CHAPTER - 1

INTRODUCTION

1.1 PROBLEM AND JUSTIFICATION

Urban water utilities are at risk from climate change. Growing evidence indicates that the water sector will increasingly be affected by floods, droughts, or extreme rainfall events resulting in changes in quantity and quality of water resources, and greater risk of damage to its infrastructure (Danilenko et al., 2010). Mumbai, the commercial capital of India, is amongst the cities at higher risk. Apart from risks from rising sea level, it will experience higher temperatures and intense rain occurring over fewer days resulting in flash floods, fall in water tables and water quality, as also reduced availability of surface water (Sherbinin et al., 2007). Given the city's complete dependence on locally stored rainfall for its water supply, wide gap between water demand and supply, and high rate of population growth and urbanization, this can have major repercussions (Mali et al., 2006) The city therefore urgently needs to workout adaptive strategies appropriate to its technical, financial and institutional capacities to overcome such risks.

As of now Mumbai gets its domestic water from six reservoirs which are situated within the forests. To supplement it, the authorities are planning additional reservoirs in catchments that are largely under forests. Role of natural forests and well maintained plantations in protecting water quality are well established (Dudley and Stolton, 2003). Regulating forest water use by influencing the mix of tree species and ages, the forest structure as also the size of the area harvested and left open can impact water yield (Calder et al., 2007). Forests also mitigate small and local floods, protect soils as also reduce thermal stress and sediment delivery to reservoirs. Hence, forests conservation and appropriate forest management practices can not
only improve water resources but also strengthen the ability to deal with the negative impacts of climate change.

Unfortunately, there is practically no integration between forest management practices and water resource planning. Further, despite best efforts under ‘command and control’ mechanism and/or ‘Joint Forest Management’\(^1\), forests in most source areas are getting degraded. Land uses changes, like diversion of community forests or agriculture lands for construction works, have redirected needs of food, fuel wood, fodder, shelter, etc. of a large number of locals towards the forests, accelerating its degradation (Baland et al., 2006; Lele, 2006).

To address such issues many countries across the world are adopting Payment for Ecosystem Services (PES) approach (Bergkamp et al., 2003; Calder, 2007) that de facto recognizes forest dependent communities as stewards of ecosystems services (ES) and envisages payments for such services through market based instruments such as user fees, eco-taxes, etc. The approach not only provides impetus and incentives to locals to conserve, tap new source of finances but also ensures integration of water concerns with forest management and vice-versa, by way of buyer-seller relationship. Bundling of watershed services with other co-services like biodiversity, recreation, carbon sequestration and air filtration (that impact at different scales) can help tapping markets at regional and global level for higher returns (Farley and Costanza, 2010).

Success of this approach hinges on the ability to quantify the ES, forecast the returns to the investments and convert these values into effective policy and finance mechanisms (Daily et al., 2009). Unfortunately, ecosystem production functions, i.e., the relationships between ecosystem condition, management practices, and the delivery of economically valuable ecosystem services are often poorly understood.

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\(^1\)Joint Forest Management – is a programme that promotes partnerships between fringe forest user groups and the Forest Department on the basis of mutual trust and jointly defined roles, and responsibilities with regard to forest protection and development. The usufructs from forests protection are shared in predefined manner between the user (local communities) and the owner (Government). As of now the cost towards plantation and improvement of forest cover are being borne by the Government while the villagers are expected to protect and manage the resources. The Govt. also provides for some token grants for developmental works (called entry point activity).
Even with respect of Forest Watershed Services – a service that is widely recognized and even institutionalized through PES mechanisms in some parts of the world like USA, France, Mexico, Africa – the biophysical relationships between forests and services such as stream flow stabilization, water quality and water quantity are undefined. Further, influence of multitude of local factors on forest-water relationships makes it difficult to translate research findings between countries and regions, between different catchment scales, between different forest types and species, and between different forest management regimes (IUFRO, 2007) leading to information gaps and uncertainties that hamper the decision making process. Calder et al. (2004) cautions that though water is the predominant factor which can motivate people to pay for maintenance of forest, many scientific studies suggest disparity between scientific and traditional public perceptions of the ability of forest and afforestation programmes to provide “hydrological services” and “headwater conservation function”. Hence, the disparity between two perceptions also needs to be addressed before policies in relation to PES are devised. Apart from this, economic feasibility of PES i.e., its cost effectiveness vis-a-vis other alternatives has rarely been analyzed. Market dynamics is also poorly understood. All these create hurdles in decision making and scaling up the efforts.

On the other hand, there is preparedness among the political leaders and policy makers in India to charge for environmental services through additional taxation. TOI, 23rd Aug 2008 reports Maharashtra as the first State in the country which in-principle has decided to introduce a 'green cess' to boost forest cover including 2% cess on Municipal Corporation of Greater Mumbai as well as other civic bodies and industries that procure water from reservoirs in forest areas. Some States like Gujarat, Himachal Pradesh and Punjab have recently imposed green cess specifically for boosting green cover while other States are planning for it. However, the approach to collection and utilization of these funds appears to be traditional. Theoretically, if such funds are collected and utilized in a manner akin to PES then better results could be expected. However, India has not really experimented with PES and there is lot of scepticism amongst the policy makers about this tool. Therefore, any move in this direction may only be possible by generating information on key decision points, such as forest-
water relations, cost effectiveness of PES, market dynamics, etc. Hence, research studies that fill such information gaps at this critical juncture can not only help policy makers and other stakeholders in making appropriate policy decisions regarding such adaptive strategies but also address the forest management needs and its integration with water resource planning, and vice-versa.

1.2 OBJECTIVES

This study aimed at characterizing the relationships between forests and, water quality, water quantity and cost of water treatment in the Western Ghats of peninsular India as well as evaluating Payment for Watershed Services (PWS) as a cost effective alternative to investments in water treatment and other such costs in drinking water supply. In addition the study aimed at identifying the policy drivers and institutional arrangement that can facilitate PWS. In view of the above, the objectives of the study are framed as under:

1. To study the effect of forest degradation and deforestation (FDD) on water supplies of Mumbai.
2. To evaluate PWS as an adaptive strategy for water security through economic valuation and cost effective analysis.
3. To assess the tradeoffs and opportunities of bundling watershed services with other ecosystem services, particularly carbon sequestration and recreation services.
4. To study the mechanics of market evolution and identify the policy drivers and institutional arrangement that can facilitate user-financed PWS.

It may be pertinent here to mention that the term PWS is used when payments for watershed service only is considered, while PES is used when payments are not just for the watershed services but also for the other ecosystem services (ES) extended by the forests. A significant correlation was defined as one with a probability of results from chance associations of the data equal to less than 5 percent (p value < 0.05).


1.3 RESEARCH QUESTIONS

What is the effect of FDD on local water regime? Is there sufficient economic basis to have PWS as an adaptive strategy for water security? Is it cost effective? Whether bundling of watershed, climate mitigation and recreation services of forests lead to expanding of market base and higher gains to locals? What are the opportunities and tradeoffs in bundling ES? Whether user based market possible for forest ecosystem services in India and what would be the key challenges?

1.4 HYPOTHESIS

1. FDD adversely impacts surface water yield as also surface water quality and has significant economic implications.

2. There is untapped potential for PES in metropolitan regions of India because of demand for clean water, recreation, greens, etc.

3. The locals would be willing to conserve when they benefit from the returns of conservation.

4. PES would be economically feasible when range of benefits provided by the ecosystems is bundled.

5. By including mitigation co-benefits in ecosystem bundle issue of financing can be addressed.

1.5 THE STUDY AREA

The Greater Mumbai, the second most populated city in the world, is completely dependent on locally stored rainfall for its water supply. Since 1860 the city has impounded water by building of reservoirs in the adjoining Western Ghats mountain ranges. These water sources are at greater distance than those of many water systems in the world (Fig. 1.1). Domestic water supply to Mumbai is through six such watersheds (see box 1.1 and Fig. 1.1) lying in two clusters between longitudes 73.23° E and 73.65° E and latitude 19.50° N and 19.92°N, and longitude 72.895° E and 72.94° E and latitude 19.13°N and 19.215°N. Except for the watershed Upper Vaitarna, forests occupied over 60% of the watershed area till early eighties.
However, urbanization and population pressure have taken heavy toll on the forests in most of the watersheds.

**Box 1.1 DOMESTIC WATER SUPPLY OF GREATER MUMBAI**
Source: MUNICIPAL CORPORATION OF GREATER MUMBAI

Domestic water supply to Greater Mumbai is through six reservoirs, i.e., Tulsi, Vihar, Tansa, Lower Vaitarna, Upper Vaitarna and Bhatsa (Fig. 1.1). Vihar reservoir was first to be commissioned. The initial supply was just 32 million litres a day (MLD), which was increased by raising the height of the dam in 1872, to 68 MLD. By 1868, the Tulsi scheme, which consisted of damming the river Tasso and diverting its waters into the Vihar Lake, was commissioned. In 1884, Tulsi and Vihar waters were still insufficient so the Tansa water works was sanctioned. It was completed in 1892 and supplies 410 MLD to the city. Powai was commissioned when Tansa work was underway and a water famine seemed imminent. This source was developed over four stages and the dam celebrated its centenary year in 1991-92. But its inferior quality of water, led it being used for other purposes rather than drinking. Lower Vaitarna was built in 1957 across river coming from Trimbhakeshwar in Nasik district. Upper Vaitarna was commissioned in 1972 on the upper reaches of this river for the supply of water and hydro-electric power. Water from here flows to Lower Vaitarna after generating power and water is then supplied to Mumbai. Large scale water shortages towards the end of the 1960's also resulted in taking up of the Bhatsa project which added 1,365 MLD of water to water supply of Greater Mumbai. Future plans to augment water supplies include Bhatsa III A Scheme, Middle Vaitarna Scheme, Gargai Project and Pinjal Project. Of these works of Bhatsa IIIA Scheme and Middle Vaitarna Scheme have already been started.

The salient features of the reservoirs are given in Table 1.1

The watersheds of five reservoirs supplying drinking water to Greater Mumbai – Tulsi, Tansa, Upper Vaitarna, Lower Vaitarna and Bhatsa – along with the Pise (watershed of the Panjrapur Water Treatment Plant of the Municipal Corporation of Greater Mumbai) and its adjoining Manda watersheds were selected for the study (Fig. 1.1).

The selected watersheds lie along the Western Ghats mountain range – an internationally recognized biodiversity hotspot. The main geological formation is the basaltic Deccan trap. This rugged tract is network of deep cut ravines, numerous cross spurs and isolated hills. Most hills have plateaus with grassy lands and less tree cover as compared to the dense cover on slopes. The Tulsi is a much smaller watershed as compared to other watersheds and has a warm, humid tropical climate with mean daily maximum temperature of 32.9°C in summer and mean daily minimum
temperature of 16.8°C in winter. The other watersheds are comparatively less humid with slightly lower average daily minimum temperature in the winter and higher average daily maximum temperature in the summer. The distinct seasons in a year are winter (December to February), summer (March to June), southwest monsoon season (June to September), and post-monsoon season (October to November), which is hot and humid in coastal areas. The southwest monsoon season, June to September, provides about 94% of the annual rainfall. July is the wettest month with a rainfall of about 40% of the annual total. The average weighted rainfall is 2470 ± 575.98 mm per year.

Agriculture is the main economic activity and engages most of the inhabitants either as cultivators, share croppers or as agricultural labourers. Owing to the inadequate irrigation facilities, mostly crops depend on the monsoon. Paddy (wet rice) is the principal crop while some millets and lentils are also grown in this season. Slash-and-burn agriculture and shifting cultivation are still practiced on a large scale causing rampant fires in forests and grasslands during summer.

The other relevant details of the study area are given in different chapters as each objective of the study focuses on different aspect and various combination of the watersheds.

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2 Slash-and-burn agriculture refers to the practice of cutting, collection and spreading of biomass like leaf, grasses, twigs and cow dung (slash) on permanent agricultural lands before a dry season. The “slash” is permitted to dry, and then burned in the following dry season. The resulting ash fertilizes the soil, and the burned field is planted at the beginning of the next rainy season with crops such as rice and millets. Most of this work is typically done by hand, using machetes, axes, hoes, and other such basic tools.

3 Shifting cultivation begins by clearing of forests, typically less than one to several acres by an individual farmer. The biomass is burned and the site is used to grow agricultural crops in a manner similar to slash-and-burn agriculture. The area is abandoned after a few years and new area is cleared for cultivation. Earlier the abandoned area was left fallow for a period of 15-20 years before reusing it for agriculture but now the abandoned tract is reused after 4 to 5 years due to increased population.
1.6 THESIS STRUCTURE

The thesis is organized into following chapters.

Chapter 1: Introduction
The chapter identifies the problem, the knowledge gaps and the justification for taking up the research study followed by the objectives, research questions and hypothesis for the PhD research work. The chapter briefly describes the study area and its water supply.

Chapter 2: Literature review
The chapter explains the ES approach and, the reasons why it is thought to provide a compelling argument for the conservation and sustainable management of forests. It touches upon the methodologies of integrating ES in decision making and the experiences with PES – a fiscal instrument of ES approach. Forest management scenario in India and hurdles in implementation of PES are also explored. Based on this review theoretical framework of the research has been framed.

Chapter 3: Effect of the forest cover on water yield
The chapter brings out the details of research on spatiotemporal variations in the effects of a mix of primary forest, mature secondary forests and disturbed forests on runoff coefficients and their empirical relationships.

Chapter 4: Effect of the forest cover on water quality
The chapter brings out the details of research on the effects of a mix of primary forest, mature secondary forests and disturbed forests on water quality parameters.

Chapter 5: Deforestation induced costs on drinking water supplies of Mumbai Metropolitan
The chapter details the estimation of the deforestation induced costs towards treatment of raw water, increased water losses due to backwash and desludging and losses in the water yield for Panjrapur Water Treatment Plant through empirical relationships and their valuation through market price/replacement cost methods.
Chapter 6: Socioeconomic determinants of forest dependence and resource governance

The chapter details the method and results of socioeconomic study conducted to assess how peri-urban and rural communities of the Pise watershed utilises and values the forests resources, and evaluate their initiatives towards forest protection.

Chapter 7: Economic feasibility of Payments for Watershed Services (PWS)

The chapter details the method and results of the Cost effective analysis of PWS.

Chapter 8: Opportunities and tradeoffs in bundling ES

The chapter reviews the opportunities and tradeoffs in bundling carbon sequestration and recreation services of forests (ES having better market potential) with its watershed services and attempts at identifying the forest management needs for their optimization in a source area.

Chapter 9: Policy drivers and institutional arrangements

The chapter explores the modalities for development of markets for ES and identifies the policy needs and institutional arrangements essential for it.

Chapter 10: Summary and conclusions

The summary and conclusions of the research are presented in this chapter.
Fig. 1.1 Location of the study area, the hydrometric region of Mumbai Metropolitan Region, the selected watersheds and the Panjrapur Water Treatment Plant (PTP)
(Source – Mumbai Metropolitan Region Development Authority)
Table 1.1 Salient features of the reservoirs supplying drinking water to Greater Mumbai (Source: Municipal Corporation of Greater Mumbai, Mumbai)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Feature</th>
<th>Vihar</th>
<th>Tulsi</th>
<th>Tansa</th>
<th>Lower Vaitarna</th>
<th>Upper Vaitarna</th>
<th>Bhatsa</th>
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<tbody>
<tr>
<td>1</td>
<td>Catchment Area (Km²)</td>
<td>18.9</td>
<td>6.7</td>
<td>135.975</td>
<td>290</td>
<td>160.8</td>
<td>388.5</td>
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<td>2</td>
<td>Av. Annual Rainfall (mm)</td>
<td>2540</td>
<td>2790</td>
<td>2400</td>
<td>2800</td>
<td>2540</td>
<td>3404</td>
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<td>3</td>
<td>Full Supply Level (FSL in M MSL)</td>
<td>56.2</td>
<td>113.69</td>
<td>103.15</td>
<td>137.59</td>
<td>603.504</td>
<td>142.07</td>
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<tr>
<td>4</td>
<td>Carry Over Level (COL in M MSL)</td>
<td>49.43</td>
<td>105.59</td>
<td>93.39</td>
<td>117.78</td>
<td>595.645</td>
<td>104.95</td>
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<td>5</td>
<td>Maximum Draw Down Level (MDDL in M MSL)</td>
<td>47.55</td>
<td>105.59</td>
<td>91.87</td>
<td>111.68</td>
<td>586.59</td>
<td>79.2</td>
</tr>
<tr>
<td>6</td>
<td>Gross Storage (MCM)</td>
<td>41.766</td>
<td>10.415</td>
<td>184.6</td>
<td>204.981</td>
<td>350.72</td>
<td>957.1</td>
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<td>7</td>
<td>Storage below COL (MCM)</td>
<td>10.937</td>
<td>2.379</td>
<td>39.712</td>
<td>76.23</td>
<td>128.9</td>
<td>260.7</td>
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<td>8</td>
<td>Storage below MDDL (MCM)</td>
<td>4.95</td>
<td>2.379</td>
<td>24.532</td>
<td>52.49</td>
<td>22.66</td>
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<td>9</td>
<td>Carry Over Storage (MCM)</td>
<td>5.987</td>
<td>0</td>
<td>15.18</td>
<td>23.74</td>
<td>106.24</td>
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<td>10</td>
<td>Live Storage (MCM)</td>
<td>30.829</td>
<td>8.036</td>
<td>144.888</td>
<td>128.751</td>
<td>221.82</td>
<td>696.4</td>
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<td>11</td>
<td>Storage upto MDDL (MCM)</td>
<td>36.816</td>
<td>8.036</td>
<td>160.068</td>
<td>152.491</td>
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