, "rules of the game" as prescribed by Ostrom (1990), which lay out who the beneficiary is and how much can he use along with who should take decisions on usage and defining the constraints is called institutional arrangements. The hierarchical perception that the government is the only decision making body is changing to a more polycentric approach recognising the direct role of users collaborating at different levels of the institutional structure (Pahl-Wostl, Mostert and Tàbara, 2008). The binary aspect of institutional arrangements – both as a facilitator of individual action on one hand and as a barrier, to keep a check on undesirable behaviour on the other hand, is of utmost importance when it comes to sustainable water resource management (Bandaragoda, 2000) .

Institutional arrangements help stakeholders to apply policies to the real world scenario, distribute responsibilities and define strategically how management goals can be accomplished (Hamdy, Abu-Zeid, et al., 1998). According to Pahl-Wostl (2009) along with formal institutions, informal networks play a critical role in managing ecosystems, through social norms which lay out the expectations from the society to use and access resources. There is an increasing interest in polycentricism of institutional settings incorporating governance systems which exists at different levels with a certain level of autonomity simultaneously overlapped by authority (Low, et al., 2003). This system involves authorities and users from overlapping jurisdictions to communicate with each other to decide what regulations and conditions each of them should act under, for public benefits (McGinnis, 2011). Therefore, "polycentric governance systems are defined here as complex, modular systems where differently sized governance units with different purpose, organization, spatial location interact to form together a largely self-organized governance regime" (Pahl-Wostl, 2009) . Polycentric systems can be flexible characterising freedom at various levels, wherein the power of decision making does not rest in any one level of the hierarchical setting (Pahl-Wostl, 2009).

Arun Agarwal (2001), after reviewing three landmark works by Ostrom, Wade and Baland and Platteau concluded that " members of small local groups can design institutional arrangements to help manage resources sustainably".

Characteristics of resource includes variables like resource size, nature of groups can be defined by social capital and leadership (Agrawal, 2001). Critical aspects of institutional regimes include monitoring, sanctions and institutional rules (Agrawal, 2001). Particulars of external environment can include attributes like technology, levels of governance, demographic changes and markets (Agrawal, 2001). To understand successful management of common pool resources, a combination of the above variables should be looked at in order to establish a casual relationship between institutional arrangements and sustainability (Agrawal, 2001).

2.6.1 Collective Action and Social Capital

When we talk about institutional arrangements and sustainability, it is necessary to focus our attention to social capital and collective action, which forms a critical role in establishing that relationship. In literature on both institutional arrangements and sustainability of water resources social capital appears as a common variable to both. Thus it is interesting to see how the relationship between institutions and sustainability is held together by social capital. Social capital is an attribute of collective action and in this study the impact of social capital (independent variable) on collective action (dependent variable) is analysed.

Collective action is a form of polycentric governance and an important concept around which the SES framework is structured. It can be described as the configuration of many actors with multiple characteristics who interact with each other at various levels using multiple governance strategies directed towards producing an outcome like the sustainability of lake ecosystems. The scope of collective action studies covers both individuals and organizations as unit of analysis (Adapted from Ostrom, et al., 1994; Ostrom, 2009; McGinnis, 2011; McGinnis and Ostrom, 2012).

Olsons view of collective action stated that self-interested individuals put only their needs before they contribute to public goods and will not act collectively unless the size of the group is small (Olson, 2009). Later scholarship by Hardin and Ostrom says that the relationship between group size and collective action is not that direct. New policies identify the limitations of the state to manage natural resources and recognise that communities with high social capital engage in collective action as compared to the state or private organisations who look at market based solutions (Folke, et al., 2005).

Collective action forms the essence of management of most natural resources (Adger, 2010). Most of them whether agriculture, forests or water resources fall under the regime of multiple users who have very limited knowledge about climatic changes on sustainability (Adger, 2010). There are underlying societal rules that operate how resources are distributed especially when scarce. According to Adger (2010), this collective action to establish rules and make decisions requires information exchange and networks. These networks are termed as social capital and form strong assets of societies. “Social capital captures the nature of social relations and uses it to explain outcomes in society” (Adger, 2010)

There are two forms of social capital – private and public. Private social capital is characterised by a single individual but cannot be isolated from the context he or she works in (Dasgupta, 2001). Public social capital is attributed to the relationships between different

individuals collectively (Adger, 2010)These networks finally describe the institutional framework for ecosystems (Adger, 2010)

Social capital when looked at from an institutional lens is defined by the quality of interactions with formal establishments (Adger, 2010). It is seen that for a well functioning state, there has to be cooperation between the government and society (Adger, 2010) According to Adger (2010), when actors maintain both internal and external networks along with keeping up social and policy learning from the state, it makes an ideal environment for a well functioning state as represented below:

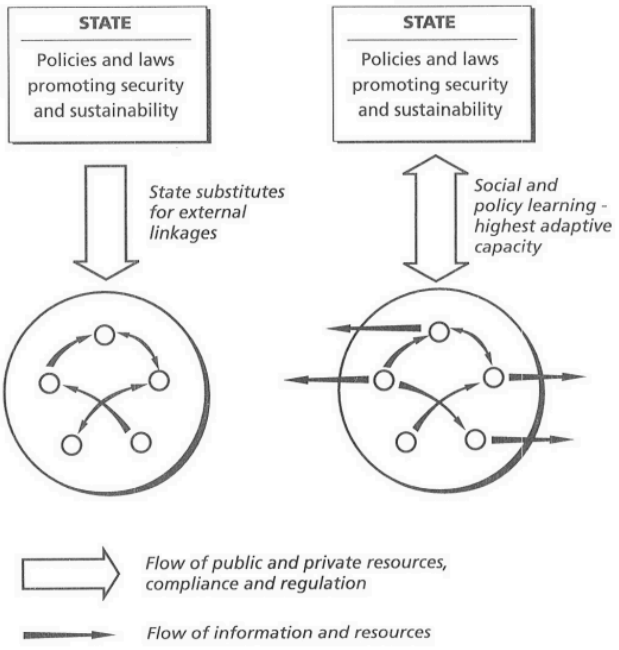

Figure 5: Types of Networks between Actors and State (Source : (Adger, 2010)

In conclusion "open processes of democratic participation and environmental governance can promote both self regulation and sustainable use of environmental resources"(Agrawal, 2001).

2.8 Conceptual Framework

On the basis of theoretical review this research focusses on the role of institutional arrangements at various levels towards achieving sustainable ecosystems.

Institutional arrangements aim to understand a ecosystem through the actor-resource centric approach at various levels. This is also the approach to understand sustainability of water resource systems which includes the social, economic and environmental spheres. The SES framework tries to understand the influence on sustainability of a socio ecological system through the association between social and environmental aspects at multiple levels (Partelow, 2018). Figure 6 below is the conceptual framework.

The framework analyses the co relations between selected variables (representing characteristics polycentric governance) and their influence on the sustainability of the lake

ecosystems in Bangalore. The interface between institutions and socio ecological systems will be analysed and understood through the lens of Ostroms SES framework. While sustainability will be assessed using the sustainability model by Brattebø et al. (2013) simultaneously documenting the

This framework facilitates a deeper understanding of a socio-ecological system while integrating various knowledge areas especially those including not only qualitative but also quantitative data.

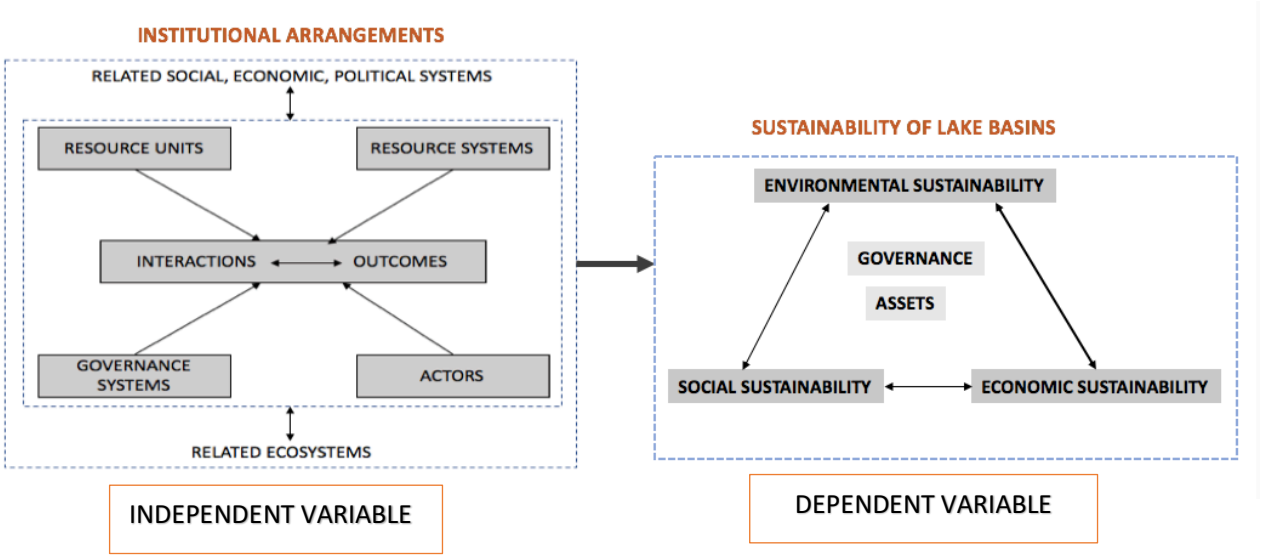

Figure 6: Conceptual Framework (Source: Author)

Chapter 3: Research Design and Methods

3.1 Introduction

The choice of research approach, strategy, operationalisation of selected variables and methods of data collection are described in this chapter.

3.1.1 Revised Research Question

The main research question is:
How is the sustainability of lake basins being influenced by institutional arrangements in Bangalore?
The research sub questions are

1. What are the institutional arrangements with respect to lake basins in Bangalore?
2. How can lakes in Bangalore be categorised as common pool resources ?
3. What are the variables that facilitate or inhibit sustainability of lake basins in Bangalore?

3.1.2 Research Type, Approach, and Strategy

While analysing socio-ecological systems, the overall SES thinking including the vocabulary of urban lake system form the epistemology; the variables and the sub-variables of SES form the ontology; the structure of the variables and the sub-variables of the SES is the methodology; and the method is primarily the case study method.

The issues related to institutional arrangements and sustainability of lake basins in Bangalore forms the background of this research. An explanatory approach is taken to conduct this study to describe the influence of institutional arrangements on the sustainability of lake basins in Bangalore using the common pool theory. It is interpretive in nature, assuming a voluntaristic model of the man with every person having their own perspective and view of reality (Van Thiel, 2014) . The diagnosis is done in 3 stages: exploring the institutional arrangements of urban lakes in Bangalore; understanding the lake basin from the position of common-pool resources theory and finally, analysing the facilitators and barriers to sustainability of lake basins in Bangalore.

Case study of 3 different lake basins in Bangalore is selected as a research strategy for this study. Considering the case study focuses on only 3 situations, the researcher has the opportunity to understand the case thoroughly and mainly look for depth and not breadth, focussing on the details while taking into account the linkage between the situation and the context (Van Thiel, 2014). The case study approach fits the need, since only three cases are being analysed and the number of resource units are less but the number of factors and independent variables affecting the situation is unknown and large. A case study is used to study a comparison between multiple cases when a repeated occurrence is seen (Van Thiel, 2014) . Here, the repeated occurrence is the institutional system that governs sustainability of lake basins in Bangalore.

When the researcher has limited authority over the situation and is seeking to answer questions of ‘how’ and ‘why’ the recommended strategy is the case study. He also establishes that to make this strategy more reliable and valid, it has the flexibility to be combined with other approaches of data collection by triangulation(Yin, 2003).

3.1.2.1 Challenges in Case study

The major challenge in case study is, since the number of cases are small, it is not possible to generalise the data gathered from a few cases to a larger number of subjects. Hence the validity and reliability in a wider context comes into question (Yin, 2003) The method is especially suited for qualitative analysis and does not provide a good arguement for quantitative study. This approach can encourage the researcher to focus more on verifying the assumptions regarding the subject laid out at the beginning of the research instead of taking into consideration all aspects with an unbiased approach. However, according to Flyvbjerg (2006) researchers bias can influence other research strategies as well. Additionally, the personal bias of interviewees can also influence the quality of data collected. The validity and reliability is questioned also because the number of respondents are not high. Van Thiel (2014) suggests the method of triangulation, and through secondary qualitative and quantitative analysis, the information gathered can be cross checked. Another challenge could be that potential respondents like experts in the area of the subject being studied, because of their busy schedule might not be willing to give time for an interview. In this case, informants (eg. Former employees of an organisation) can help with information regarding the case (Van Thiel, 2014).

3.2 Case Selection

The choice of studying Bangalore lakes is a strategic one. Bangalore has many lakes in and around the city and over the last ten years there have been citizen activism with respect to lake management (Lele and Sengupta, 2018a).

The city has seen exponential growth over the past few years which has been marked by a loss of urban commons and ecological degradation, posing challenges to the sustainability of the city and human well being. There are about 210 lakes and the city has seen some rejuvenation projects but most are visibly unsuccessful. This study aims to explain the influence institutional arrangements on the sustainability of lake basins in the city.

Three lakes are selected for this research based on the phase of redevelopment there are in. Since most lakes in the city are being consolidated with the BBMP and there are lake development efforts being undertaken, this study tries to understand the influence of institutional arrangements and how they have evolved over the last 10 years. The Puttenhalli lake was one of the first lakes in city to be revived in 2009, the Kowdenhalli lake was revived a year back (works started in 2016) and the Kaggadaspura lake is just beginning its rejuvenation process (Although there have been plans of redevelopment since 2016). All three lakes lie in the same drainage valley of the city to narrow down on contextual background for this research:

1. Kaggadaspura lake
2. Kavadenahalli lake
3. Puttenahalli lake

3.2.1 Background on selected lakes

3.2.1a. Puttenhalli Lake

This is one of the first lakes in Bangalore to see citizen action which resulted in a successful rejuvenation outcome. Like most lakes in Bangalore, this too was a swampy garbage dump because of neglect and encroachment. In 2009, in an initiative headed by Mrs Usha Rajagopalan , the BBMP was approached and a petition for lake restoration was made. This effort successfully resulted in BBMP handing over the maintenance of the lake to the Puttenhalli Neighbourhood Lake Improvement Trust (PNLIT) after cleaning and developing Puttenhalli lake, making them the first citizens organisation to become custodians of a lake in Bangalore.

Puttenahalli lake has played an important part in maintaining the delicate ecosystem of the Puttenahalli neighborhood. Part of the Sarakki lake series, the tank measures about 3.75 hectares with a water volume of 5.7 ha-m (Bruhat Bengaluru Mahanagara Palike, 2018c). The lake is located in 7th phase, JP nagar surrounded by multi-storeyed apartment complexes of L&T southcity and Brigade millennia. Commercial and institutional buildings like convention centres, schools, malls and offices dot the neighbourhood (Bruhat Bengaluru Mahanagara Palike, 2018) .

Figure 7: Google Earth Image of Puttenhalli Lake and Surroundings (Source: Google Earth)

The population of the surrounding catchment is 2, 20,513 with a net population density of 262 persons per hectare (Bruhat Bengaluru Mahanagara Palike, 2018). The catchment area of the tank is 0.23 sqkm and water from the catchment runs off into the lake through stormwater drains. Although most of the storm water is diverted, a part of it accompanied by waste water from the residential neighbourhoods enters the lake. Along with the waste water, there is also silt that is being carried from the catchments area and this is being deposited on the tank bed. The lake also has an encroachment on the east side by a slum with 80 families, who claim

that the settlement is a minimum of 40 years old (Bruhat Bengaluru Mahanagara Palike, 2018). Main parametres of the tank are given in Annex 3.

This lake was selected because of its size and being the first lake to be rejuvenated in the city through citizen participation. To analyse the challenges in this context will give an understanding of what are the measures that are being taken to try and improve the sustainability of this lake basin over the last 10 years and what is its present condition.

Figure 8: Images of Puttenhalli Lake and Surroundings (Source: Author)

3.2.1b. Kowdenhalli lake

The Kowdenhalli lake was a deserted swamp but now it is a lively lake premise with many walkers, tree species and migratory birds. The lake is situated in Ramamurthynagar in the northern part of Bangalore. It is situated in the Hormavu planning district with a population of 1,23,507 and a net population density of 178 persons per hectare. It has a number of residential units in its precinct.

Kowdenhalli today stands as a seasonal water body and it covers an area about 13.8 ha. The volume of water in the lake has been estimated as 5.76 ha-m. The lake is formed largely due to the natural topography of the land. The Kowdenahalli watershed has a catchment area extending nearly 2.93 sq Km. The watershed has been largely disturbed due to urbanization and there is very little water reaching the tank at present. Although the lake has been rejuvenated, the quality of water is still poor (Bruhat Bengaluru Mahanagara Palike, 2018b) .

Figure 9: Google Earth Image of Kowdenhalli Lake and Surroundings (Source: Google Earth)

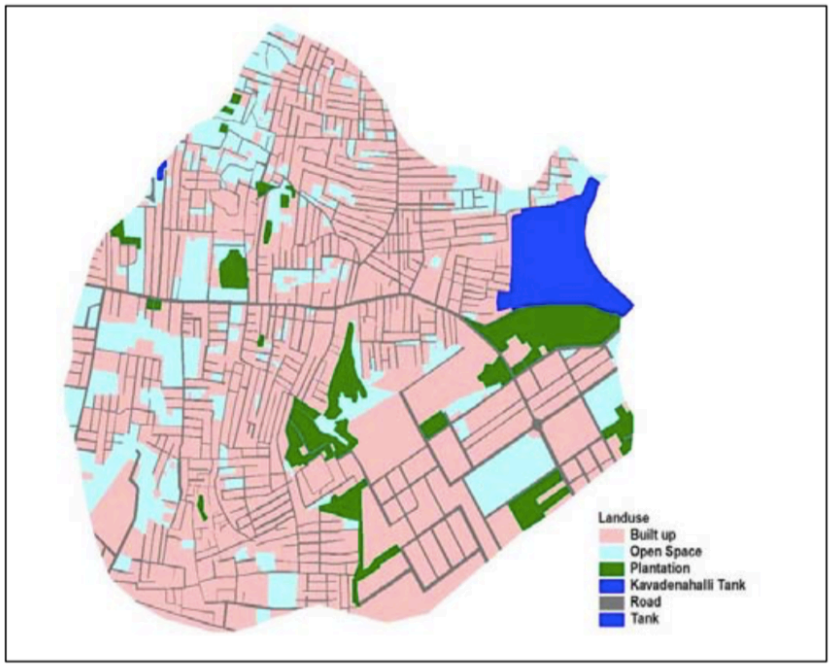

Figure 10: Kowdenhalli lake catchment Source: (Bruhat Bengaluru Mahanagara Palike, 2018)

The lake has two constructed drains bringing water from the surrounding catchments area. The one on the south west measures 7m by 2.5m and northwest 5m by 2.5m wide acting as the main feeder to the tank. The water flowing into the tank is a mix of storm water and waste water (Bruhat Bengaluru Mahanagara Palike, 2018). Main parametres of the tank are given in Annex 3.

This lake was selected because it has very recently completed its restoration process a year back. Another factor was its size, as it is bigger than Puttenhalli lake and to learn how measures have evolved over time and whether best practices are incorporated from previous efforts to improve sustainability.

Figure 11: Images of Kaggadaspura Lake and Surroundings (Source: Author)

3.2.1c. Kaggadaspura lake

The Kaggadaspura lake is measured at 15.03 hectares in the Kaggadaspura area of Bangalore with a catchment area of 3.87 sqkm. It is connected upstream to Kelagiankere and downstream to Doddenakundi lake. It has two inlets one on the north west side with a total length of 1.5km and the other from south west side bringing overflows from the Kelagiankere lake. Both the inlets bring in debris and waste water from surrounding areas. It is surrounded by settlements on all sides and some area of the lake has been encroached.

Figure 12: Google Earth Image of Kagadaspura Lake and Surroundings (Source: Google Earth)

The main parameters of the tank are given in Annex 3.

The Kaggadaspura lake is larger than both Puttenhalli and Kowdenhalli lake. The renovation works have recently started although it has been under the radar of the government for redevelopment since 2009. Presence of citizen participation is also seen. It has been selected for this study to understand the reasons why this delay took place and what are the institutional reasons that is hindering sustainability of the lake basin.

Images Figure 13: of Kaggadaspura Lake and Surroundings (Source: Author)

3.3 Operationalization: Variables and Indicators

Operationalising the characteristics of the causal relation lead to following logical inquiries:

1.what are the variables;
2.how do they interact with each other;
3.how do their interactions describe the existing influence of institutional arrangements on sustainability of lakes.

To operationalise the 5 variables and 9 sub variables are selected from Ostroms SES framework. Indicators, based on literature review were selected to analyse each of the sub variables. The variables are selected based on *how closely they characterise collective action* and their noticeable variation across the 3 selected lakes.

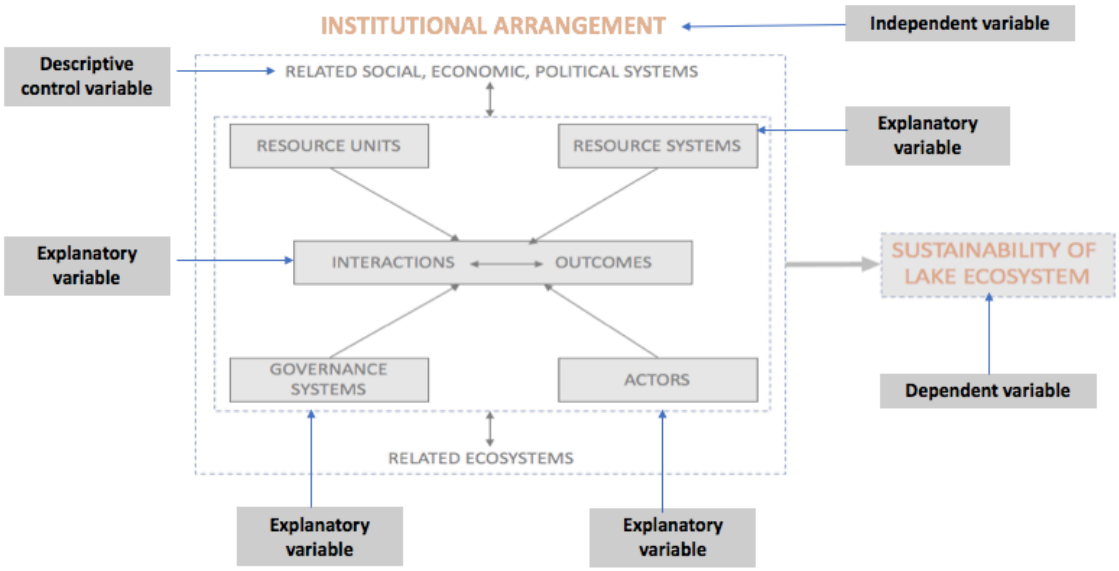

Figure 14: Classification of selected variables from Osrtoms SES framework

The selection of sub variables was based on the understanding of on ground situation of lake basin management in Bangalore and the assessment of academic literature.

The description of sub variables, their associated indicators and method of data collection are given in Table:1,Table:2 and Table:3 below. The reasons explaining the choice of specific sub variables from the SES framework is listed in *Annex 2.*

Table 1:Variables and indicators to analyse independent variable

Sl. No	VARIABLE	SUB VARIABLE	WORKING DEFINITION	INDICATORS	METHOD OF DATA COLLECTION
1	**Resource Systems (RS)**	RS3: Size of resource system	Absolute or relative descriptions of the spatial extent of a resource system (Castilla et al. 1998)	Size of lake (Castilla et al. 1998)	BBMP data from Detailed Project Report
2	**Governance Systems (GS)**	GS5: Operational rules	Implementation of practical decisions by individuals authorized or allowed to take actions and the creation of institutions and policy decisions by those actors authorized to participate in the collective decision (McGinnis, 2011a)	Presence of community rules for the activities permitted in the lake (McGinnis, 2011a)	Semi structured interviews
3	**Actors (A)**	A1: Number of Actors	Number of actors that participate in resource harvest activities within a particular social- ecological system region (Basurto, Gelcich and Ostrom, 2013)	Direct users of natural resources (Basurto, Gelcich and Ostrom, 2013)	Semi structured interviews
				Other actors (Basurto, Gelcich and Ostrom, 2013)	Semi structured interviews
		A5: Leadership/entrepreneurship	Actors who have skills useful to organize collective action and are followed by their peers (Cudney-Bueno and Basurto, 2009)	Presence of individual/s to lead betterment efforts (Basurto, Gelcich and Ostrom, 2013)	Semi structured interviews
		A6: Norms of trust, social capital	Degree by which one or several individuals can draw upon or rely on others for support or assistance in times of need (McGinnis, 2011a)	Participation of individuals (McGinnis, 2011a)	Semi structured interviews
		A8 Importance of resource (dependence)	The resource constitutes a source of monetary income, cultural values, practices, and services,and plays a major role in to sustain their livelihoods (Bromley, et al., 1992; Basurto, 2005)	Usage of the lake for recreation and exercise (Bromley, et al., 1992; Basurto, 2005)	Semi structured interviews
				Usage of the lake for religious purposes (Bromley, et al., 1992; Basurto, 2005)	Semi structured interviews
				Usage of lakes fo fishing (Bromley, et al., 1992; Basurto, 2005)	Semi structured interviews

Sl. No	VARIABLE	SUB VARIABLE	WORKING DEFINITION	INDICATORS	METHOD OF DATA COLLECTION
		I8:Networking activities	Networking and partnership activities of the users within and outside the community (del Mar Delgado-Serrano and Ramos, 2015)	External networking (del Mar Delgado-Serrano and Ramos, 2015)	Semi structured interviews
4	**Interactions (I)**				
		I9: Monitoring activities	Monitoring activities on the use and management of resources (e.g. locally-de ned by users, controlled by the government) and their performance (del Mar Delgado-Serrano and Ramos, 2015)	Existence and level of implementation of monitoring and evaluation mechanisms to measure to what extent water policy fulfils the intended outcomes and water governance frameworks are fit-for-purpose (del Mar Delgado-Serrano and Ramos, 2015)	Semi structured interviews

Table 2:Variables and indicators to analyse control variable

5	**Socioeconomic and political settings(S)**	S4 - Government resource policies	Top-down policies adopted by the national, regional and local governments to manage natural resource (del Mar Delgado-Serrano and Ramos, 2015)	Governmental regulatory framework for natural resources Environmental policies (del Mar Delgado-Serrano and Ramos, 2015)	Secondary data analysis is in the form of reports from official organisations like The National Green Tribunal (NGT), Karnataka Lake Conservation Development Authority (KLCDA) and Bruhat Bengaluru Mahanagara Palike (BBMP)

Table 3: Variables and indicators to analyse dependent variable

Sl. No	VARIABLE	WORKING DEFINITION	SUB VARIABLE	INDICATORS	METHOD OF DATA COLLECTION
1	**Environmental (E)**	Ecological and hydrological integrity of water resources needs to be maintained for present and further generations.The quantity and quality of surface or ground water along with the gains and damage to the resource can be encompassed in this principle (Kondratyev, et al.,	E2.Minimize downstream negative impacts	Pollution prevention (Brattebø, et al., 2013).	Semi structured interviews / CPCB grade of the water
2	**Social (SO)**	The 'social' principle mainly addresses the fulfilment of the needs of users, access to the water resource services, the public approval and the appropriate role in the community of these services (Fleming, 2008) There should be available water for peoples use in recreation and household apart from economic benefits like production of food or other goods and services(Schneider, et al., 2015) .	SO1. Access to urban water services	Physical service accessibility (Brattebø, et al., 2013).	Semi structured interviews
			SO2. Effectively satisfy the current users' needs and expectations	Quality of service (Brattebø, et al., 2013).	Semi structured interviews
3	**Economic (EC)**	This dimension focusses on the economic objectives related to urban water sustainability for example: users access to financial and material resources (Marques, da Cruz and Pires, 2015)	EC1. Ensure economic sustainability of the UWCS	Investment in resource (Brattebø, et al., 2013).	Semi structured interviews
4	**Governance (G)**	Governance relates to the political, social, economic and administrative processes which affect the development, delivery or management of water resources and services(Brattebø, et al., 2013)	G1. Public participation	Participation initiatives (Brattebø, et al., 2013).	Semi structured interviews
			G2. Accountability	Individual and collective accountability(Brattebø, et al., 2013).	Semi structured interviews
5	**Assets (AT)**	Along with being correlated with physical infrastructure, this dimension also constitutes soft infrastructure like social capital, information and knowledge management (Schneider, et al., 2015).	AT1. Human Capital	Adequacy of training, capacity building and knowledge transfer (Brattebø, et al., 2013).	Semi structured interviews

3.4 Data Collection Methods

3.4.1 Primary Data Collection

Primary data is collected first hand through semi structured interviews and observations. I have used semi structured interviews in this study. These interviews are conducted using a guideline – an interview manual, unlike the open interviews (Refer Annex 1). The manual usually has a set of questions prepared earlier (Van Thiel, 2014). The variables selected guides the questions for the interview. This approach is appropriate for topics when there is atleast some information available on them, but should also be able to gather ideas from selected respondents with flexibility.

There is sufficient literature on the theories of institutional arrangements, but in the case of socio ecological systems, where a large part of the understanding is about the role of collective action, each case is different and the understanding of governance is contextual, with different levels of participation from stakeholders. Semi structured interviews is the best tool to represent this situation. It allows the researcher to fine tune his interview questions focussing specifically on the topic while also allowing him/her to dive deeper into the subject keeping the conversation on a fixed track.

Interview manuals have to be made in order to conduct interviews – one for officials representing government organisations, one for non governmental organisations and another for direct and indirect beneficiaries of lakes. The manuals include two parts - an introduction to the research and objective; and then the questions. They are focussed on performance of collective action of the involved stakeholders.

Using photographs, notes and video recordings, primary observations are also made on the 3 selected lakes – studying the water quality, quantity and physical environment.

3.4.2 Secondary Data Collection

Secondary data is collected through the study of policy and legislative measures in the form of reports from official organisations like the Karnataka Lake Conservation Development Authority (KLCDA) and Bruhat Bangalore Mahanagara Palike (BBMP). Other secondary sources are reports from Energy and Wetlands Research Group – IISc, Bangalore and Ashoka Trust for Research in Ecology and the Environment. The data collected as quantitative and qualitative categories. The physical sustainability of lake basins is analysed using quantitative data. Primary data is triangulated with secondary qualitative data to increase the interal validity of the research. Other secondary data sources include online newspapers, journals and articles.

3.5 Sample Size and Selection

There are no rules that determine the number of respondents to interview. However, Van Thiel (2014) maintains that a selection of units of study will have to be made as it is not possible to study all of the units in the research. These selected units are called samples. Sampling can be categorised as two main approaches, namely: Probability sampling and Non-probability sampling. Non-probability sampling has been identified as the sampling technique for this research. This method enables the researcher to make a deliberate choice of units of study, most appropriate to provide information on the subject of the study and reflecting a conscious research decision (Van Thiel, 2014). Especially because of constraints

in time for data collection, non probability sampling is best suited as it can ensure an admissible validity of the study through low number of respondents.
Out of the four different types of sampling methods, i.e quota sampling, purposive sampling, snow-balling and self selection, quota sampling is chosen for this research. The potential respondents are identified based on their level participation in lake basin management. The primary samples are chosen from the inhabitants living and working in the area who realise the lake being studied on a daily basis.

NO	RESPONDENTS	NO: OF RESPONDENTS
1	Direct user	5(per lake)
2	NGO/ Lake Trust representative	1(per lake)
3	BBMP representative	1
4	Expert from Environment Support group	1
5	Expert from United Way Bangalore	1
TOTAL NUMBER		21

Table 4: Respondents for semi structured interviews

3.6 Validity and Reliability

When it comes to non probability sampling, it is not possible to generalise the information and assume it is applicable for all lakes in Bangalore. However, the goal of the research is to give an idea and identify potential non-structural factors that affects sustainability of socio ecological systems, a subject not explored in the context of Bangalore. In the recent years, sustainability of lakes is usually analysed through the technical lens, this research will introduce a new outlook to the study of sustainable SES through a more qualitative lens, giving an understanding of interactions between institutional arrangements and sustainability of lake basins.

Internal reliability and validity is reinforced by the choice of semi structured interviews, which is triangulated with secondary data collected from sources mentioned in section 3.4.2. Clarity of questions and clean guidelines of the interview further increases reliability, minimising the possibility of socially accepted responses.

3.7 Data Analysis

Qualitative data analysis is done using Atlas Ti® Software. Atlas Ti can screen and examine numerous texts, interview transcripts, secondary research data and other notes all in the same portal. The documents are first coded on the software according to the identified indicators and finally interpreted and assigned causality through analysis by the researcher.

Chapter 4: Research Findings

4.1 Bangalore: City of Lakes

Bangalore lies in the south east part of Karnataka and covers 741 square kilometres. After independence, it earned the title of Silicon Valley because of the information technology boom (Environmental Management and Policy Research Institute, 2017) . The city experienced uncontrolled growth and lost its glory due to unplanned and thoughtless urbanisation (Ramachandra, et al., 2016). The land use analysis of greater Bangalore region from 1973 to projected growth in 2020 by Ramachandra et al., shows the uncontrolled urbanisation of the city below.

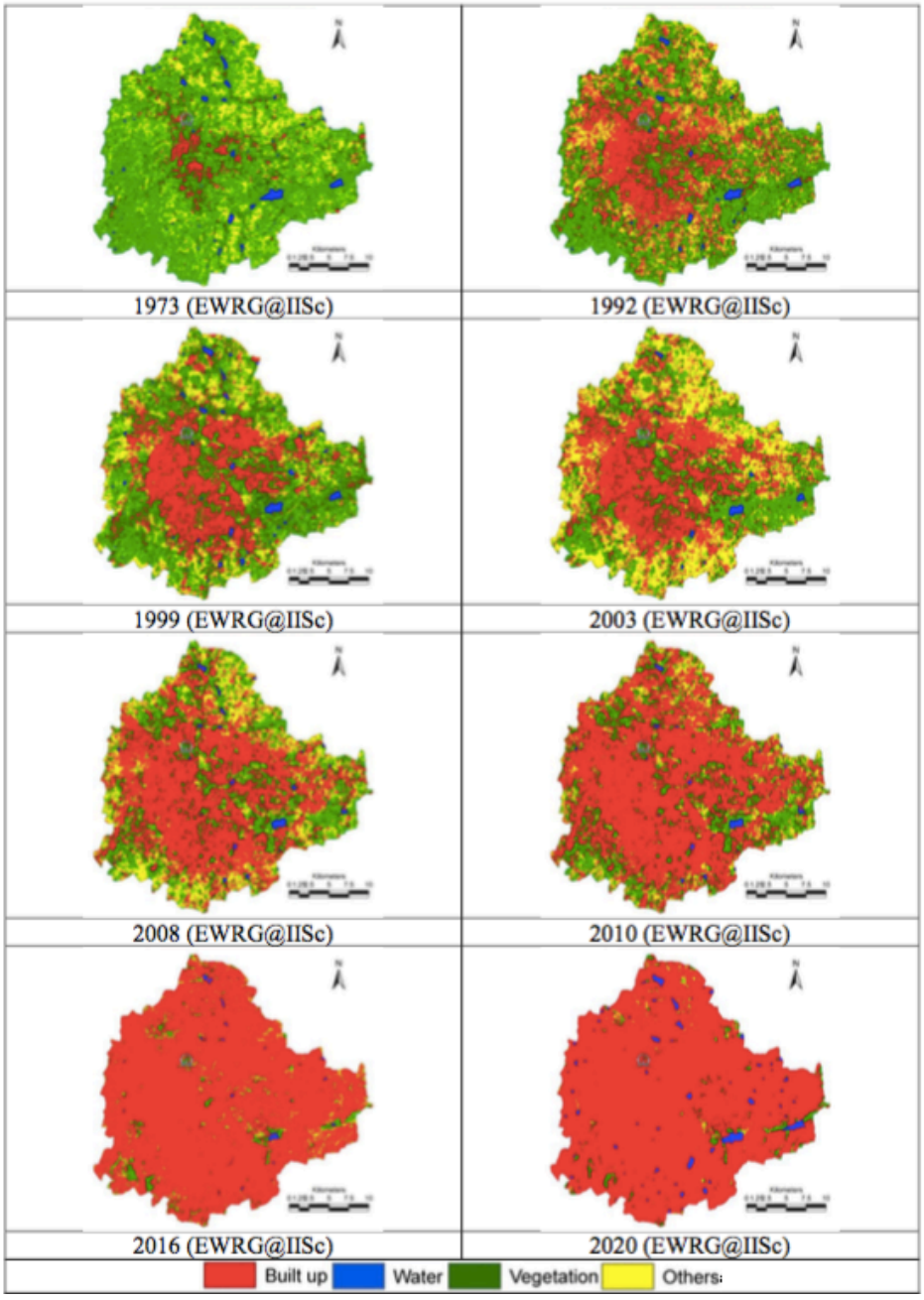

Figure 15:Landuse Analysis of Bangalore Region (Ramachandra, et al., 2016)

As per the 2011 census data, within BBMP limits, the decadal increase in population for Bangalore has increased from 5.8 million in 2001 to 8.4 million in 2011(Ramachandra, et al., 2016). Along with receiving an average rainfall of 800mm, the creation of connected lakes

was aided by the undulating terrain of Bangalore which varies from AMSL 700m to 962m (Ramachandra, et al., 2016). Flooded with 285 lakes in the early seventies, Bangalore was famous for being the 'city of lakes'. Lakes were engineered to be interconnected, so that excess water from one lake would flow into the other. These lakes would serve to recharge ground water, used for drinking, support agricultural activities and provide a habitat for fishes and ecosystems (Mundoli, Manjunatha and Nagendra, 2018a) .

4.2 Lakes and Water of Bangalore

The three tributaries of the Cauvery river, namely, the Arkavathi, the Shimsa carry water to it. Being located on the ridge, the geography of Bangalore forms 3 valleys – the Hebbal valley, the Koromangala-Challaghatta valley and the Vrishabhavati valley (Ramachandra, et al., 2016). The areas of the 3 valleys within the BBMP boundaries are as follows:

Koromangala-Challaghatta	255 square kilometres
Vrishabhavati valley	165 square kilometres
Hebbal valley	207 square kilometres

The drainage from K&C valley and the Hebbal valley joins the Pinakini tributary of the Cauvery and the drainage from Vishabhavati valley joins the Arkavathy tributary of the Cauvery.

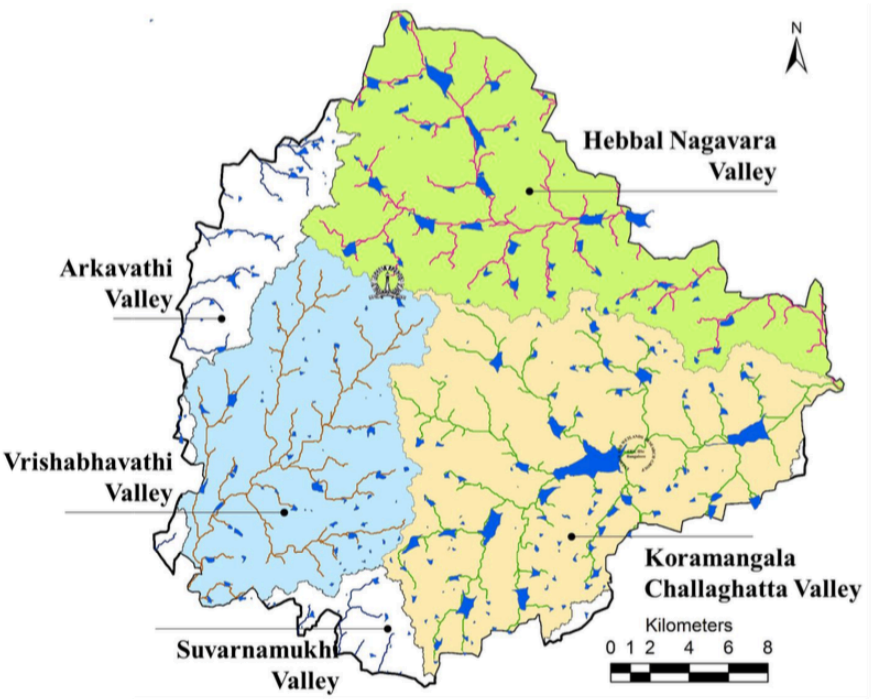

Figure 16:The three major valleys of Bangalore showing major lakes and rivers network (Ramachandra, et al., 2016)

Some aspects of the lakes of Bangalore as highlighted by Lele and Sengupta (2018) are as follows:

1. All the 285 lakes in Bangalore were man made reservoirs and did not occur naturally
2. The technology to construct bunds made of earth across two and three tier streams developed in Karnataka, Tamil Nadu and Andhra Pradesh. One reservoir overflowed

into the next through a canal called the ‘raj kaluve’ which were given official status to prevent encroachment to allow uninterrupted flow of storm water.

3. The third feature is that plenty of these lakes stopped finding their use in irrigation because of the reduction in agriculture as labour started being hired within the city leading to growth of large eucalyptus farms in the fringe areas and the emergence of the borewell technology to use groundwater for irrigation instead of reservoirs which resulted in drying up of lakes.
4. Lakes which were used for irrigation in Bangalore never functioned as ‘commons’ because they were only privately owned by landlords who used them for their personal agricultural uses. Washing and bathing were open to all but even fishing was historically allowed through paid licences.
5. Currently the lakes in the city find their use in recreation, aesthetics and conservation. This is because they are no longer used for irrigation and the drastic change in demographics of the population (comprised mostly of urban middle class) driven by the information technology wave. The result of these is a standard template for lake rejuvenation schemes by the government involving dredging, construction of bunds to prevent sewage inflow, making walkways and parks at the lake peripheries and islands in the middle to create secluded bird habitats (Mundoli, Manjunatha and Nagendra, 2018b)
6. The sixth aspect is the high level of citizen activism that has been seen around lake development recently. Some groups participate and initiate lake rejuvenation efforts with the government by either filing PIL’s or have been following up endlessly with officials.
7. Lastly the official arrangements, ownership status and regulations surrounding lake management and development activities are in constant flux.

4.3 History of Lakes and Water Crisis in Bangalore

Bangalore city has grown considerably since its inception in 1537AD. It was founded by Kempe Gowda who defined the extents of the city and constructed a fortified city within (called pette). The city has seen its share of several battles fought within its boundaries since then. From the Marathas and Mughals to the Britishers, all have contributed to Bangalores topography (Hasan 1970, Annaswamy 2003). During the independence of India, Bangalore was 69 sqkm with a population of 0.7 million (Sudhira et al. 2007) , now the city spreads over 741 sqkm with a population of 12.27 million in 2019. In the 1990’s the city saw the information technology boom resulting in a sudden expansion of the city. This expansion was pronounced by the reduction of green and open spaces especially in the peri urban areas which was one of the fundamental challenges for Bangalore’s environmental sustainability (Nagendra et al. 2012).

Centuries before the city was established, the communities of Karnataka were constructing tanks and understood the technology and the importance of managing them (Vatsala Iyengar, 2004). They connected the tanks in series such that one tank would flow into the other and became the source around which settlements grew. Historically, Kempegowda I and following rulers constructed the Sampangi, Karanji, Agrahara and the Dharmambudhi lake which supplied drinking water to the city (Mundoli, Manjunatha and Nagendra, 2018). When the British troops defeated Tippu Sultan in 1799, they were initially stationed in Srirangapatnam near Mysore and later moved to Bangalore making it their capital. This led to the establishment of the cantonment in Bangalore in the year 1809 (Natl. Arch. 1888a).

Several lakes were constructed during this period to meet the city's rising water needs – Sankey tank, the Millers tank series, the Shoolay and the Ulsoor lake were made between 1860 and 1890. Along with the previously constructed lakes these supplied water to the settlements in the cantonement (Natl. Arch. 1888a). However, records state that these sources of water were greatly affected because of poor rains in early 1880's (Mundoli, Manjunatha and Nagendra, 2018). By 1888 the Dharmamabudhi reservoir was completely dry and water from lakes in the north of the city like Sankey tank and Rachenahalli lake was diverted to fill the Dharmamabudhi reservoir (Mundoli, Manjunatha and Nagendra, 2018) .

However, these efforts were insufficient as the growing needs of the city were not being met by these lakes. As a solution, a reservoir was constructed over the Arkavathy river under the Chamarajendra Water Works banner. The water that was collected in this lake formed the Hessarghatta lake. Thus on August 7th, 1896 for the first time, treated water was started to be supplied to the pete and the cantonment (Natl. Arch. 1930, 1931). In just about ten years the Hessarghatta scheme started becoming insufficient for a growing city with growing water consumption. The population had also increased from 1,80,366 in 1896 to 2,37,496 by 1921. Water was rationed at 9 to 10 gallons per person per day.

A temporary measure was proposed in February 1926 to transfer water from the Y Chetty lake to Hebbal lake till a proper solution can be found (Mundoli, Manjunatha and Nagendra, 2018). While this project was being implemented, efforts were being made to make plans to reduce additional water use. The inflow of people into Bangalore needed a check and citizens were motivated to leave Bangalore till the water crisis was fixed (Natl. Arch. 1926c).

The Y Chetty lake started being filled with water from upstream lakes, making it an important source of water for the expanding city limits of Bangalore in 1926. The Hessarghatta lake with the Y Chetty lake contributed 3.5m gallons per day till the year 1933 (Rao 1961). The population of Bangalore kept increasing . In 1931 it was recorded as 3,06,470 (Natl. Arch. 1931). Water shortage kept becoming a repeated crisis in the city and it became necessary to find a more permanent solution.

This led to the formulation of 'The Thippagondanahalli scheme' (TG scheme) which proposed the construction of a dam on the Arkavathi river. This project increased the availability of water to 6 million gallons catering to 3 lakh people. Up until the Cauvery scheme was introduced in 1970, the TG scheme was the primary source of water for the city. The water from 'Cauvery Water Scheme' is 100 kilometres away and pumped up to the city with the capacity to provide 1350 million litres a day the entire population of Bangalore currently. But even today, shortage of water is experienced in the city and the demand is far ahead from the supply.

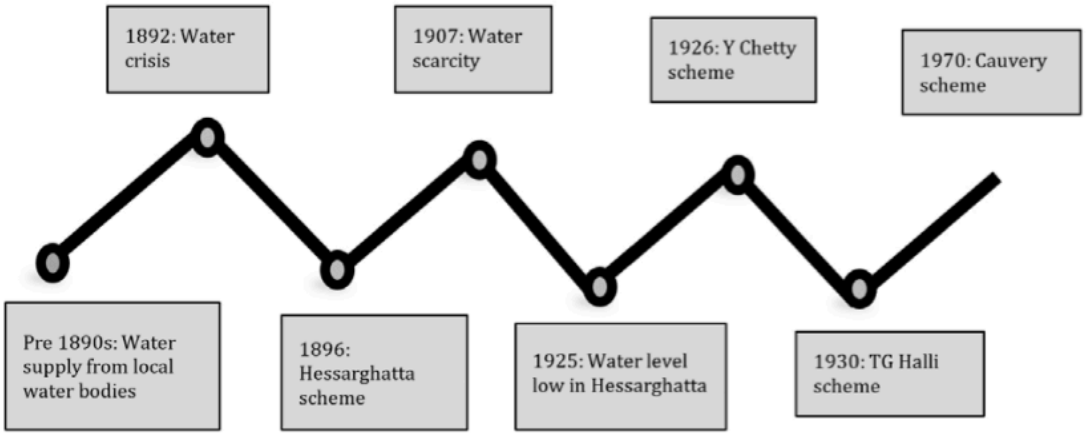

Figure 17:Broad Timeline of water crisis faced by Bangalore : 1800 to 1970 (Mundoli, Manjunatha and Nagendra, 2018)

4.4. Analysing Independent Variables - Using SES Framework to understand Institutional Arrangements

4.4.1. Control Variable - Government and Resource Policies (S4)

The constitution of the Lakshman Rau Committee in 1985, by the government of Karnataka was probably the first effort towards lake management. The recommendations of the committee to this day outlines the basis of all administrative and legal actions to be undertaken to conserve and restore lakes in Karnataka (Ramesh, 2017).

In 2002 the Karnataka government established the Lake Development Authority, mainly manned by the forest department. But almost as soon as they were formed they started inviting private players to develop lakes. 4 lakes were leased out in the public-private partnership model, which resulted in massive commercialisation within lake property – like food courts, hotels and water parks. These were 15 year leases given out at very low rents. However, the four selected lakes were already recently developed under the umbrella of National Lake Conservation Programme. The only requirement was maintenance and not development. This led to the complete opposite of lake restoration, because so much construction only reduced the water storage capacity.

To challenge this policy, a PIL was filed by ESG in 2008 to question the privatisation of lakes. The issue was that the privatisation model was not only illegal but also excluded communities and took away their right to access the lake. The court heard this petition at length and declared a stay order to any further privatisation. During this time, the LDA maintained that it was only through private participation that lakes could be managed. This complexity led the Karnataka high court to form a committee presided by Justice NK Patil, the judge of the high court with representatives from the 9 departments that were connected with lakes of Bangalore. The result was a detailed report called “Preservation of Lakes in the City of Bangalore”. This report directed the government to draft a scheme for “effective” administration of lake governance and conform with the Lakshman Rao Committee recommendations of 1988 and the principles of lake conservation by MoEF. This

report was accepted in March 2011 by the court. Dr M.K Ramesh (2017) highlights the detailed recommendations with importance on

- The involvement of community organisations,
- Declaration of no development zones around lakes,
- Conducting a survey of all lakes and raj kaluves
- Proposing fencing around lakes with indigenous plant species
- Restoring lakes with a plan to make them fit for drinking and swimming
- And most importantly trying to reclaim the title of "Land of Thousand Lakes" for Bangalore city

Beginning in 2008, as this case ran through 4 years, in 2012 the principal bench of the court was dissolved. A new bench was appointed and the PIL was petitioned to a new bench. The final hearing was in April 2012. The judgement overlooked the NK Patil report and allowed privatisation of lakes. But this judgement was based on a previous order by the high court WP No. 1841/2006 which holds the NK Patil report guidelines as binding. This has left the final judgement a bit confusing.

But the bureaucracy is so strong in the state that none of these orders are taken seriously. In 2014 the Citizens Action Group filed another PIL. They argued from the point of view based on Article 21 which guarantees a suitable clean environment to all citizens. Uncontrolled discharge of sewage into drains and encroachment had left the drains in a horrible condition depriving citizens of their basic rights. In the judgement in 2014, the high court then issued orders and made BBMP and BWSSB accountable to ensure all lakes are pollutant free, by stopping any sewage, effluents or industrial waste from being dumped into storm water drains. Along with this, an apex court was created to handle lake related issues. Another petition was filed in 2018 along with several others, as issues were raised against the 2014 order. There were still encroachments by residential projects on storm water drains. Alternate sewage lines were being made which were connected and emptied into lakes. In June 2019, a landmark judgement was issued. Although interim, this kind of order has not been passed in Karnataka at least. It looks upon the constitutional rights, that is right to environment and very importantly relied on Article 21 – the right to life. This right to life has been elaborated by the supreme court, not only as a right to live but also the right to clean environment. This has been further elaborated saying the natural resources, the lakes, rivers etc has to be protected by the state especially for future generations. The court drew upon the supreme courts previous decisions to impose that the state needs to protect lakes and sewers. NEERI a central government body has also been appointed to do a detailed study of lakes and suggest short and long term measures to protect lakes.

It must also be noted that there is an absence of policies with respect to preparing detailed project reports. So every lake that is being redeveloped is done using best practices from previous lakes without understanding whether those methods were successful or not. A standard DPR is being prepared for every lake without understanding the specific context of each lake.

4.4.2. Size of the resource system (RS3)

The detailed project reports by BBMP of the three lakes selected for the study record that the Puttenhalli lake is the smallest measuring 3.75 hecatres (9.26 acres), The Kowdenhalli lake measures 13.8 hecatres (34.1 acres) and the Kaggadaspura lake is 19.02 hectares (47 acres).

According to Nagendra et al., (2018) the lake size plays a significant role as a facilitator or barrier to restoration. Through the interviews and secondary data analysis it is observed that larger the lake size automatically affects the cost of restoration and maintenance. The cost of developing Kaggadaspura Lake proposed by BBMP is Rupees 135850000 (Bruhat Bengaluru Mahanagara Palike, 2018a) and the Puttenhalli lake according to Nupur Jain " was Rupees 10000000 for 3 phases of restoration". Compartiviely, the Kowdenhalli lake development costed Rupees 49625385.96 (Bruhat Bengaluru Mahanagara Palike, 2018). This also implies gathering financial assets to develop these lakes becomes tougher as the size increases. On the other hand it is seen that larger lake catchments make more social capital available for lake development efforts.

4.4.3. Operational Rules (GS5)

Research suggests that earlier, irrigation water for agriculture was given only to landowners who owned land with reservoirs , which occupied less than 20 percent of agricultural land in an entire village. These were owned mainly by the upper caste and rich who decided the rules for these water bodies (Lele and Sengupta, 2018b). These lakes could be freely used by everyone for domestic purposes but fishing rights were paid for (Lele and Sengupta, 2018b). From the interviews it can be stated that now the operational rules of most lakes are mainly created and enforced by government bodies but this top down approach is being challenged by lake trusts who are keen on being custodians of lakes themselves.

Puttenhalli lake: The PNLIT group maintains and operates the lake. No timings are maintained to access lake premises to allow the slum encroachers within the lake premises who have jobs as labourers in the city, enter and exit their houses without restrictions. Also keeping in mind access for students and teachers into the Puttenhalli high school. Separate bins are maintained for composting and other waste and feeding fish is not allowed for outsiders. Fishing operations are managed by the department of fisheries. During festivals, there is no separate tank provided for idol immersions as a conscious decision. One respondent is quoted saying ***"We never allowed a Kalyani, we are against festivals. It is a nuisance. So we put a drum full of water to immerse ganeshas. Another 2 drums are for flowers which we compost. Once the ganesha dissolves we just mix it with the mud."***

Kowdenhalli lake: The trustees of KR Puram Lake and Environment Trust maintain and operate the lake. Timing to access lake is maintained from 5am to 10am in the morning and 4:00pm to 6:00pm in the evenings after which the three gates are closed. To maintain and operate the lake, the trust also has a rule to collect Rupees 200 from every new member who joins the trust. This comes into question many a times by citizens who think that lakes are public and should be free. Banning bathing, bringing pets and cycling are other rules that are enforced in Kowdenhalli lake. Although they still allow a particular community to access the temple within the lake premises, which is centuries old and conduct their religious practices.

Kaggadaspura lake: Even though the lake park was built two years ago, the sewage diversion work and the project to clean up the lake is being implemented only now. Rasmita, a member of 'Save Kaggadaspura Lake' organisation says ***"We will start initiating operational rules only once the lake is filled and there is no sewage water being pumped into it".*** It was observed that because of the absence of rules, the weeds that have overgrown in the lake bed is being used for cattle grazing making it accessible. However a regular walker was quoted saying ***"It is a nuisance near our residential area because so many illegal activities are***

happening within these premises at night. The gates remain open throughout the day even though there is a fencing around and these activities can be controlled".

4.4.4. Number of Actors (A1)

Until the 20th century, till the colonial government took over the lakes, they were owned by local communities (Lele and Sengupta, 2018b). Post-independence, the minor irrigation department became managers and the Revenue department became owners of the lakes(Lele and Sengupta, 2018b) . The fisheries department has the right to auction the licenses to fish in the lakes. With peri urbanisation and as more water bodies started being included within city limits, the Bangalore Development Authority (BDA) became managers of some lakes, while others were transferred to the Karnataka State Forest Department and a few to the municipal corporations(Lele and Sengupta, 2018b). The Lake Development Authority (LDA) was established in 2002 but was dissolved soon as they started leasing out lakes to private companies. In response the Karnataka Lake Conservation Development Authority (KLCDA) was formed in 2012 with ownership of only 4 lakes but acting as a technical support system for other lake development efforts (Lele and Sengupta, 2018b). Slowly and recently the custody of most lakes in Bangalore is being transferred and collated with the Bruhat Bangalore Mahanagara Palike (BBMP). Of the 210 lakes in the city, BBMP currently has the responsibility of 168 lakes, 32 are with BDA, 9 with the state forest department and 1 with the Bangalore Metro Rail Corporation Limited.

Besides the actors representing the government, other actors in lake related activities include lake improvement trusts formed by citizens, legal and research advocacies like Environment Support Group, global NGO's like United Way and residents living in the lake catchment area. In the case of all 3 lakes, direct users are mainly walkers and joggers who use the lake premises for recreation and exercise.

Puttenhalli lake: The Puttenhalli lake has only 7 members as a part of the trust and 11 member volunteer group of women. But the population density around the catchment is 262 persons per hectare owing to the large multi-storeyed apartments in Puttenhalli. A small but a cohesive group of residents took up the challenge with the BBMP to revive the lake and became successful. Although the main trustees are few in number they receive plenty of support from actors like experts who advise on plant species and water quality, local residents who make voluntary contributions each year to the trust and corporates who direct their CSR funds for lake related activities. The 850 students and faculty of the Puttenhalli school within the lake premises are also stakeholders in this case. Here since the number of actors are large, but the lake size is small, the dependence on the lake is lesser as compared to the other two lakes.

Kowdenhalli lake: Incase of Kowdenhalli lake, the number of actors involved are the highest and dependence and social capital is also high in this case.. One respondent is quoted saying ***"Within our trust itself we have 480 members and 11 core team members who have always worked in unison".*** These members are lower and middle class residents and do not comprise the slum dwellers near the lake. Along with the members of the KR Puram Lake and Environment Trust, United Way which is an NGO that collects and diverts CSR funding from corporate companies towards lake redevelopment activities is a stakeholder at Kowdenhalli lake. They also mobilised 6000 to 7000 volunteers over the last 3 years from Wells Fargo. The population density is 178 persons per hectare in the catchment.

Kaggadaspura lake: Unlike the other lakes, here an informal group called 'Save Kaggadaspura Lake' is the only active group of residents fighting to restore the lake. Although the dependence on the lake is high here, it has the least number of actors participating with the lake group and this could be because of a lack of strong leadership and failed government promises every year. Rasmita Jain, founder of the 'Save Kaggadaspura Lakes Group' is quoted saying ***"we have 11 members in the group but actively only 4".***

4.4.5. Leadership/Entrepreneurship (A5)

Strong leadership is seen in Kowdenhalli and Puttenhalli lake. Both these lakes also show very strong collective action. Leadership is mainly in the form of one individual person in both cases who finally is able to mobilise a small cohesive group into action. These groups are first seen to interact informally and then establish themselves as a formalised network and distribute duties and take ownership of portfolios. In Puttenhalli lake it was Mrs Usha Rajagopalan who single handedly took the initiative and with the help of Ashwin Mahesh, enabled the lake redevelopment in two phases. She is the one who then gathered other residents to create the Puttenhalli Neighbourhood Lake Improvement Trust, who are now full custodians of the lake. In Kowdenhalli lake it was a similar process, A small group led by Mr Narayanappa first approached the BBMP and United Way to initiate the process of reviving the lake. United Way was then instrumental in bringing in other members to finally form the KR Puram Lake and Environment Protection Trust. Leadership seen in Kaggadaspura lake is weak. There is no one person leading efforts but a group of residents who are informally connected called 'Save Kaggadaspura Lake'. Apart from successfully organising awareness initiatives and protests, they have not been able to successfully lobby with the government and work in collaboration with them. Because of their informal nature, efforts taken are dependent on the availability of time and interest of these residents making it harder to hold someone accountable. It can be noted that strong leadership helps in networking with government, corporates and citizens along with influencing social capital.

4.4.6. Social Trust and Capital (A6)

Norms of social trust and capital are very high in Kowdenhalli lake, where connections have been retained with both the new urban working population and the older local residents in the area. Social capital is high owning to the high density of residents around Kowdenhalli lake. Social trust is also the highest in comparison to the 3 lakes. This is known through the interviews because the trust has 480 members who represent all levels of the socio economic hierarchy and different religions, age and income groups. Puttenhalli lake has high social capital, as it is surrounded by high end multi-storeyed apartments occupied by residents of high income group. Here, social capital enables collection of funds but was not found adequately represented in the trust group. Kaggadaspura lake has the lowest social capital with very low involvement from urban residents. It can be concluded that although relevant, it is not necessary that when the number of actors are high, social capital is also high. Strong leadership can enable high social capital , which in turn influences efficient networking, operations and monitoring activities.

4.4.7. Importance of the Resource (A8)

Originally, the lakes in Bangalore were created as a network such that water from upstream lakes overflowed and filled water in downstream lakes through canals. (Nagendra, 2010). These lakes were used for agriculture, drinking, fishing and domestic purposes. When water receded, lake beds were used for grazing cattle (Lele and Sengupta, 2018b). Lakes and adjacent wetlands were also used for fishing and immersion of idols during festivals (Nagendra, 2010). Being rainfed, the small and medium ones were seasonal while the larger lakes were perennial (Nagendra, 2010).

Harini Nagendra writes, "Since most lakes were seasonal, and pollution levels were low, it was easy to control siltation. The silt was extracted annually in the smaller lakes, and every few years from the large lakes in the dry season, for use by local communities as inputs into agriculture. These lakes also constituted important sacred spaces, and many important local religious festivals were initiated or concluded at local lakes." (Nagendra, 2010).

As the city started growing, most of the wetlands and agricultural areas around the lake started being converted to impervious concrete surfaces and these ecosystems found new purposes as bus stands and golf courses (Lele and Sengupta, 2018b).Precipitation of rainwater stopped and lakes started being filled with sewage and industrial waste reducing the quantity and quality of water in lakes. Currently, the major use of these lakes is recreation, aesthetics, and conservation (Nagendra, 2010).

Puttenhalli lake: Apart from being used for fishing, walking, recreation and exercise, the lake premises are used for plenty of educational activities. Activities for school students to teach them about different plant species, drip irrigation methods, rainwater harvesting and also the process of composting are conducted by the PNLIT trustees. A lot of science students come to take water samples for testing. Boards are provided to identify plants and also bird boards to educate people. Nupur Jain says that ***"This also helps us spread awareness about common methods people can use at home to contribute to the environment".***

Kowdenhalli lake: According to David Kumar, ***"It is mainly used for walking, jogging by around 300-400 people everyday. Weekends the numbers go to 800".*** Fishing tender is given to one person by ministry of fisheries. Besides that , several medicinal plants that are planted are plucked for by walkers without any restriction. Also through observation, the playground created is used by parents to bring their kids to play and elderly people and adults use the outdoor gym.

Kaggadaspura lake: Although the lake is filled with sewage water and outgrown with weeds, farmers bring their cattle to this lake for grazing. The lake park, like other lakes is used for walking, jogging, recreation and exercise. A temple in the premises is visited by devotees and the yoga centre receives atleast 80 students on a daily basis. Although there are no timings, the premises cannot be used beyond 6pm because of the problem of mosquitoes and snakes.

4.4.8. Networking Activities (I8)

Various types of networking activities are observed in these lakes. Kowdenhalli and Puttenhalli lake have shown the most successful networking with the government agencies,

corporate organisations, biodiversity experts and local residents. These two lakes have also been the most successful in terms of redevelopment efforts.
Puttenhalli lake: The PNLIT group are constantly working with the BBMP for lake development related works. They are connected with Indian Institute of Science for biodiversity and water related feedback and with SK Srinivas, an environmentalist who advises on water quality. A volunteer from the PNLIT is quoted saying ***"Corporate companies are also part of our network, especially by helping with volunteers and CSR funds. We first give them introductory sessions here at the gazebo, tell them the whole process and educate them before we use their volunteering help. We are also connected to other lake groups through various water conferences and seminars. We have also tied up with Earth watch institute. When they come here, we put up photos and write ups for them".***

Kowdenhalli lake: The network of KR Puram Lake and Environment Protection Trust includes continuous networking with government agencies. According to David Kumar from United Way, the trustees organise regular visits to the lake with BBMP officials to keep them updated with lake development works so in the future they can mobilise funds or resources easily. Other networks are with United Way Bangalore , who helped channel CSR money from corporates(in this case Wells Fargo) to Kowdenhalli lake restoration. United way becomes the single point of contact and along with funds helps mobilise the community and volunteers. They train the residents with knowledge about lake management, how to organise awareness initiatives and provide support with interactions with government and experts like 'Indus Herbs' (expert on plant species). All networks maintained by the trust are first established and mediated through United Way. Once they handover the lake, the members of the trust are expected to maintain these networks themselves.

Kaggadaspura lake: Least networking activities are seen when it comes to this lake. A local resident group called 'Save Kaggadaspura Lake' is pursuing the efforts to coordinate with the government and follow up on plans concerning rejuvenation of the lake. Parallelly they are also interacting with organisations like Environment Support Group and Citizens Action Group to understand the legalities. However, they have not gone further than this to register officially as a trust and be accountable as a group, which makes networking in their case more challenging.

4.4.9. Monitoring Activities (I9)

At the national level, prevention of water pollution by maintaining the biological, physical and chemical properties of water is encompassed in the Water Act of 1974 (Bal, 2013). Standards for water quality, marking the level of waste water discharge have been enlisted by Central Pollution Control Board (CPCB) , and finally at the state level the Karnataka State Pollution Control Board (KSPCB) is accountable for the quality of lake water while representing the CPCB (Bal, 2013). The lack of institutional mechanisms to monitor water pollution and impose hard fines on the polluters, makes the application of the standards challenging. Moreover, it is seen that in most cases the polluters and encroachers are mainly government agencies and taxing them becomes complicated(Bal, 2013).

However in the case of the Kowdenhalli and Puttenhalli lake, the local trusts who are custodians of the lakes have taken up the challenge of monitoring the water quality and premises. Puttenhalli lake water quality is done every three months and published on their website. These tests are usually managed with minimum costs from institutions like Indian

Institute of Science and BMS College of engineering. Lake premises are monitored by security personnel appointed by BBMP. BBMP provides 2 to 3 security and labourers per lake after they have been redeveloped as a part of their monitoring scheme, who make sure lake premises are kept clean and there are no illegal or untoward activities in the premises. No monitoring activities have been reported or observed in Kaggadaspura lake. It is seen that informal monitoring activities are driven when government policies have failed to be implemented. When the dependence on the resource is higher , strong social capital and high accountability through leadership enables better and effective monitoring efforts.

4.5. Analysing the Dependent Variable - Sustainability of the Resource System

4.5.1 Environment (E)

It is observed and documented that water in the lakes do not find much use for domestic purposes like washing and bathing like in earlier days. Wetlands around the lakes are no longer used for grazing. Most lake redevelopments now have standard improvement proposals. Within these infrastructure plans is to strengthen the bund, which involves paving the pathway for walking and jogging. According to Leo Saldhana from Environment Support Group, "***this design philosophy is very inefficient because concretising the pathways does not allow rain water precipitation and inturn does not recharge the ground water***". Earlier ground water in Bangalore used to be available at 150-200 feet now it has dipped to 1400 to 1600 feet. Jagannath Rao from BBMP claims that their lake development efforts will make ground water available at 300 to 400 feet. Saldhana also says that "***these bunds are reducing the actual area of the lake and water carrying capacity"***. Of the 3 lakes, Puttenhalli lake shows a more conscious effort to use water and materials efficiently. Dried leaves from trees are composted within the lake premises and the compost is used for further landscaping. Even extra materials like stone blocks or concrete pavers for infrastructure works are reused to create benches for sitting.

With respect to prevention of downstream pollution, the Karnataka State Pollution Control Board reports show that all 3 lakes have class E water with water quality index as unsatisfactory (Environmental Management and Policy Research Institute, 2017).

As per ISI-IS: 2296-1982	
Classification	**Type of use**
Class A	Drinking water source without conventional treatment but after disinfection
Class B	Outdoor bathing
Class C	Drinking water source with conventional treatment followed by disinfection
Class D	Fish culture and wild life propagation
Class E	Irrigation, industrial cooling or controlled waste disposal

Table 5: KSPCB standards, Source: (Environmental Management and Policy Research Institute, 2017)

This is because to utilise the complete lakes water carrying capacity, treated and sometimes untreated waste water is pumped into the lakes from the catchment. Overflow from these lakes results in pollution of water in the downstream lakes as well.

Environmental sustainability is evaluated through the quality of water in the lakes, which affects level of pollution downstream. The institutional variables that affect environmental sustainability of lake basins in Bangalore are understood to be Resource size (RS3), the control variable-governance and resource policies (S4) , networking activities (I8) and monitoring activities (I9), leadership (A5) and social capital and trust (A6). On one hand the interaction of these variables is not direct, they corelate in a very non linear pattern which finally defines the environmental outcome. On the other, the governance variable and economic sustainability directly affects the environmental sustainability. Based on water quality data from EMPRI, the Kowdenhalli lake has better water quality and is contributing least amongst the 3 lakes to downstream pollution. Although, the lake size is much bigger than Puttenhalli lake, its water quality is reported to be better. Kaggadaspura lake has the lowest quality of water (See Annex 3).

It is seen that stronger the collective action, stronger is the environmental sustainability. Leadership, guided networking and monitoring activities and was instrumental in mobilising local residents in both Kowdenhalli and Puttenhalli lake, which led to improvement in quality of water and turned the lake around from being a dumpyard to ones containing water inhabited by fish and other biodiversity. Networking with experts in Puttenhalli lake resulted in creation of artificial floating islands containing atleast 70 varieties of plants, the roots of which would purify the water and prevent pollution. A drastic improvement was observed in the water sample reports from 2016 to 2017. Associations of Kaggaspura area have only recently started networking with other activist groups and lake organisations and beginning to question government efforts so that they are directed towards improving water quality and not just beautification of lake premises.

4.5.2 Social (SO)

Access to urban lake and quality of service are chosen as a dimension to describe social sustainability in this research. The social sustainability of the 3 lakes is characterised as follows:
Puttenhalli lake: Local residents use the lake for walking, jogging and evening outings. Since the lake does not have any fixed timings and remains open, it also welcomes may delivery agents, courier service men and drivers who come and eat their lunch within the peaceful premises of the lake. The slum dwellers within the lake are also not restricted with respect to access, as they mostly have labour and vendor jobs outside. To make the lake more accessible, another gate has been provided on the south side for easy access by residents from L&T South city apartments. There is also enough parking provided outside the lake for visitors with vehicles like scooters, cycles or cars.

However access beyond the peripheral pathway and to the water is not permitted. The water cannot be used for any domestic or agricultural purpose. Fishing is permitted but only through a tender issued by Ministry of Fisheries. These rules have seen some resistance from the slum dwellers, who claim that this has been their home for the last 40 years and they should be allowed to use the lake for washing and bathing. Access to the lake for any religious ceremonies are not allowed even. The lake park does not have any other amenities like public toilets or children's play area besides a gazebo that serves as a place for small events and seating. This might change if the slum is cleared and the squatters are rehabilitated. The PNLIT group has filed a petition and waiting for orders to be passed.

Kowdenhalli lake: Kowdenhalli lake maintains lake park timings for access by users. This is to prevent any criminal or unlawful activities within lake premises at night or during afternoons when the lake is accessed by very few users. Like Puttenhalli lake, this lake is also used for walking, jogging, exercise and recreation. But in addition the premises supports an open gym, childrens play area and 2 public toilet blocks. These facilities makes the lake open to more users from various age groups and objectives. The quality of service is higher as compared to Puttenhalli lake. The access road to the lake is narrow and has space provided only for bike parking and not cars. This restricts some users from longer distances. The lake has been provided with 3 gates to allow ease of access. The use of water for domestic or other purposes in the lake is not permitted.

Kaggadaspura lake : Kaggadaspura lake has a lake park that was constructed two years ago, but the quality of water remains extremely poor and cannot be used. The lake park is used for jogging, walking and recreation. It also houses a play area , temple and yoga centre. According to one of the resident respondents ***"even though it is equipped with all amenities, the condition of the lake over grown with weeds attracts several snakes and mosquitoes making it unusable after 6pm***".

Originally, lake ecologies were socially highly sustainable. Water in lakes were freely used for drinking, washing and bathing. During monsoons, water overflowed into wetlands surrounding lakes which was for agriculture. When water levels began to retreat, these wetlands called 'gomalas' were used for grazing cattle by the community. During festivals, idols were immersed in lakes. Although the ownership rested with the feudal lords, the access to lake water was not restricted. The last few years has seen a strong decrease in social sustainability.

Where diversity of actors are high like in Kowdenhalli and Puttenhalli lake, there is least elimination of users and social capital(A6) is high with powerful leadership(A5). Decisions on setting operational rules(GS5) is seen to influence social sustainability. Access to lakes and satisfaction among users is moderate in both Puttenhalli and Kowdenhalli lake. Of the 5 direct users interviewed at Puttenhalli lake, 1 user who lives in the slum that is encroaching the lake property said that he feels "***insecure about whether he will have a roof over his head the next day***", as he fears eviction. The water in the lake is inaccessible to them for domestic purposes like washing and bathing. However, the other 4 users reported that they are completely satisfied with being able to use the lake park for recreation and exercise. One respondent pointed out that the solution to idol immersion during festivals is inadequate. Similarly in Kowdenhalli lake, access to the lake is controlled by maintaining lake timings. In the case of Kaggadaspura lake, barriers to social sustainability include inadequate implementation of policies by the government(G2), lack of strong leadership(A5) and few number of participating actors(A1). Considering all the landuse maps show a dense residential settlement around each of these lakes, it is essential lakes are able to cater to the users adequately.

4.5.3 Economic (EC)

Adequate investments towards lake development is essential for economic sustainability of lake basins. In this study of the 3 lakes, it has been seen that investments for development and maintenance of lakes are in the form of:

- Funds allocated from BBMP, and/or
- Funds from corporate companies as a part of their corporate social responsibility, and/or
- Voluntary donations collected from residents, and/or
- Maintenance fees collected from users of lake premises

Puttenhalli lake mobilised BBMP funding for redevelopment of about Rupees 1 crore for 3 phases. For maintenance of the lake they have an annual average budget of Rupees 10 lakhs to 15lakhs. From their auditing sheets of expenditure for the year 2018-2019, it is noted that their total maintenance expenditure was Rupees 11,93,833. This was financed by Deloitte CSR funds which contributed Rupees 10 lakhs and the rest from voluntary donations from local residents living in the area. Kowdenhalli lake was maintained under the shadow of United Way Bangalore, which is a mediating agency between lake trusts, government and corporates. They mobilised Rupees 25 lakhs from Wells Fargo each year for the past three years since they undertook the project. The KR puram Lake and Environment trust were themselves able to mobilise Rupees 2 crores from the MLA fund for the past 3 years. The total cost of the redevelopment was Rupees 5 crores. The Kaggadaspura lake redevelopment is estimated to be Rupees 13.58 crores. All the investment for this lake is intended to come from government funding as of now.

It is observed that lake size (RS3) becomes a barrier to economic sustainability. The larger the size of the lake the more expensive it is to restore, making it tougher to gather sufficient funds for development thus affecting the economic sustainability of lake basins. The restoration of Kaggadaspura lake, being the largest, is estimated at Rs 13.2 crores, Kowdenhalli lake was redeveloped at Rs 5 crores and Puttenhalli lake being the smallest was redeveloped at Rs 1 crore. The maintenance costs of the lakes are also seen to follow the same hierarchy.

Presence of strong leadership (A5) and networking (I8) has shown to facilitate economic sustainability of lakes. Both Kowdenhalli and Puttenhalli lakes have been redeveloped primarily because of a strong leader who has been able to successfully network and finally mobilise funds through those networks. For instance, Mrs Usha Rajagopalan took the initiative for Puttenhalli lake. Every year through her emails, she successfully manages to collect voluntary donations from residents. The PNLIT members are active in networking with corporate companies to mobilise their CSR funds. Similarly in Kowdenhalli lake, it was Mr Narayanappa who led the restoration process by first reaching out to BBMP and bringing in United Way to gather sufficient funds. Leadership and networking in Kaggadaspura lake the weakest. Residents have been following up with the government since 2016 but lack of an accountable group or individual is making it tougher to interact with and get clarity from the government on investments allocated. Lack of sufficient interaction with other lake organisations also makes this particular group less aware of the best practices followed in successful lake redevelopment projects, especially when it comes to mobilising funds.

Social capital and trust(A6) is highest in Kowdenhalli and moderate in Puttenhalli lake. Through the interviews, it is clear that residents, corporate investors and direct users of lake premises have shown continuous trust in the lake organisations (PNLIT and KR Puram Lake and Environment Trust) year after year. This has been a strong facilitator for economic sustainability. Whether through voluntary donations as in the case of Puttenhalli lake or willingness to pay a membership fee in Kowdenhalli lake, all actors have displayed high trust in these two lakes.

4.5.4 Governance (G)

Public participation and accountability are dimensions that define sustainability in terms of governance for urban lake resources.

Puttenhalli lake: Puttenhalli lake has seen active public participation from residents in the area. They formed the Puttenhalli Neighbourhood Lake Improvement Trust with 7 core members. After the lake was developed, they were given the responsibility of being custodians of the lake. They host several events to raise awareness like art competitions, 'kere habba' (lake festival), workshops on rainwater harvesting, composting and sharing knowledge on plant and bird species. They also attend conferences to learn from other lake groups and share knowledge. Networking is an important aspect of their philosophy. They also take complete accountability for upkeep of the lake and make all lake related information like annual reports, budgets and water quality freely available on their website to welcome more participation from locals .

Kowdenhalli lake: This lake has seen the maximum public participation. The KR Puram Lake and Environemnt Trust trust has 480 members and 11 core members. They have also seen maximum number of volunteers around 6000 of them from Wells Fargo, because of United Way Bangalore. Kowdenhalli lake also shows the maximum population density in the lake catchment. The trust has hosted several awareness initiatives, festivals, lake cleaning drives, childrens activities etc to gather more people in the group. The trust also displays high accountability for instance by voluntarily scheduling visits by BBMP officials to voice local requirements and lobby for future works.

Kaggadaspura lake: This lake has the least public participation and accountability. This could be because the presence of an informal resident association on social media is insufficient, unlike the other two lakes which are being led by formalised organisations.

Constitutional Provisions and applicable legislations in relation to Conservation of water Bodies include Inter-State Water Dispute Act of 1956,Environment Protection Act of 1986, Water Resources Planning Act of 1992, Water Act of 1974, River Boards Act of 1956, Central Ground Water Board Act of 1997,The National Environment Policy of 2004 and Central Board for the Prevention and Control of Water Pollution Rules of 1975. MoEF has been implementing the National Lake Conservation Plan of 2001 lake conservation.

At the state level there are again several acts to ensure lake protection like the Karnataka Irrigation Act of 1965, Karnataka Cauvery Basin Irrigation Protection Act of 1991, The state urban development authorities Act of 1987, The Karnataka Panchayat Raj Act of 1993 and The Karnataka Public Premises Act of 1974. These have directly or indirectly influenced lake restoration activities.

Right now there are many policies and frameworks that can guide development in Bangalore but there is a serious need to integrate them into one consolidated document. It is still unclear which policy or framework should be followed. Even with respect to preparation of detailed project reports there are no standard guidelines that should be followed for lake development.

Series of overlapping policies and change of government departments has affected the accountability for the present condition of lakes. Governance and resource policies (S4) and

Leadership (A5) is instrumental is stronger accountability. Participation is characterised by an integration of social capital (A6) , dependence (A8), Number of actors (A1) and Networking (I8) variables.

4.5.5 Assets (AT)

Human capital is measured through adequacy of training, learning and knowledge transfer. In both Puttenhalli and Kowdenhalli lake, trutees have said they have regular sessions to train new trustees about the process of lake management. Puttenhalli lake has been organising workshops for employees of corporate companies teaching about the process of lake management and creating an awareness about how critical it is to revive them. Trustees are also reported to conduct workshops for students from nearby schools on environment friendly methods to save the environment that can be practiced at home – eg, simple methods to harvest rainwater and home composting. Training in Kowdenhalli lake has been taken up by United Way. They have been training the trustees on lake management practices – for example: working with different government agencies, types of awareness initiatives to be conducted and how to mobilise the community. Kaggadaspura lake has seen knowledge transfer within a very closed network of residents only, but who are now slowly networking with other lake groups and attending workshops. There is potential for this exchange and knowledge transfer to gather pace as lake redevelopment work shows progress.

4.6 Relationship between Institutional Arrangements and Sustainability

This research reveals that the current institutional arrangements with respect to lake basins in Bangalore has become very weak over the past few years. Although the government is trying to change this status it has not shown any improvement. The objective of this study is to understand how these arrangements have affected the sustainability of lakes in the city. Ostrom herself says that the interactions between variables in her framework are non linear and are constantly affecting each other that establishing a direct casual relationship to them is challenging. However, this research tries to help understand the dynamics between the dependent and independent variables and identifying the weaknesses in the system and recommending possible opportunities for progress.

The role of and dependence on lakes has changed over time. Traditionally, lakes in Bangalore were seasonal and pollution levels were lesser and the silt was removed from lake beds and used by local communities in agriculture. Wetlands around lakes were used for grazing when there was no water and helped recharge groundwater when lakes were overflowed. Lakes were also places of worship and played a key role in religious festivals. But with urbanisation, use of lakes became restricted to recreation and exercise. They have also become social spaces and at most times the only connection with ‘nature’ in the city. Even now people expect to use these lakes for purposes that are religious but operational rules and pollution control policies restrict their use for religious significance, which is preventing pollution of lakes as they are not seasonal anymore. Although social sustainability in this regard is low, environmental sustainability is positively impacted because of operational and monitoring rules.

Earlier leadership was in the form of elite landowners who owned agricultural lands with tanks for irrigation. Nowadays, an individual takes the initiative and the leadership is slowly transferred to a group of people who establish a formal or an informal network with the government, other residents, experts and lake groups. Thus strong leadership is most likely

seen where collective action and social capital is the highest. Making decisions on how to operate lakes for better access and user satisfaction and extending networks with experts, to understand best practices, or other residents and corporates to collect funds and create awareness directly influences the 5 dimensions of sustainability. It should be noted that strong local leadership is one of the main reasons for likely success of lake basin sustainability in Bangalore.

Targeted networking is seen to be successful is asset building through several awareness and education programs and raising funds from corporate organisations and residents. Networking has also contributed to the environmental sustainability of the lake though consultation with biodiversity and lake experts. Awareness programs are helping with gathering volunteers for lake improvement activities. Successful networking with the government is seen to speeden things up on ground, holding authorities accountable for the lakes health.

Incompatibility between government policies and the local context has led to rapid urbanisation over the last few years, without concentrating on water resources. Lack of accountability and failure to implement lake protection policies has converted many of the wetland landscape into impermeable surfaces because of unchecked construction. This has led not only to tremendous decrease in ground water but also decrease in lake areas because of encroachments, resulting in unsatisfied residents.

Lake areas are being reduced by constructing lake parks, childrens play areas, pathways for walking and plantations with water hungry species. Restoration plans are not fully thought through. A few lakes that are restored is done without reviving upstream and downstream lakes in the series and neither treating the channels connecting them, thus taking the lakes back to their original polluted condition. These decisions are made by authorities without understanding local context and without involving local users of lake ecosystems, to understand their actual requirements.

Lake administration and policies has been in a state of constant change with the changing urban landscape of the city. Village communities who lived around lakes took the responsibility to manage them, along with maintaining the canals and bunds with financial support from kings. The roles and responsibilities were specific, adaptive and catered to the local context. Over time these were taken over by several government departments like the LDA, BBMP, BDA, Department of Fisheries, Ecology and Environment, Minor irrigation and KSPCB and at most times with overlapping administration. This complicated institutional distribution held no one department solely accountable for the health of lakes in the city. Only recently, the supreme court order from June 2019, directs BBMP to be custodians and taking charge of all lakes and established NEERI, a committee responsible for overlooking lake protection activities and checking compliance with existing regulations.

Although the NK Patil report and recent court orders were responses to petitions filed as public interest litigations by the citizens, on ground the situation is different. Government policies or officials have not given citizens the window to participate in decision making processes. Decisions at operational level is made by some active citizen groups, but still there are differences with the government in some areas of lake operations. Detailed project reports are being prepared by external consultants in a cookie cutter approach without following a standard guideline and has the same framework for all lakes. This has weakened the trust between the government and citizens affecting social capital. It must also be mentioned that

insufficient initiative to question and seek official information from residents is also seen. At a policy level, there is also a lack of capacity building initiatives and incentive for citizens to participate in lake restoration activities. Social capital is completely dependent on voluntary participation.

Historically, strong social capital enabled monitoring lakes and enforcing community rules for their protection. Nowadays, the sense of ownership towards water resources has disappeared and the government is failing to monitor locally because of illegal sanctioning of encroaching real estate developments on lakes and raj kaluves and the absence of a single accountable government body. All departments are constantly pushing the blame on each other without taking any responsibility. Monitoring of water quality in lakes is taken up by KSPCB but they do not test the water regularly and the weight of monitoring is also shifting to local lake trusts.

In conclusion, the interaction between independent variables from Ostroms framework and the dependent variable is dynamic. The independent variables also share a dynamic relationship with each other, for example: the level of economic sustainability directly impacts the environmental sustainability and leadership directly influences the social capital , networking and operational rules. Collective action comes out as a strong facilitator towards increased lake sustainability. This study highlights the barriers and facilitators towards lake basin sustainability in Bangalore and paints a picture of how institutional arrangements relate to it.

Chapter 5: Conclusions and recommendations

5.1. Research Objective

Within the broader goal of socio-ecological sustainability, the objective of this research is to analyse the interface between institutions and ecosystems on one hand and social systems on the other : where they conflict, transgress, converge, or reinforce each other. The objective is also to help policy makers solve collective action problems in the face of sustainability challenges.

5.2. What are the institutional arrangements with respect to lake basins in Bangalore?

Institutional arrangements with respect to lake basins in Bangalore traditionally involved local village communities managing lakes themselves based on trust and social capital. Lakes were usually owned by landlords with agricultural lands and specific families were given the responsibility to maintain lakes, bunds and canals. Permissions were given out for fishing but religious, washing and bathing activities were freely allowed for all. In time, an array government organisations replaced these local communities and took charge of lake management activities. The responsibilities were distributed across the Bangalore Development Authority, Fisheries department, the Karnataka Forest Department, the state pollution control board, Minor irrigation department, Lake development authority and Ecology and Environment department.

The Lakshman Rao committee was formed in 1983 as an answer to increasing citizen concern regarding the health of lakes in the city, which led to the handover of most lakes to the state forest department. The forest department surveyed and fenced many lakes but it didn't improve the condition of lakes. To further efforts, the lake development authority was set up in 2002. The LDA tried to involve private partners through PPP models in lake development but was faced with a lot of opposition from citizens, environmentalists and activists. Through filing public interest litigations, these groups managed to move the court to issue a stay order on privatization in 2008. The complicated nature of lake governance led the Karnataka government to form the NK Patil committee which drafted a report that outlined the way forward for lake restoration and protection in the city, it was accepted in 2011. This report was to be the umbrella framework guiding all lake protection efforts. The LDA was dissolved in 2012 and currently the management of most lakes in the city is being consolidated with BBMP along with BDA, the Forest department and Bangalore Metro Rail Corporation Limited. 168 lakes are managed by BBMP, 32 lakes by BDA, 9 lakes by forest department and 1 lake by BMRCL.

We can arrive at the conclusion that there has been a drastic change in institutional arrangements of lakes in Bangalore from lakes being managed by local community participation historically to a hierarchical system with the government is making decisions for the community without much bottom up feedback. Social capital has reduced which has affected collective action in the institutional regime. However this system is being challenged by citizen groups and there is possibility for it to change in the coming years. Currently, lake groups, where they exist are participating in networking activities to make their requirements heard, establishing non structural regulations like operational and monitoring rules, supporting awareness efforts and are being instrumental in mobilising funds. This is

promising phase when it comes to sustainability of lakes and if supported, can result in drastic changes in water conservation in the city.

5.3. How can lakes be categorised as common pool resources?

Common pool resources are those resources which have the characteristics of :

1. High excludability : It is very difficult to stop people from using and benefitting from the resource, and
2. High subtractability: When one individual benefits from a resource it reduces the availability of the same benefits for other individuals.

According to Ostrom, any natural or human made goods that cannot exclude users from benefitting from it are common pool resources. They are rival but difficult to exclude (Ostrom, Elinor, 1990). Appropriation is the act of consuming a common pool resource and the consumers are called "appropriators". Resource units make up common pool resources which appropriators extract from the resource systems. "Appropriators can exclude other appropriators from a resource unit that has been appropriated, but not from the resource system and other resource units" (Ostrom, et al., 1994).

Lakes in Bangalore exhibit the same characteristics as common pool resources. They share high excludability with public goods. Lakes in the city have traditionally belonged to the communities from adjacent villages and were maintained by them. Even now, they belong to the society and only managed by the BBMP. Owing to their public characteristics, it is difficult to exclude sections of society or individuals from using lake resources. For example, in Puttenhalli lake it is seen that even though there is a slum encroachment within lake property, access to the lake has to be provided throughout the day and cannot be restricted. Kowdenhalli lake is another example where operational rules established by the trustees (also appropriators) such as no washing or bathing in lakes, stops users from using the resource units but enjoying the lake (resource system) for natural beauty, recreation and exercise cannot be restricted.

Lakes form the resource system and an example of resource units are the fish in the lakes. High depletability is characteristic of lakes in Bangalore. Fishing tenders are given out only to one fisherman per lake. He extracts fish for his private consumption thereby reducing the availability for other users and also for birds who hunt fish for their food. Users of lakes in Bangalore are:

1. Spending sufficient energy and time to design a practical institutional framework to manage lakes, for instance in 2 out of 3 lakes studies there is sufficient contribution in terms of time and effort by citizens to pursue lake management efforts
2. Follow expensive regulations with knowledge that other users will follow them as well – for instance in Puttenhalli lake special separate bins are maintained for composting leaves and normal garbage. It is assumed that users will respect this rule and use the bins
3. Monitor each others adherence to these rules. By creating specific operational rules, lake trusts in Bangalore have been monitoring the lake premises and water quality.
4. Impose sanctions on each other at a cost to themselves – In Kowdenhalli lake for example, membership fee is collected by the trustees although this implies applying the same cost to themselves.

Based on theory, these establish lakes in Bangalore as commonpool resources.

5.4. What are the variables that facilitate or inhibit sustainability of lake basins in Bangalore?

Sustainability is looked at from the lens of environmental, economic, social, governance and assets approach.

Environmental sustainability which is evaluated by assessing the prevention of downstream pollution is affected by a multi-layered, non-linear interaction between the variables of the SES framework. Large resource size, lack of strong leadership which directly results in low social capital, weak networking and weak operational rules and monitoring efforts, have become barriers to environmental sustainability. In Bangalore, it is seen that social capital has the potential to mobilize citizens and networks with governments, experts and other lake organisations to negotiate successful restoration efforts. The control variables - demographic trends of Bangalore, unclear government policies and unclear allocation of responsibilities has also had negative environmental outcomes. All 3 lakes studied in this research have been categorised as class E as per CPCB standards and the quality of water still remains unhealthy because of the current management systems.

Access to lake services and level of satisfaction of users needs are dependent variables that are used to assess the social sustainability of lake basins. Social sustainability was much higher earlier. Traditionally, lakes were managed by communities and operational rules did not restrict use of lakes for domestic, religious and agricultural purposes. Nowadays, use of lakes is restricted only for recreation and exercise. Operational rules that are put in place mainly by lake protection trusts (only where they exist) are seen to directly influence social sustainability. Strong operational rules is a result of strong social capital and trust, which facilitates social sustainability. Networking with experts has also contributed to effective restoration measures which has been effective in improving user satisfaction. Failure to make lake protection policies that are coherent with the local context has resulted in uncontrollable construction leading to impervious surfaces thus resulting in decrease in ground water recharge. This leaves most citizens unsatisfied decreasing social sustainability year after year.

Economic sustainability is characterised by sufficient investments for lake restoration. Economic sustainability is low when it comes to lake basins in Bangalore. It is observed that lake size becomes a barrier to economic sustainability. Presence of strong leadership (by an individual or the government) and networking has shown to facilitate economic sustainability of lakes by enabling lake trusts and citizens to mobilise sufficient funds.

Understanding the dimension of sustainability through governance and assets are characterised by public participation, accountability and human capital. Social capital plays a very important influence on both governance and assets. The role of social capital in institutional arrangements has diminished over the years. Public participation has reduced drastically. Networking through awareness programs, conferences, training sessions, workshops and social media is being focussed on regaining social capital to improve public participation in lake management. They also have a potential impact on successfully building human capital by providing adequate transfer of knowledge to equip the society to pursue environmental issues. It must be noted that there are no policies favouring or incentivising participation. The size of the resource and inturn the dependence of people on them is also seen to facilitate public participation. Larger the size of the lake, greater is its contribution to ground water and higher is the dependence of residents on the lake. This aspect has pulled in

several citizens interested in lake management efforts , who are then eager to network with the government to find answers to the dilapidated state of lakes.

Unclear government policies and a constantly transitioning governance regime has resulted in the lack of accountability of government bodies towards lake management. Presence of strong leadership positively affects accountability of groups in custody of whom lakes are managed. Since knowledge transfer is still not adequate enough and the absence of sufficient trust between direct and indirect users, the present governance regime is curbed to make sustainable changes to lakes.

5.5. Main research question: How is the sustainability of lake basins being influenced by institutional arrangements in Bangalore?

Inadequate urban water regulation has been the outcome of change in landuse in Bangalore. Lake redevelopment efforts are piece meal. Lakes are being revived at random, based on political intent and interest from residents. Upstream and downstream lakes in series are sometimes left untouched which has been resulting in pollution of developed lakes taking efforts back to square one.

To ensure sustainability of lake basins in Bangalore, existing encroachments need to be cleared, choked inlets and outlets have to be cleaned and discharge of sewage and industrial waste into lakes have to be stopped. In most cases, diversion of sewage lines and desilting lake beds is necessary. These structural changes have to be made at the government and policy level. Although in Bangalore, it is evident that currently there is intent to restore most lakes, there is a gap in understanding the context of each lake and the specific local requirements. Another factor is, considering most lake custody is being consolidated with the BBMP, it is reported that the department is stretched thin from an internal human resource allocation point of view, where lake development is not the only portfolio of works being handled by the department. A number of citizen activist groups are working to collaborate with authorities but the system is currently inefficient and inadequate not covering all lakes in the city. Capacity building and transferring knowledge to include and encourage more participation is also limited.

Public interest litigations are being filed by these citizen groups to raise issues of ineffective monitoring efforts, illegal sanctioning to encroachers and inefficient spending of allocated funds. These issues have redued ‘natural’ open spaces for the city and increased the amount of impervious surface leading to ground water shortage and leaving users completely dissatisfied. Detailed project reports for lake rejuvenation plans by the government , in this case the BBMP, is outsourced to external consultants who follow a cookie cutter approach and make similar plans for every lake without getting a grip of local situations.

Networking by lake groups with biodiversity experts, research organisations and technical experts like architects and designers has been successful and positively influencing sustainability. However it must be noted that there is still a long way to go to ensure downward accountability. Currently the system follows a top down approach and because it has been in a state of constant flux, upward accountability is insufficient. Economic costs for lake restoration are still being born by people and not the polluters and encroachers. Funds for lake development is still highly dependent on voluntary donations or active networking by mediating organisations like United Way with corporate companies for their CSR funds.

Strong leadership is influencing exercise of operational and management rules to improve environmental outcome but at the same time restricting access to lake water.

It is necessary to also conclude on the influence of institutional arrangements on social capital. The evolution of institutions has degraded social capital over time. Lakes saw plenty of participation initially but over time, social capital has decreased. Since the dependence on lakes has reduced in the city, social capital relies on voluntary time and effort by residents, who are at most times busy with their own routines. This decrease has negatively affected degree of collective action and the robustness of the governance regime and limited its capacity to maintain lakes sustainably.

These are the reasons why lake basin sustainability has decreased drastically over the years. The relationship between institutional arrangements and sustainability is dynamic and they keep having alternate influences on each other. Based on research on ground it is seen that the following networks develop when we talk about institutional influence on sustainability:

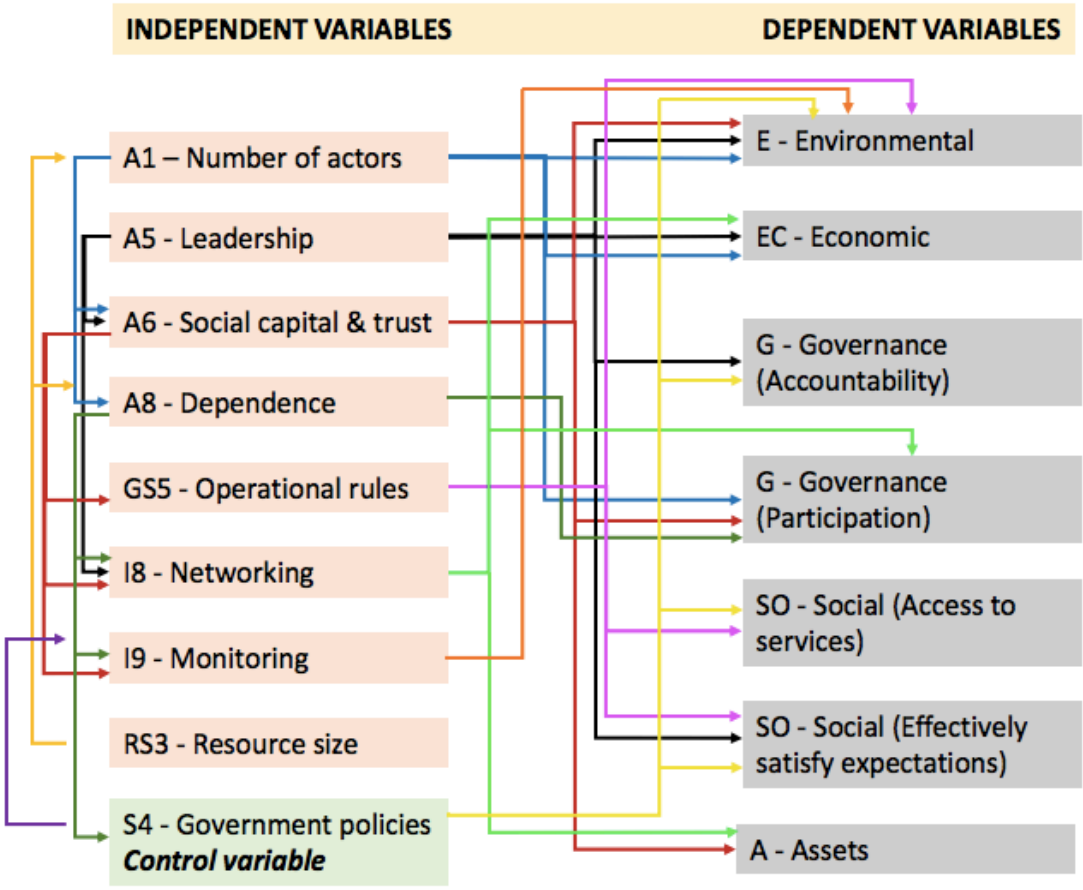

Figure 18: Illustration of the Interactions between Institutional Arrangements and Sustainability Variables

5.6. Recommendations

Inclusive and participatory approach to lake management has been side-lined up until now in the urban context by policymakers and urban planners especially in rapidly developing cities like Bangalore (Mukhija, 2005; Colding, Lundberg and Folke, 2006; Ananda, Crase and Pagan, 2006). Transaction costs can be lowered by involving local residents in the process of designing restoration plans for lakes while bringing in local contextual requirements (Colding et al. 2006). Structural needs like desilting, dredging, bund creation, construction of STPs, diversion of sewage lines and providing manpower should be taken up by the government. Non-structural responsibilities like enforcing rules and regulations for lake premises and coordination with various stakeholders can be transferred to the community (Colding et al. 2006).However, this should not be expected as a voluntary contribution of time and efforts. Government regimes should incentivise this approach for example: providing opportunities to include active participants (especially the ones taking leadership and ownership) in the decision making council as a part of the formal institutional arrangement or supplementing efforts through monetary incentives like tax rebates or even standard annual salaries through contractual agreements.

Participative approaches will ease the pressure from BBMP who are already understaffed. Allowing further independence to strong lake trusts like ESG and PLNIT in decision making will also enable upward accountability. Top down accountability can be enhanced by also increasing incentives for local government officials who coordinate with the community for lake development efforts. Incorporating methods like bottom up feedback mechanisms and using social media to publicise their efforts (which will help increase their vote bank in future elections) are some approaches that can be put in place. Using technology by creation of mobile applications for grievance redressal and updates on their settlements can also be incorporated.

Government supported workshops and training programs will help transfer knowledge and create awareness towards lake improvement methods and current efforts. It is critical for various lake organisations to exchange information and learn from best practise. Using existing PIL's to fight causes instead of filing new litigations will speeden things up from the courts point of view.

This study gives a comprehensive understanding on the usefulness of the SES framework in analysing the interactions between variables that impact collective action and environmental outcome. To get a deeper understanding of this, we select more lakes in the city and analyse them using all of the variables proposed in the SES framework. But respecting the scope of the study and the time constraints, this thesis has tried to bring to light the influence of institutional regime on sustainability of lake basins in Bangalore in an extensive way.

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Annex 1: Research Instruments

Interview Guidelines for Organisations

Introduction

My name is Noireeta Chowdhury. I am currently pursuing my masters in Institute of Housing and Urban Development Studies, Erasmus University Rotterdam. The interview will be used to guide my analysis on the research titled "Analysing the Influence of Institutional Arrangements on the Sustainability of Lake Basins in Bangalore" and will be used only for academic work.

Date and Time of the Interview:

Respondent:

- Name: Noireeta Chowdhury
- Email: noireetachowdhury5@gmail.com
- Institution: IHS, Institute for Housing and Urban Development Studies, Erasmus University Rotterdam

Questions

1. What is the dependence on the lake by various users?
2. Who has taken the lead in the lake rejuvenation? What was the process involved?
3. How many members are involved with the organisation ? Is there clarity on who takes the responsibility for various functions of lake management?
4. What is the cost of developing and maintaining a lake? What are the sources of funding for lake management?
5. Do you'll collaborate in modifying the rules with the government? If yes, how? Do the current set of rules take into consideration your requirements?
6. In your experience, can you identify the type of formal and informal networks in the management of the lake? How do you build the network?
7. When it comes to operational rules, how are they implemented? Is there any integrated monitoring plan for lakes?
8. How is the quality of water maintained?
9. Are there any limiting factors that hinders lake management?
10. What role does your organisation play in lake management?
11. How do you ll cope with uncertainty – eg while removing encroachments, or excess sewage inflow a particular year?

Interview Guidelines for Government

Introduction

My name is Noireeta Chowdhury. I am currently pursuing my masters in Institute of Housing and Urban Development Studies, Erasmus University Rotterdam. The interview will be used to guide my analysis on the research titled "Analysing the Influence of Institutional Arrangements on the Sustainability of Lake Basins in Bangalore" and will be used only for academic work.

Date and Time of the Interview:

Respondent:

- Name: Noireeta Chowdhury
- Email: noireetachowdhury5@gmail.com
- Institution: IHS, Institute for Housing and Urban Development Studies, Erasmus University Rotterdam

Questions:

1. What is the size of the lake and catchment ?
2. What is the lake used for currently?
3. Do you have the Detailed project report for the lake redevelopment?
4. What is the cost of developing and maintaining the lake? How are funds allocated for lake development and how are they utilised?
5. Do the residents participate in modifying the rules? If yes, how do they participate and what is their level of interaction with you ?
6. Do you ll work with NGO's and private companies for lake development?
7. What kind of operational and monitoring rules exist for lake management?
8. How do the polluters or encroachers pay for going against rules?
9. What are the various regulatory frameworks and environmental policies for lakes in Bangalore (at national level and city level)? How do you ensure compliance with the regulations?
10. Classification of the lake and physical condition ?
11. What are the measures taken to improve lake water quality and prevent pollution?
12. What is the use of the particular lake in question? If used for fishing then how many tenders are allocated? If industrial effluents are dumped, how are they regulated and monitored?
13. Are there any existing guidelines for lake redevelopment in Bangalore?
14. What are the kind of networks are present in the process of lake management?
15. Are there any limiting factors that hinders lake management?

Interview Guidelines for Users

Introduction

My name is Noireeta Chowdhury. I am currently pursuing my masters in Institute of Housing and Urban Development Studies, Erasmus University Rotterdam. The interview will be used to guide my analysis on the research titled "Analysing the Influence of Institutional Arrangements on the Sustainability of Lake Basins in Bangalore" and will be used only for academic work.

Date and Time of the Interview: Respondent:

- Name: Noireeta Chowdhury
- Email: noireetachowdhury5@gmail.com
- Institution: IHS, Institute for Housing and Urban Development Studies, Erasmus University Rotterdam

Questions:

1. How often do you visit the lake and of what importance is it to you?
2. Are you aware of who is responsible for the lake protection efforts ?
3. Are you part of any resident associations or groups involved in lake activism?
4. Do the interventions incorporate your requirements?
5. Have you ever participated in changing the existing rules?
6. Is there anything that limits your water consumption or use of the lake?
7. How are you involved in the process of lake management? Are you willing to volunteer or participate with either the local trust or individually?
8. Are you satisfied by the restoration of the lake?

Annex 2: Reasons for Variable Selection from SES framework

Code	Variable	Applicability	Reason
S	**Socio Economic and political settings**		
S1	Economic development	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
S2	Demographic trends	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
S3	Political stability	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
S4	Other governance system - Governance and resource policies	YES	This variable is used as a control variable. Although there is no variation across the 3 lakes, it is still an importat aspect of institutional arrangements as it has impacted lake sustainability over the years in the city
S5	Markets	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
S6	Media organizations	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
S7	Technology	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
ECO	**Related Ecosystems**		
ECO1	Climate patterns	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
ECO2	Pollution patterns	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
ECO3	Flows into and outof focal SES	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes

RS	**Resource Systems**		
RS1	Sector (e.g., water,forests, pasture, fish)	NO	All lakes fall in the same sector
RS2	Clarity of system boundaries	NO	
RS3	Size of resource system	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009); Sizes of the 3 lakes vary considerably; Lake size is identifies as an important aspect in consideration with productivity, ecological condition in the contextual research area and locatio of the lake, either downstream or upstream (Nagendra et al. 2012).
RS4	Human-constructed facilities	NO	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009); but can be directly linked to variable resource size RS3 (Nagendra et al. 2012) , which is already included
RS5	Productivity of the system	NO	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009); but can be directly linked to variable resource size RS3 (Nagendra et al. 2012) , which is already included
RS6	Equilibrium properties	NO	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009); but can be directly linked to variable resource size RS3 (Nagendra et al. 2012) , which is already included
RS7	Predictability of system dynamics	NO	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009); but can be directly linked to variable resource size RS3 (Nagendra et al. 2012) , which is already included
RS8	Storage characteristics	NO	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009); but can be directly linked to variable resource size RS3 (Nagendra et al. 2012) , which is already included

RS9	Location	NO	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009); The factor that characterises location is whether the lake is situated upstream or downstream;but can be directly linked to variable resource size RS3 (Nagendra et al. 2012) , which is already included
RU	**Resource Units**		
RU1	Resource unit mobility	NO	In Bangalore lake management does not takeinto consideration resource units, thus RU sub variables are not included for this analysis
RU2	Growth or replacement rate	NO	In Bangalore lake management does not takeinto consideration resource units, thus RU sub variables are not included for this analysis
RU3	Interaction between resource units	NO	In Bangalore lake management does not takeinto consideration resource units, thus RU sub variables are not included for this analysis
RU4	Economic value	NO	In Bangalore lake management does not takeinto consideration resource units, thus RU sub variables are not included for this analysis
RU5	Number of units	NO	In Bangalore lake management does not takeinto consideration resource units, thus RU sub variables are not included for this analysis
RU6	Distinctive characteristics	NO	In Bangalore lake management does not takeinto consideration resource units, thus RU sub variables are not included for this analysis
RU7	Spatial or temporal distribution	NO	In Bangalore lake management does not takeinto consideration resource units, thus RU sub variables are not included for this analysis
A	**Actors**		
A1	Number of relevant actors	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009)

A2	Socioeconomic attributes	NO	Surroundings of all 3 lakes has been gentrified especially because of the IT boom. The mix of residents that live in the study area is similar to all 3 lakes
A3	History or past experiences	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
A4	Location	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
A5	Leadership	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009)
A6	Social capital and tust	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009)
A7	Knowledge of SES/ mental models	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
A8	Importance of resource (dependence)	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009)
A9	Technologies available	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
GS	**Governance Systems**		
GS1	Government organizations	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
GS2	Nongovernmental organizations	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
GS3	Network structure	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
GS4	Property-rights systems	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
GS5	Operational-choice rules	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009), operational

			rules are different across the 3 lakes in the city
GS6	Collective-choice rules	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
GS7	Constitutional- choice rules	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
GS8	Monitoring and sanctioning rules	NO	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009),however there is no official rules in places for lake management in the city
I	**Interactions**		
I1	Harvesting	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
I2	Information sharing	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
I3	Deliberation	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
I4	Conflicts	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
I5	Investment activities	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
I6	Lobbying activities	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
I7	Self-organizing activities	NO	No distinct variation is observed in reconnaissance survey across the 3 selected lakes
I8	Networking activities	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009), There are several types of networking activities observed in all 3 cases with the government, experts , corporates and citizes

I9	Monitoring activities	YES	Observed as a critical variable determining collective action and environmental sustainability by Ostrom (2009), Presence of different forms of informal monitoring is seen in the lakes studied
I10	Evaluative activities	NO	No evaluative activities take place in lake management in Bangalore
O	**Outcomes**		
O1	Social performance measures	NO	Social outcomes are addressed in the dependent variable to avoid overlap
O2	Ecological performance measures	NO	Environmental outcome is addressed in the dependent variable to avoid overlap
O3	Externalities to other SESs	NO	The institutional arrangements are analysed from the perspective of collective action , therefore externlities are not considered

Annex 3: Survey of Lakes in this Study by EMPRI

EMPRI Cartography for Puttenahalli *Kere*

Disclaimer:

- Lake Cartography is for visual purpose only, which describes the features at the time of visit and not to scale.
- Encroachment of lake is only indicative. It needs to be verified with Department of Survey Settlement and Land Records (SSLR), Government of Karnataka.
- This is put out for general information of public at large, so the information is not usable to determine any boundary. Accordingly, the map information is indicative & user shall oneself verify as per prescribed legal procedure the actual boundaries of the survey number. No claim based on this information shall be entertained by the Government or any of its Departments.
- This information is for indicative purpose and is not usable for any legal purposes. Any use by anyone shall be at their own risk and cost.

EMPRI

Lake Name: Puttenahalli *Kere* **Date of Visit:** 20.01.2016

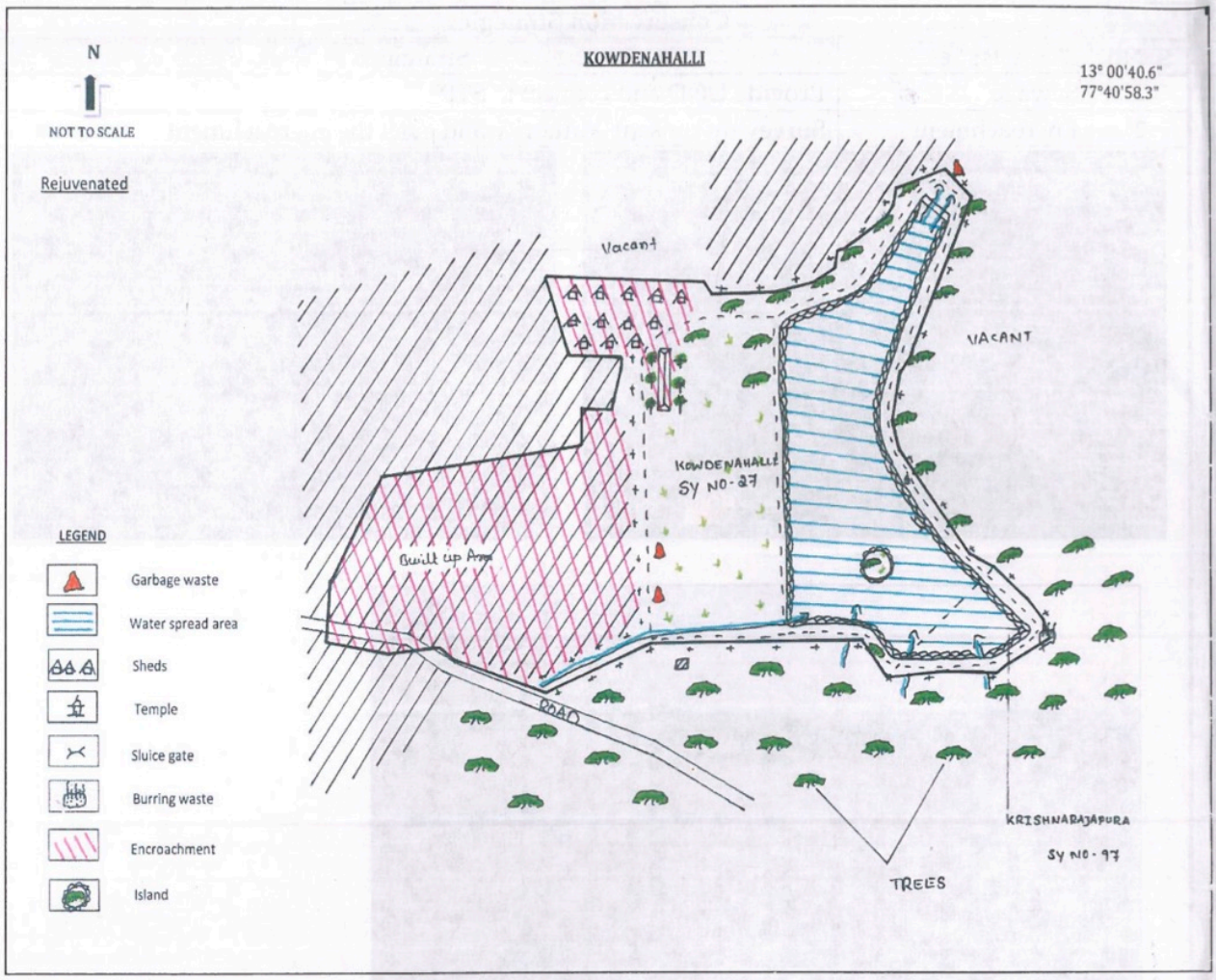
BASIC INFORMATION				
Other Name : Nil	**EMPRI Code** : BUBSUHput_kr1-1358			**Maximum Depth** (m) : 3
District Name: Bengaluru Urban	**MI Tank Reg. No.** : Nil			
Taluk Name : Bengaluru South	**Year of Creation** : ≈ 1904			**Geographical Coordinates**
Hobli Name : Uttarahalli	**Year of Rejuvenation** : 2014-15			**Lat.** 12°53'29.4" **N**
Village Name	**Survey No.**	**Extent Area (A-G)**	**Source**	**Long.** 77°35'09.4" **E**
Puttenahalli	42	13.25	RTC	**Preservation Authority**
Total Extent (A-G)		**13.25**	-	BBMP

MORPHOLOGY	WATER QUALITY	Inlet	Outlet	HYDROLOGY
Elevation (m) : 911	**Temperature** (°C)	24.4	23.4	**Status** : Clean
Inlet Drain : 5	**pH**	7.9	7.8	**Type** : Seasonal
Waste weir : 1	**Conductivity** (µS/cm)	572	567	**Source of water** : Rain & drain fed
Sluice gate : No	**Transparency** (m)	0.31	0.52	**Upstream water body** : Nil
Fence : Mesh	**TSS** (mg/l)	20	8	
	TDS (mg/l)	460	480	
	Turbidity (NTU)	22	16	**Downstream water body** : Sarrki *Kere*
Culverts : Nil	**DO** (mg/l)	8.4	2.1	
Check dam : Nil	**BOD** (mg/l)	180	7.7	
Road : 3	**COD** (mg/l)	456	24	
Surrounding Area: Agriculture, Settlement & Plantation	**Nitrate** (mg/l)	17	14	**Nature of Catchment** : Urban
	Phosphate (mg/l)	ND	ND	
	Total Coliform (MPN/100ml)	30	170	
	Water Class	D	E	ND is Not Detected

BIOTIC DATA	SOCIO-ECONOMIC VALUE
Vegetation Cover : Partially	**Drinking Water** : Not Observed
Vegetation Type : Growing on bank.	**Washing** : Not Observed
Aquatic Flora : Emergent, Submerged & R. Floating	**Bathing** : Not Observed
Fauna : Birds, Butterfly & Dragonflies	**Livestock Management** : Not Observed
	Irrigation : Not Observed
	Fishing : Not Observed
Amphibian : Not Observed	**Cultural Activities** : Not Observed
Reptile : Not Observed	**Recreational Activity** : Not Observed
Mammals : Not Observed	**Others Uses** : Park Maintenance

THREATS	
Direct Point Source Pollutants	: Dumping of Garbage wastes & Construction Debris
Indirect Point Source Pollutants	: Nil
Quantity of Sewage Inflow (Cumecs)	: No
Encroachment	: House & Road (4%)
Soil Excavation	: No
Weeds	: Partial

EMPRI Cartography for Kowdenahalli *Kere*



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EMPRI

Lake Name: Kowdenahalli *Kere* **Date of Visit:** 12.01.2016

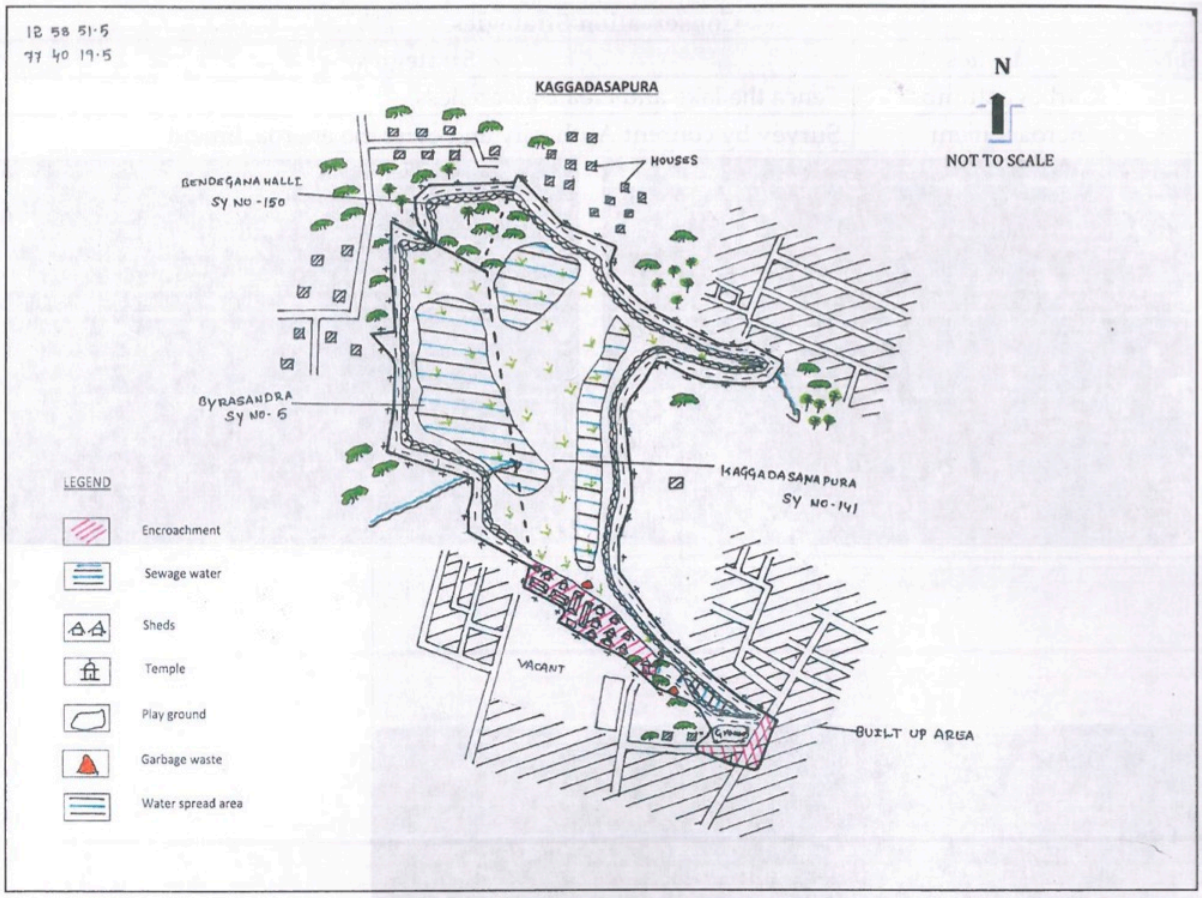
BASIC INFORMATION				
Other Name: Nil		**EMPRI Code:**BUBEKRkwd_kr1-716		**Maximum Depth** (m): 3
District Name: Bengaluru Urban		**MI Tank Reg. No.:** Nil		
Taluk Name: Bengaluru East		**Year of Creation:** ≈ 1958		**Geographical Coordinates**
Hobli Name: Krishnarajapuram		**Year of Rejuvenation** :2010		**Lat.:**13° 00' 40.6" N
Village Name	**Survey No.**	**Extent Area (A-G)**	**Source**	**Long.:**77°40' 58.3"E
Kowdenahalli	27/*,27/p1	65.05	RTC	**Preservation Authority**
Krishnarajapura	97	2.34	RTC	
Total Extent (A-G)		**67.39**	-	BBMP

MORPHOLOGY	WATER QUALITY	INLET	OUTLET	HYDROLOGY
Elevation(m) :904	**Temperature** (°C)	22.8	23.6	**Status** : Clear water
Inlet Drain :3	**pH**	8.8	8.8	**Type** : Seasonal
Waste weir :1	**Conductivity** (µS/cm)	560	548	**Source of water** : Rain &Drain
Sluice gate :1	**Transparency** (m)	0.17	0.23	**Upstream water body:**
Fence: Wall & Mesh	**TSS** (mg/l)	40	22	Vijinapura *Kere2*
	TDS (mg/l)	360	380	
	Turbidity (NTU)	32	18	**Downstream water body:**
Culverts :Nil	**DO** (mg/l)	5.2	7.4	K R Puram lake
Check dam :Nil	**BOD** (mg/l)	20.9	24.76	
Road : 2	**COD** (mg/l)	144	128	
Surrounding Area:	**TKN** (mg/l)	28	32	**Nature of Catchment** : Urban
Vacant land & Houses	**Total Phosphate** (mg/l)	ND	ND	ND is for Not Detected
	Total Coliform (MPN/100ml)	34	140	
	Water Class	> E	> E	

BIOTIC DATA		SOCIO-ECONOMIC VALUE	
Vegetation Cover	: Partial	**Drinking Water**	: Not Observed
Vegetation Type	: Growing on Bank	**Washing**	: Not Observed
Aquatic Flora	:Emergent	**Bathing**	: Not Observed
Fauna	: Birds & Fish	**Livestock Management**	: Not Observed
		Irrigation	: Not Observed
		Fishing	:Yes
Amphibian	: Not Observed	**Cultural Activities**	: Not Observed
Reptile	: Not Observed	**Recreational Activity**	: Not Observed
Mammals	: Not Observed	**Others Uses**	: Not Observed

THREATS	
Direct Point Source Pollutants	:Nil
Indirect Point Source Pollutants	: Sewage
Quantity of Sewage Inflow (Cumecs)	:No flow through Storm water drain
Encroachment	: Houses, Shed & School
Soil Excavation	: Nil
Weeds	: Partial

EMPRI Cartography for Kaggadasapura *Kere*



Disclaimer:

- Lake Cartography is for visual purpose only, which describes the features at the time of visit and not to scale.
- Encroachment of lake is only indicative. It needs to be verified with Department of Survey Settlement and Land Records (SSLR), Government of Karnataka.
- This is put out for general information of public at large, so the information is not usable to determine any boundary. Accordingly, the map information is indicative & user shall oneself verify as per prescribed legal procedure the actual boundaries of the survey number. No claim based on this information shall be entertained by the Government or any of its Departments.
- This information is for indicative purpose and is not usable for any legal purposes. Any use by anyone shall be at their own risk and cost.

EMPRI

Lake Name: Kaggadasapura *Kere* **Date of Visit:** 01.01.2016

BASIC INFORMATION				
Other Name : Nil		**EMPRI Code**BUBEKRkgd_kr1710		**Maximum Depth** (m): 3
District Name: Bengaluru Urban		**MI Tank Reg. No.:** Nil		
Taluk Name : Bengaluru East		**Year of Creation:** ≈ 1962		**Geographical Coordinates**
HobliName : Krishnarajapuram		**Year of Rejuvenation** :Yes		**Lat.:**12 ° 58' 37. 2" **N**
Village Name	**Survey No.**	**Extent Area (A-G)**	**Source**	**Long.:**77°40'25.9" E
Kaggadasapura	141	32.16	RTC	**Preservation Authority**
Byrasandra	5	14.24	RTC	
Benniganahalli	In Sy no 124 (3)	3.18	RTC	
Total Extent (A-G)		**50.18**		BDA

MORPHOLOGY	WATER QUALITY	INLET	OUTLET	HYDROLOGY
Elevation(m) : 889	**Temperature** (°C)	23.6	22.8	**Status** : Sewage
Inlet Drain : 3	**pH**	7.2	7.3	**Type** : Perennial
Waste weir : 1	**Conductivity** (µS/cm)	1752	1333	**Source of water:** Rain& Drain
Sluice gate : Nil	**Transparency** (m)	UM	UM	**Upstream water body:**
Fence : Mesh	**TSS** (mg/l)	32	750	Byrasandra *Kere1*
	TDS (mg/l)	680	660	
	Turbidity (NTU)	104	82	**Downstream water body:**
Culverts : 2	**DO** (mg/l)	0.1	0.1	Doddanekundi *Kere*
Check dam : Nil	**BOD** (mg/l)	27.22	19	
Road : 2	**COD** (mg/l)	192	128	
Surrounding Area:	**TKN** (mg/l)	35	28	**Nature of Catchment** : Urban
Apartment,Temple,	**Total Phosphate** (mg/l)	14	8	
Playground & buildings	**Total Coliform** (MPN/100ml)	17	>1600	UM is Unable to Measure due to weeds
	Water Quality Class	E	E	

BIOTIC DATA		SOCIO-ECONOMIC VALUE	
Vegetation Cover	: Partial	**Drinking Water**	: Not Observed
Vegetation Type	: Growing on Bank	**Washing**	: Not Observed
Aquatic Flora	: Emergent	**Bathing**	: Not Observed
Fauna	: Birds & Butterfly	**Livestock Management**	:Yes
		Irrigation	: Not Observed
		Fishing	: Not Observed
Amphibian	: Not Observed	**Cultural Activities**	: Not Observed
Reptile	: Not Observed	**Recreational Activity**	: Not Observed
Mammals	: Not Observed	**Others Uses**	: Not Observed

THREATS	
Direct Point Source Pollutants	: Dumping of Garbage dump
Indirect Point Source Pollutants	: Sewage
Quantity of Sewage Inflow (Cumecs)	: Unable to Measure due to weeds
Encroachment	: Sheds (3%)
Soil Excavation	: Nil
Weeds	: Partial

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