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FRAMEWORK FOR ASSESSING TRIPLE BOTTOM LINES ATTRIBUTE OF SUSTAINABILITY IN CASE OF IMPLEMENTATION OF ROOFTOP RAINWATER HARVESTING, KOLKATA, INDIA

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ABSTRACT

The study is done for assessment of Rooftop Rain Water Harvesting (RRWH) for non potable uses in a humid urban catchment. In this study, an user response survey was conducted, with 390 sample size, in five types of building uses; Residential, Educational, Medical, Institutional and mixed use Commercial, with variable roof sizes and situated in four different zones of KMA, having wide variation in piped water supply. A database of 32 years of daily rainfall data has been analyzed , in order to find out demand for different end uses for various building, supply from roof runoff, demand supply ratio, priority of different socio-economic factors for each type of building using AHP analysis, user's opinion on choice of end-use using regression analysis and finally developed a DSS model. Analysis also revealed that the highest acceptance of RRWH are in favor of the Medical uses building, the lowest being mix-Commercial building. Further factors like toilet flushing is found to be most potential end use options, followed by landscaping and cleaning. The regression model clearly show that the variables like ground condition, scale of development, degree of contact, storey's of building and water scarcity are key to decision making.

KEY WORDS: *Roof top Rain Water Harvesting (RRWH), non potable use, Decision support system (DSS), Analytical Hierarchy Process (AHP), End-use potential, Urban Local Bodies (ULB)*

1.0. INTRODUCTION

In India, different approaches towards alternative water supply system had been adopted in different region state to another, which aims at the varied benchmark for the service delivery in water sector (Ashton, 2005). Ground water abstraction is a common practice in urban area which usually meets up large share of the demand. In small and medium towns in India, 33.3% of the population still depends on groundwater. While in cities with population more than 10 lakhs the same figure turns to 14.9%. Present trends of receding groundwater table will require policy attention and an improved and efficient management of the urban water resources (Shaban, 2007). Despite that large amount of financial investment, and improvements in water supply, majority of the population still lack access to minimum amount of water supplied per day (Butterworth et. al, 2001, ELRS, 2012). The causes of persisting water supply system failures (from an urban planner's eye) has been explored and noted during development planning

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process in the ULB of KMA for three years (2005-2008). Those socio physical constraints are not properly addressed during planning, like technical knowledge gap, poor management of assets, political non-coherence, increasing demand supply gap and various other social factors. These are very important input during comprehensive planning and implementation of the subsequent water management of facilities in city's utility network (ELRS, 2012).

This study elaborates and emphasizes the importance of *rain water utilization*, as a metric through which working mechanism of ULB can be realized and further planning can be done to create sustainable and longer-term benefits/changes. Traditional system of Rain Water Harvesting (RWH) would become more efficient if scientific knowledge is included to revive this vernacular technology (Sharma, et.al. 2010).

1.1. Barriers to implementation of Roof top Rain Water Harvesting (RRWH)

From previous literature and research outcomes by different scholar around the world it was found that Roof top Rain Water Harvesting (RRWH) is quite common in arid regions. However the humid region faces an adverse situation. There is scarcity of water during summer meanwhile there are issues of flooding during monsoon. Presently conventional water supply and waste water disposal systems are regulated by guidelines and standard. As a result those are not appropriate for design and implementation of integrated approach for water conservation (Jain, 2003; Jasrotia, 2009). Guidelines, standards and regulations, by their nature, tend to lag behind leading edge practice, but more flexibility is required to foster innovation whilst protecting public health and the environment (Mitchell, 2004).

Due to the relatively short history of RRWH in West Bengal, most people involved in such projects were inexperienced and confronting it for the first time. As for the obvious reason the users neither always had the required skills themselves nor have the appropriate analysis tools and techniques to implement the same (Glendenning et al, 2012; Goswami, 2002). Thus none of the projects implemented in this region at premises level of urban catchment had supported integrated urban water management and subsequently led to failure. (Chakraborty et al 2009). Government of West Bengal had devised certain guidelines rules and regulation on RRWH in 2010. The guideline had only suggested for the building to adopt RRWH that is having roof area more than 10,000 sqft and was not supported with any tax or other incentives. However this barrier of urban rain water management has been resolved in many parts of the world in the last few years through introduction of rebates and other incentives (Mitchell, 2004). Still, the issue of unclear guidelines and regulations, and the often-lengthy development approvals process (at the government end) act as counteracting forces for the water conservation measures in some cases (Mitchell, 2004). The users implementing RRWH project for the first time could not find sufficient help or any other means of support. Some pilot projects had been launched but could not be sustained for a longer period in KMA. As a matter of fact residents living in this region are not conversant with the fact of water scarcity. Water conservation or using alternative technology for water supply is still not acceptable to the stakeholders in this region (Ghosh, 2010; Shaban, 2008). Thus to adopts a holistic approach to sustainable water usage, IWRM has to take into account the following four dimensions: water resources, water users, spatial and temporal scales. It critically assesses supply options, including developing alternative water resources.

2.0. SYSTEMATIC APPROACH

Historical evidence suggests that community attitudes to the alternative sources were critical to its success. A major barrier to some of these management approaches had been a lack of community acceptance. As such, an in-depth understanding of the mechanisms that lead people to be supportive of alternative water sources was critically important. The study of water-related consumer behavior was essential to provide insight into community attitudes to alternative water sources and related user behaviors. Despite the importance of such research, very little work had been undertaken in that area. As will be demonstrated in this thesis, the work that had been undertaken concentrates on a very limited section of behavioral theory. Then to provide a comprehensive review of the current state of knowledge related to reuse of harvested rain water based on which the final conceptual model had been developed. The review of water-related literature aimed at capturing every single social aspects dealing with issues of acceptance of water from augmented sources. To achieve that, all journals the titles of which include either "rooftop rainwater harvesting" or "reuse of water" had been searched. The identified articles were used to find additional work through reference lists. As such the paper provides a research agenda for social scientists in the field of community attitudes to alternative water sources and water-related behaviour. This research work will help public policy formulation in countries facing water shortage.

3.0. INFERENCES DRAWN FROM LITERATURE REVIEW

The literature review on Harvesting Rain Water (RWH) in Indian context had been characterized by an overall sense of policy failure and barriers to access, punctuated with numerous examples of successful short term 'cases'. Cases tend to be written up as examples of what their particular authors were interested in – of private sector participation, of fiscal reform, of willingness to pay, of civil society participation. It remained a challenge to answer the key question for designing an affordable and sustainable urban drinking water program. In this section, we return to the prominent themes in the literature and draw attention to some unexplored but policy-relevant questions. Because both the constraints on and the pressures for water sector reform in urban India mirror those of many rapidly-growing cities elsewhere, our suggested directions for more effective research, data collection, and policy reform were relevant beyond the Indian context.

A major gap in the vast literature on cost recovery was the question of how the poorest urban citizens could be subsidized. Too often cost recovery was treated as a goal in itself rather than as a means to extending universal access. Targeting methods had both direct and hidden costs for the administration and for the poor (van de Waal 1998). Few empirical studies on cost recovery contain thoughtful discussions on cross-subsidization, though they may admit that it was necessary (e.g. WSP 1999). While increases in price were required, the evidence suggests that subsidies will still be needed to provide for the poor. Rather targeting of subsidies along with an emphasis on connection subsidies should probably be used to provide for conservation of natural resources through wise use of water. With respect to private sector participation, relative to the burgeoning literature on efficiency or prices, analyses of the kinds of contracts, regulatory regimes and citizen oversight that could ensure accountability and the inclusion of this alternative water supply in integrated planning and development process, had been rare. Cairncross (2003) further points out that it was precisely those countries with severely malfunctioning water systems that most lack experience in negotiating contracts and establishing regulations with the large water issues. Some Indian states were more capable than others in that regard, and had more effective citizen oversight. Without case-specific analyses of the environment, the debate around utilization of Rainwater runoff had been likely to remain in the grey areas of decision making.

There was remarkable consensus in the literature that governments should not be in the water provision business, but should ensure that private providers were regulated with respect to price structures and water quality, and should provide incentives for these providers to implement alternative sources of water. That new role for government translates to developing partnerships with the private sector and with civil society for water delivery. Finally, a major barrier to research and the design of appropriate policies was the lack of reliable, up-to-date and publicly accessible information, database of the Indian water system (Ghosh 2005). Baseline information was necessary in order to evaluate various reforms in progress, and in order to allow for benchmarking against Government targets, other states and nearby countries. A lack of transparency over the national level policies and inefficient municipal systems calls for public participation for major reforms that may be needed. Incomplete and difficult-to-find information on groundwater withdrawals makes urban and peri-urban drinking water interventions unsustainable (Jaglin 2002). While efforts were underway to carry out some benchmarking of financial and institutional performance of several water utilities, regular and comparable data need to be made available on, inter alia, water quality, subsidization, metering, groundwater levels, and infrastructure maintenance. The power of benchmarking would be further enhanced if other countries were also to follow such procedures.

With respect to the physical alternatives to fulfill sustainable management of freshwater, there are two solutions:

1. Finding alternate or additional water resources using conventional centralized approaches;
2. Utilizing the limited amount of water resources available in a more efficient way.

To date, much attention has been given to the first option and only limited attention has been given to optimising water management systems. Among the various technologies to augment freshwater resources, rainwater harvesting and utilisation is a decentralised, environmentally sound solution, which can avoid many environmental problems often caused by conventional large-scale projects using centralised approaches

In urban areas, scarcity and accelerating demand of water is a major problem and it can be reduced by rainwater harvesting, using various existing structures like rooftops, parking lots, playgrounds, parks, ponds, flood plains, etc.

As cities continue to grow in the future such problems are likely to become increasingly common.

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Since cities comprise numerous impervious surfaces designed to encourage rainwater runoff the scope for rainwater collection is substantial. Atmospheric pollution remains a major constraint as it contaminates both the rainwater and catchment surfaces making rainwater unsuitable for drinking in many cities around the world. Nevertheless, rainwater can still be used for non-potable uses such as toilet flushing, clothes washing and gardening. Furthermore, greater use of rainwater in urban areas could in future significantly strengthen the idea to clean up the urban atmosphere entirely.

4.0 A DSS FOR ROOFTOP RAINWATER HARVESTING IN TROPICAL CLIMATE

Sustainable water management involves analyzing the interaction between society and the water system. A sustainable water management strategy is robust and flexible. Robust means being able to cope with different future events and developments in the social and water system (like changing social perspectives, floods, droughts, and increased discharges). Flexible means that a strategy can be adapted to changing social and physical circumstances if it is not able to cope with them. In other words; a sustainable strategy has to be acceptable under different futures or it should be easy to adapt it in order to become acceptable again (Po,et al 2005; Gibson et al, 2001).

This thesis is aiming at a method to explore social response for sustainable rain water management capacity to adapt to changing conditions. First results of this type of analysis show that surprises are important ingredients for perspective change and social support. A sustainable strategy could then be a strategy which is robust for climate variability (fluctuations within the climate) and social change in the near future, and flexible enough to adapt to climate change (fluctuations between different climates) and social change on the long term (Baumann, 1983; Poyhonen, 2000). The pilot project for validation of the DSS Model was not been in the scope of work of this thesis due to cost and other legal constraints, some assumptions had to be made.

4.1 Reflection in urban setting

To analyze perspectives and explore future perspective changes, a valid framework is required to start from. A valid framework is incorporating all existing perspectives and recognizable in both reality as well as comparable existing typologies. Moreover, different reasons have been discussed in literature to explain why implementation has been problematic. There are three sets of explanation. First ones argue that the RWH and management concept is flawed and such features of it as negligence to the local conditions and interests and the approach of "one size fits all" (Moss 2003, 2004), tendencies towards centralized and inflexible management that in practice contrary to rhetoric only discourages public participation in decision-making and planning (Ramaswamy 2005, Kaika et al 2003).

The second set of explanations rests on the belief that the capacity of national planners and implementers is the main reason for unsuccessful attempts for IWRM, and requires efforts and time for capacity-building. This discourse is prevalent among the International Organizations and the International NGO-s (GWP 2003, 2005; UNEP 2006).

Depending on the scale, construction of RWH systems can be very simple and local people can easily be trained to build these themselves. This reduces costs and encourages more participation, ownership and sustainability at community level (Hatum 2006). In order to identify the need of this specific water supply facilities for a particular community and proceed for installation of a suitable RWH option (different types of RWHSs), the following activities have to be undertaken.

- Community Situation Analysis (CSA): CSA must be conducted at cluster/ community with facilitation
- Site verification for proposed RWHS

5.0 DEVELOPMENT OF INDICATORS

The indicators represent an attitude which makes it possible to hope to do away with the concept ambiguity. That attitude could be related to a "technocratic" request. Faced with the concept impression the decision makers and the technicians would wish to acquire a series of characteristics measurable, which could be reproduced in time, comparable between geographical areas, enabling an outlook that could be a reference or a consensus, on situations and their evolutions (Zaccaï, 2002). According to J. Theys (2002) building indicators aiming at achieving all these roles at the same time, was doomed to failure. The water reuse project draws up the sustainable indicators profiles:

- Levels of decision making (strategic, programme or project levels).
- Different tools: benchmarking, appraisal/assessment, comparison, or monitoring.

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- Typology of indicators suggested by DPSIR model: driving force, presses, state, impact, response, and others.

The purpose of indicators was often built starting from various raw data and was supposed to have certain characteristics (Pastille, 2002). Considering the multidimensional character of the sustainable development the indicators were numerous. To handle and use them requires obviously a multi criteria analysis. Aggregating these indicators or "indicator set" in only one index was not always well appreciated since it erases, by compensation or by weighting, information which the indicators carry. Other approaches (non compensatory method) were thus privileged, like graphic methods or the methods which rank solutions (Bertand-Krajewski et al., 2002, Ashley et al., 2002).

Let us note that indicators but also multi-criteria methods were supposed to take into account data uncertainties. Those were not negligible in urban hydrology and were propagated in the computation models. Bertand-Krajewski et al. (2002) illustrate the incidences of uncertainties in the performance evaluation of a detention basin. The scientific and technical literature was rich in articles and publication on the sustainable rainwater management. The majorities of these materials formulates the question or support an approach like storage and infiltration of rainwater or their reuse (Lawrence et al., 1999, Larsson Kärppä, 1997, Burkhard et al., 2000, Urbanos, 1997, Chocat, 2002, Bertrand-Krajewski et al, 2000, Rijsberman & van of Ven, 1999). Many of them give examples of projects or achievements (Sibeud, 2001, McKwassock et al., 2001, Andersen & Schilling, 2001) or compare options by using criteria specific to the studied project (Aalderink & Icke, 1998).

Whatever the space scale considered, publications relative to the sustainable rain water management indicators (table 2.6.) use often a downward analysis which starts from criteria, develops them in sub-criteria and indicators and ends in the data required to the evaluation. We describe three approaches which were different by their objectives. The first one was interested in an infiltration tank and aims at comparing alternatives of design or of management. The second one aims analyzing and comparing rainwater systems. The third approach builds and uses indicators to compare technological options.

Table 1 Framework for assessing triple bottom lines attribute of sustainability

Goal	Criteria	Evaluation question / statement
Technical feasibility	Increase in total supply	*Percentage increase in total supply due to non-potable water use*
	Potential supply to current demand	Ratio of potential non-potable supply to current demand for non-potable water supply
	Distance	Average distance between potential supply and demand
	Non-potable water use	Potential for human contact with the non-potable water
	Treatment technology	Treatment technology readily available?
	Retro-fit system	Ease to retro-fit a dual system?
	Supply reliability	Reliability of non-potable water supply (51 weeks a year / 98% of the time)?
	Treatment quality reliability	Treatment technology meets effluent quality requirements under expected operating conditions?
	Operation & Maintenance	Level of skill required to operate and maintain the dual system
	Utilize existing infrastructure	Potential to utilize existing infrastructure (e.g. a STW)?
	Upgradeability	Extent dual system could be readily expanded

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Goal	Criteria	Evaluation question / statement
		to supply future flows?
	Long-term applicability	Period of impact of the system? (short to long term)
	Flexibility	Technology could be adapted to meet more stringent effluent standards in the future?
	Future supply to current demand	Ratio of future non-potable supply to future demand for non-potable water supply
Economical feasibility	Cost difference	Difference in the overall cost of supplying potable and non-potable water
	Savings	Extent of cost savings for non-potable use
	Financial help	Extent of cost savings for non-potable use
	Job creation	Potential for job creation
Social feasibility	Disgust	Extent of 'disgust' to non-potable water use
	Acceptance**	Acceptance of the dual system by the Community
	Aesthetics	Unpleasant sight, noise and/or odor emissions from the system
	Trust/confidence in service provider	Consumers' level of trust and confidence in the potable water service provider
Institutional feasibility	Acceptance**	Availability of Institutional capacity to operate the system
	Local capacity	Acceptance of the dual system by decision makers
Legislative availability	Legislation / Regulation	Municipal Regulations/by-laws available to guide system planning and operation

Source: Ilemobade et al., 2008

This literature review has shown that a considerable amount of knowledge exists for planning, designing, and implementing *Rain water harvesting management* (RWHM) schemes in developing countries around the world. Generic decision support systems and techniques are used to tackle the daunting task of calculation of storage capacity and cost involvement. Currently missing from the literature are site-specific decision support systems that utilise local hydrological and socio-economic data for assessing implementation of rain water harvesting issues at plot level.

However, the tools used to make informed decisions are not effective, leading to failure of Rooftop Rain water harvesting and management systems, in particular Tropical metropolitan urban catchment schemes. The development of a DSS to help stakeholders make better decisions regarding the selection of end use of the harvested rain water is the focus of this research. The conceptual model for the prototype DSS is described in Chapter 4. Currently there is no structured method for assessing potential End use in the West Bengal, India (Goswami, 2002). Many criteria are typically used to evaluate potential water end uses and have been incorporated into the prototype DSS in the form of modules. These criteria are described along with the possible end use with the harvested rain water in five different uses of building. Only relevant socio economic criteria are incorporated into the prototype DSS since one of the goals of the decision support system development is to base the framework on local conditions.

6.0 OUTCOME

This excellent time-saving contrivance has been used to find out an uncomplicated implementation mechanism of rain water harvesting at the plot/premises level. This decision support system model would simulate acceptance of Rain water harvesting at the plot level, assess the reliability of rainwater runoff from the rooftop against the choice of potential end-use. An extensive literature review was done to find the gap which acts as barrier to implement RRWH in the study area. The factors responsible for acceptance of rooftop rainwater harvesting were derived from literature survey. Thereafter the criteria responsible for potential choice of end use with reference to the acceptance level were extracted to define indicators.

Research finding demonstrates that urban RRWH management with its sector specific approach works out to be effective in the long run and hence rain water collection and utilization should be viewed as an effective supplementary source. Complete city level survey is neither possible nor required to justify the purpose of RRWH in this urban metropolitan development. In order to understand the responses of citizens, five different building uses types, in four different ULBs, had been selected to conduct a door-to-door survey, with a suitably structured questionnaire. Survey was conducted to find out the acceptability of RWH and its suitable end-uses by the users, along with various area details of those premises.

The expected outcome would be a methodology that would go a long way in bringing forward several policies for adoption in real world situation under vernacular condition. The DSS model would certainly enable the urban local bodies to prescribe various alternative methods to policy makers and professionals at large for adopting sustainable RRWH.

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